TRAFFIC PROJECTION AND ASSIGNMENT

RESEARCH REPORT 119-3F
Final Report

by

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Prepared in cooperation with the
Texas Highway Department
and the
U. S. Department of Transportation, Federal Highway Administration

Study No. 2-10-68-119

Texas Transportation Institute
Texas A&M University
College Station, Texas

September 1971

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ABSTRACT

Two traffic assignment packages were developed for use on the Texas Highway Department's IBM 360/50 Computer System. The Texas Small Network Package, which will accommodate small networks of up to 4,000 nodes, implements a new algorithm which allows the trees to be built and the network simultaneously loaded. The Texas Large Network Package, which will accommodate a network of up to about 16,000 nodes, uses a new minimum path algorithm which is considerably more efficient than any previously used. A battery of computer programs for trip distribution was also developed and adopted by the Texas Highway Department.

The accuracy of employment and non-home trip ends from home interviews was investigated. The accuracy of all-or-nothing traffic assignments in estimating turn movements was also investigated.

Home interviews were conducted by the Texas Highway Department in 100 percent of the dwelling units in three adjacent zones in San Antonio. A preliminary analysis of the 100 percent data indicates that very high sampling rates are necessary in order to estimate the number of trips with a small confidence limit.

Key words: Traffic assignment, trip distribution, trip generation, accuracy in estimating trip-ends.

SUMMARY

Two traffic assignment packages were developed for use on the Texas Highway Department's IBM 360/50 Computer System. The Texas Small Network Package (see Research Report 119-1), which will accommodate a network of up to 4,000 nodes, implements a new algorithm which allows the trees to be built and the network simultaneously loaded. The Texas Large Network Package (see Research Report 119-2), which will accommodate a network of up to about 16,000 nodes, uses a new minimum path algorithm which is considerably more efficient than any previously used.

A battery of computer programs for trip distribution was developed and adopted by the Texas Highway Department. This package has the capability of performing several different types of trip distributions including distributions using a newly developed constrained interactance model.

The accuracy of employment and non-home trip ends from home interviews was investigated. Three methods for estimating employment were compared. It was concluded that the origin-destination survey does not yield an acceptable estimate of the employment for zones, districts, or census tracts. The accuracy of all-or-nothing traffic assignments in estimating turn movements was also investigated.

Home interviews were conducted by the Texas Highway Department in 100 percent of the dwelling units in three adjacent zones in San Antonio. An analysis of the 100 percent data was initiated. The preliminary results of this analysis indicate that unexpectedly high sampling rates would be needed in order to estimate the total number of trip ends with desirable accuracy.

IMPLEMENTATION STATEMENT

The Texas Large Network Package, the Texas Small Network Package, and the Texas Trip Distribution Package have been adopted by the Texas Highway Department and are currently being used in their urban transportation studies.

The results of the analysis of the accuracy of home interview data in estimating employment and non-home trip ends and the results of the preliminary analysis of the 100 percent data from San Antonio were used by the Texas Highway Department as the basis for their decision to abandon the traditional origin-destination survey and perform a "synthetic" urban transportation study for the Houston-Galveston area.

INTRODUCTION

Study Number 2-10-68-119 is a component of the continuing cooperative research effort between the Texas Transportation Institute and the Texas Highway Department. This three-year study was based upon research previously conducted under Study Number 2-8-63-60 and continued a number of research elements undertaken but not completed under this previous study. It also interfaces with Study Number 2-10-71-167 which began September 1, 1970; a number of research elements initiated under Study 119 are to be completed in this follow-on study.

The primary concern of Study Number 2-10-68-119 (as with its predecessor and follow-on studies) was to provide technical support for the continuing activities of the Texas Highway Department in the conduct of the several urban transportation studies throughout the State of Texas. Therefore, the project objectives were formulated and a work program was executed so as to be of maximum value in the conduct of the several urban transportation studies in the State. Since the project was to be attuned to the day-to-day performance of urban transportation studies, the study was funded and administered as a planning study rather than research study.

The close liaison between the research staff and personnel of the Planning-Survey Division of the Texas Highway Department throughout the course of the study was an essential ingredient. Through this contact, the research staff was continually aware of the operational problems and practices of the Highway Department. Similarly, the operational staff was involved in the research, development and evaluation from the time work

on individual tasks was initiated. This relationship has led to exceptionally high implementation and utilization of the study findings; in most instances research findings were applied and used in the Highway Department's operation well before drafts of the reports were developed. Indeed, most of those activities carried over into Study Number 2-10-71-167 involved the preparation of reports concerning the development and evaluation of procedures which have been adopted and computer programs which are in use by the Texas Highway Department.

Significant Accomplishments

The more important accomplishments under this study are:

1. The Texas Highway Planning Survey Division was provided with such support that normal operational activities relative to the processing of Urban Transportation study data were maintained with almost no disruption during the changeover from the IBM 7094 to the IBM 360/50 computer.

2. A traffic assignment package which will accomodate a network up to 4,000 nodes and which will operate in the normal job stream was developed for the Texas Highway Department. This package was based upon a new algorithm which allows trees to be built and the network simultaneously loaded; in addition to being convenient this procedure is exceptionally fast.

3. A new minimum path algorithm, which is considerably more efficient than any previously used, was developed and incorporated into a traffic assignment package for large networks (up to approximately 16,000 nodes).

4. The Texas Highway Department was able to continue processing urban transportation study data and to make assignments to networks already coded without the necessity for expensive and time consuming re-coding of networks for disruptive changes in procedures.

5. A battery of computer programs for trip distribution was developed and adopted by the Texas Highway Department.

SUMMARY OF STUDY ACTIVITIES

A primary activity conducted under Study 2-10-68-119 was to maintain operational capability on the part of the Texas Highway Department in the conduct of on-going urban transportation studies. The importance of this activity was dictated by the changeover from the IBM 7094 to the IBM 360 computer during the term of the study.

A second major activity was the development of a computerized trip distribution procedure that would avoid the extensive man-hour requirements of the manual Texas Pattern Trip Procedure while avoiding the shortcomings of the conventional gravity model. These and other study activities are summarized in the following sections.

Traffic Assignment Packages

The development and maintenance of the computer programs required in the conduct of the several urban transportation studies in Texas was a major component of Study 2-10-68-119. The Texas Highway Department had been using a battery of programs developed by the Texas Transportation Institute for the IBM 7094. With the acquisition of an IBM 360/50 system by the Texas Highway Department and the replacement of the IBM 7094 at Texas A&M University with an IBM 360/65 system it was necessary to undertake the development of a battery of programs for the IBM 360 system. Two sets of traffic assignment programs were developed. One, designated the Texas Small Network Package, operates under HASP and provides for convenience and fast turn-around. Traffic assignment jobs using the Small Network Package can be submitted in a regular job stream of the

computer facilities operated by the Texas Highway Department's Division of Automation. The other set of programs, designated the Texas Large Network Package, was designed to accommodate very large networks; because of the core capacity necessary for the programs in this package, traffic assignment jobs must be run "stand alone." The network capabilities of the two packages are summarized in Table 1.

Table 1

SUMMARY OF CAPACITIES OF TRAFFIC ASSIGNMENT PACKAGES

	Texas Small Network Package	Texas Large Network Package
Centroid Capacity	1,200	4,800
Node Capacity (including centroids)	4,000	16,000
Link Capacity (nondirectional)	8,000	20,000
Node Connection Capacity	6 links	6 links

Individual programs perform the basic functions in the traffic assignment process. Simplicity and ease of operation have been stressed in the two packages and their component programs. Each program is referenced by name:

Texas Small* Network Package	Texas Large* Network Package
PREPARE NETWORK	PREPARE NETWORK
OUTPUT NETWORK	PREPARE BIG SUBNET
PREPARE TRIP VOLUMES	OUTPUT NETWORK

*Operating instructions are contained in Research Reports 119-1 and 119-2 for the small and large packages respectively. Internal computer program documentation will be included in Research Reports 167-3 and 167-4.

OUTPUT TRIP VOLUMES	PREPARE TRIP VOLUMES
BUILD TREES	OUTPUT TRIP VOLUMES
ASSIGN	BUILD TREES
ASSIGN SELECTED LINKS	LOAD NETWORK
OUTPUT SELECTED LINKS	LOAD SELECTED LINKS
FRATAR FORECAST	OUTPUT SELECTED LINKS
SUM TRIP ENDS	FRATAR FORECAST
MERGE	SUM TRIP ENDS
PREPARE SPIDER NETWORK	MERGE
OUTPUT SPIDER NETWORK	
ASSIGN SPIDER NETWORK	
RESTRAINED ASSIGNMENT	

It should be mentioned that several features (e.g., BCD descriptions, vehicle-hour and vehicle-mile summaries, separation matrices, etc.) are standard output and do not constitute separate programs as is conventional practice in other traffic assignment packages.

As is suggested by the program names in the above listing, some of the programs are identical in both packages(e.g., PREPARE TRIP VOLUMES, OUTPUT TRIP VOLUMES, SUM TRIP ENDS, and MERGE). Others perform similar functions but differ in operation due to a difference in techniques.

The Texas Large Network Package accepts partitioned* or unpartitioned networks, and utilizes intermediate operating stages in order to achieve its large capacity. The Texas Small Network Package applies a simultaneous build trees and load network technique for maximum efficiency, and does

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*The capability of accommodating partitioned networks was included in order to provide convenient processing of assignments to the Dallas-Ft. Worth network which was coded in four subnets as required for large networks using the TEXAS-BIGSYS assignment package written for the IBM 7094 (see Research Report 60-6).

not accept partitioned networks. Both packages utilize a streamlined, efficient, high speed minimum path routine that resulted from recent research conducted by the Texas Transportation Institute.

Both sets of programs are designed for an IBM 360 computer with the full Operating System (OS). A 512K core storage capacity is necessary since regions of 280K or 440K are required. Both packages will operate in the MVT environment; however, sufficient storage is not available for operation of the Texas Large Network Package under HASP in a 512K computer. The Texas Large Network Package needs three extra tape drives. A minimum of one tape drive and one disk drive must be available to the Texas Small Network Package, in addition to what is required by OS.

The restrained assignment and selected link programs are two of the latest additions to the assignment packages. The restrained assignment technique permits allocating a variable proportion of trips to multiple paths between origin and destination combinations to achieve volume balances or to produce assigned volumes that conform to capacity restraints. The selected links option produces detailed interchange for trip traversing any specified links.

Trip Distribution

Work relative to trip distribution was initiated under Study 2-8-63-60. An evaluation of the gravity model trip distribution, employing data from the Waco Urban Transportation Study was reported in Research Report 60-13. This evaluation indicated that the gravity model tends to "splatter"

trips between nearly every possible combination of zone pairs. Such a travel pattern is not observable in the real world - unless a very small number of extremely large zones are employed.

Gravity Model Evaluation

The following comparisons were made using the gravity model distribution of the Waco O-D Survey data:

(1) The trip table resulting from the gravity model distribution of observed trip ends was compared with the observed trip table (zone to zone movements as obtained by the expanded Home Interview Survey).

(2) The gravity model distributed trips were assigned to the existing network (E-2) and the assigned volumes compared with the assignment of the D.U. Survey data.

A single purpose, three purpose, and seven purpose gravity model was calibrated for internal auto-driver trips. It was concluded that the three purpose (home base work, home base non-work, and non-home base) gave somewhat better results than the single purpose; and, that the seven purpose did not show significant improvement over the three purpose model.

Gravity models were calibrated with and without a "time barrier" on the Brazos River crossings. It was found that a two (2.0) minute time barrier was appropriate.

Models (single, three, and seven purpose) were calibrated with intrazonal trip ends both included and excluded.

Models were calibrated for the three purpose (HBW, HBNW, NHB) both with and without terminal times.

The following discussion is based on the three purpose model, using a two minute time barrier, without terminal times, and with the intrazonal trips being distributed by the model.

The number of zone pairs having various levels of trip interchanges are shown in Table 2. It will be noted that the dwelling unit survey produced what might be considered to be an unrealistically low estimate of zone pairs (512) having one to four trip interchanges. Analysis of the survey data would suggest that about 1,500 to 2,000 zone pairs might logically fall within this range. This "underestimate" is to be expected since expansion factors of 4 or less can occur only with a sampling rate of about 25 percent or higher. Such a small expansion factor will occur only in sparsely developed zones where the sampling rate is very high.

On the other hand, the gravity model produces an unacceptable high number of zone pairs with trip interchanges in the one to four stratum. Further, it yields a totally unrealistically low estimate of the zone pairs with no trip interchanges.

Further review of the cumulative totals and cumulative percentages shown in Table 2 suggests that the survey trip table and the gravity model trip table agree quite well beginning with the 12 to 20 trip interchange stratum. This, however, is misleading as may be seen from the data shown in Table 3. This table shows the comparisons of the survey and the gravity model results for those zone-to-zone movements for which either the survey data or the gravity model had more than 300 internal auto-driver interchanges. Although some of the comparisons agree quite well, the bulk of them show that the gravity model is severely underestimating the larger volume zone interchanges.

Other specialized summary tabulations indicated that there were 84 zone pairs for which the gravity model under or overestimated

TABLE 2

NUMBER OF ZONE PAIRS WITH THE INDICATED NUMBER
OF INTERNAL AUTO-DRIVER TRIP INTERCHANGES

Number of Trip Interchanges		Number of Zone Pairs		Cumulative Number of Zone Pairs		Cumulative Percent	
More Than	Less Than or Equal To	DU Survey	Gravity Model	DU Survey	Gravity Model	DU Survey	Gravity Model
	Zero	33671	3641	33671	3641	79.34	8.58
0	4	512	28064	34183	31705	80.55	74.71
4	12	3501	6565	37684	38270	88.80	90.18
12	20	1934	1888	39618	40158	93.36	94.63
20	28	875	825	40493	40983	95.42	96.58
28	36	562	480	41055	41463	96.75	97.71
36	44	324	248	41379	41711	97.50	98.29
44	52	244	183	41623	41894	98.08	98.72
52	60	189	124	41812	42018	98.53	99.02
60	68	116	85	41928	42103	98.80	99.22
68	76	100	62	42028	42165	99.04	99.36
76	84	63	35	42091	42200	99.19	99.44
84	92	56	42	42147	42242	99.31	99.54
92	100	33	17	42180	42259	99.40	99.58
100	108	34	20	42214	42279	99.48	99.63
108	116	24	20	42238	42299	99.53	99.68
116	124	18	21	42256	42320	99.58	99.73
124	132	21	9	42277	42329	99.62	99.75
132	140	16	10	42293	42339	99.66	99.77
140	148	15	8	42308	42347	99.70	99.79
148	156	7	12	42315	42359	99.72	99.82
156	164	8	6	42323	42365	99.73	99.83
164	172	8	4	42331	42369	99.75	99.84
172	180	9	9	42340	42378	99.77	99.86
180	188	7	7	42347	42385	99.79	99.88
188	196	8	3	42355	42388	99.81	99.89
196	204	8	2	42363	42390	99.83	99.89
204	212	3	3	42366	42393	99.84	99.90

TABLE 2 Continued

Number of Trip Interchanges		Number of Zone Pairs		Cumulative Number of Zone Pairs		Cumulative Percent	
More Than	Less Than or Equal To	DU Survey	Gravity Model	DU Survey	Gravity Model	DU Survey	Gravity Model
212	220	4	1	42370	42394	99.84	99.90
220	228	4	2	42374	42396	99.85	99.91
228	236	3	3	42377	42399	99.86	99.91
236	244	4	1	42381	42400	99.87	99.92
244	252	7	4	42388	42404	99.89	99.92
252	260	0	3	42388	42407	99.89	99.93
260	268	4	1	42392	42408	99.90	99.93
268	276	3	0	42395	42408	99.90	99.93
276	284	1	3	42396	42411	99.90	99.94
284	292	2	0	42398	42411	99.91	99.94
292	300	0	1	42398	42412	99.91	99.94
300		38	24	42436	42436	100.00	100.00

TABLE 3
LISTING OF ZONE PAIRS WITH OVER 300
INTERNAL AUTO DRIVER TRIP INTERCHANGES

Number of Trip Interchanges		
DU Survey	Gravity Model	Differences
47	343	+296
123	310	+187
161	382	+221
181	846	+665
266	362	+ 96
307	138	-169
307	139	-168
310	257	- 53
315	329	+ 14
317	202	-115
320	230	- 90
327	194	-133
333	304	- 29
334	372	- 38
336	305	- 31
338	186	-152
342	323	- 19
344	91	-253
344	249	- 95
347	236	-111
352	395	+ 43
353	145	-208
356	244	-112
358	161	-197
371	382	+ 11
377	174	-203
386	339	- 47
395	135	-160
401	108	-293
401	456	+ 55
420	695	+275
428	191	-237
441	278	-163
490	422	- 68
513	560	+ 47
537	564	+ 27
542	223	-319
547	326	-221
573	366	-207
782	651	-131
911	544	-367
1074	737	-337
1136	1063	- 73
	Algebraic Total =	-2948

the trip interchanges by more than 100 trips. These ranged from an underestimate of 366 to an overestimate of 665; the algebraic sum was -6,868.

Further analysis was made of the comparison between the DU Survey trip table and that from the gravity model. Table 4 gives the summary of this trip table comparison. The use of this tabulation might be explained through the following examples. There were 1934 zone pairs in the more than 12 and less than or equal to 20 trips stratum ($12 < t \leq 20$). This is a relatively large number of trip interchanges for a study area such as the size of Waco. It will be noted that the gravity model underestimates the number of trip interchanges for the bulk of these zones. As may be seen in Table 4, this underestimate is serious at all zone interchange levels above the 20 to 28 group.

It can be expected that the higher volume zone interchanges will be estimated with reasonable accuracy with a nominal sampling rate of 12.5 percent used in Texas. Table 4 shows that the high volume interchange (say over 60 trips) zone pairs are almost never reproduced by the gravity model. For example; there were two zone pairs that had trip interchanges in the 196-204 group; which were "simulated" to have more than 44 but less than or equal to 52 trips by the gravity model. Such gross deviation of the gravity model from the DU Survey data for high volume, accurately estimated zone-to-zone interchanges, "speaks for itself".

Even the low volume trip interchanges are shown to be highly suspect by this tabulation. For example, the figure of 3,641 zone pairs having

Table 4

Comparison of Trip Interchanges From DU Survey and Gravity Model

Number of Zone Pairs with the Indicated Number (t) of Trip Interchanges by DU Survey

Number of Zone Pairs with the Indicated Number (t) of Trip Interchange by Gravity Model	zero	0<t≤ 4	4<t≤ 12	12<t≤ 20	20<t≤ 28	28<t≤ 36	36<t≤ 44	44<t≤ 52	52<t ≤60	60<t≤ 68	68<t≤ 76	76<t≤ 84	84<t≤ 92	92<t≤ 100	100<t≤108	108<t≤116	116<t≤124	124<t≤132	132<t≤140	140<t≤148	TOTAL
Zero	3617	10	10	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3641
0 < t ≤ 4	25132	383	1682	594	151	68	31	16	2	3	1	1	0	0	0	0	0	0	0	0	28064
4 < t ≤ 12	3921	81	1198	722	308	160	84	35	32	7	9	2	5	1	0	0	0	0	0	0	6565
12 < t ≤ 20	676	27	366	319	193	119	62	39	32	15	19	7	3	6	1	2	2	0	0	0	1888
20 < t ≤ 28	185	6	137	156	83	81	43	48	35	15	12	8	4	4	2	2	0	2	1	0	825
28 < t ≤ 36	82	1	53	75	57	51	35	39	21	19	13	12	6	1	6	2	3	2	1	0	480
36 < t ≤ 44	28	2	22	34	33	24	25	14	18	13	12	5	6	4	2	1	1	1	0	1	248
44 < t ≤ 52	11	0	19	15	22	19	13	20	16	8	8	7	10	1	1	2	1	3	1	0	183
52 < t ≤ 60	7	0	6	6	11	14	14	10	11	7	3	7	6	2	4	1	1	3	1	2	124
60 < t ≤ 68	4	0	2	3	6	10	6	8	5	7	6	2	5	4	3	3	0	0	2	2	85
68 < t ≤ 76	4	1	4	4	4	5	0	5	5	5	2	1	3	4	2	2	1	2	1	1	62
76 < t ≤ 84	2	0	1	1	2	4	2	1	3	2	3	2	1	1	2	2	0	2	1	1	35
84 < t ≤ 92	1	0	1	1	1	3	2	3	2	5	1	4	1	2	0	2	1	1	3	0	42
92 < t ≤ 100	0	0	0	0	0	1	1	1	1	0	2	0	2	1	2	1	2	1	0	0	17
100 < t ≤ 108	0	0	0	1	0	1	0	0	2	3	2	2	0	0	3	0	1	0	0	1	20
108 < t ≤ 116	0	0	0	1	1	0	1	0	0	4	0	0	3	0	0	0	1	0	1	4	20
116 < t ≤ 124	0	0	0	0	1	1	1	1	1	1	2	0	1	0	1	0	1	0	2	2	21
124 < t ≤ 132	1	1	0	0	0	0	3	1	0	0	0	0	0	0	2	0	0	0	0	0	9
132 < t ≤ 140	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	1	0	1	0	0	10
140 < t ≤ 148	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	1	1	0	8
148 < t ≤ 156	0	0	0	0	0	0	1	1	1	1	2	1	0	0	0	0	0	0	0	0	12
156 < t ≤ 164	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	6
164 < t ≤ 172	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
172 < t ≤ 180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	9
180 < t ≤ 188	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	7
188 < t ≤ 196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
196 < t ≤ 204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
204 < t ≤ 212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
212 < t ≤ 220	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
220 < t ≤ 228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
228 < t ≤ 236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
236 < t ≤ 244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
244 < t ≤ 252	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4
252 < t ≤ 260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
260 < t ≤ 268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
268 < t ≤ 276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
276 < t ≤ 284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
284 < t ≤ 292	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
292 < t ≤ 300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
over 300	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	24
TOTAL	33671	512	3501	1934	875	562	324	244	89	116	100	63	56	33	34	24	18	21	16	15	

Table 4 Continued

	148<t≤156	156<t≤164	164<t≤172	172<t≤180	180<t≤188	188<t≤196	196<t≤204	204<t≤212	212<t≤220	220<t≤228	228<t≤236	236<t≤244	244<t≤252	252<t≤260	260<t≤268	268<t≤276	276<t≤284	284<t≤292	292<t≤300	over 300	TOTAL
Zero	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3641
0 < t ≤ 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28064
4 < t ≤ 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6565
12 < t ≤ 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1888
20 < t ≤ 28	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	825
28 < t ≤ 36	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480
36 < t ≤ 44	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	248
44 < t ≤ 52	1	0	0	0	1	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	183
52 < t ≤ 60	0	0	0	3	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	124
60 < t ≤ 68	1	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	85
68 < t ≤ 76	1	0	2	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	62
76 < t ≤ 84	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	35
84 < t ≤ 92	3	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	42
92 < t ≤ 100	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	17
100 < t ≤ 108	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	20
108 < t ≤ 116	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	20
116 < t ≤ 124	0	2	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	21
124 < t ≤ 132	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
132 < t ≤ 140	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	10
140 < t ≤ 148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	8
148 < t ≤ 156	1	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	12
156 < t ≤ 164	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	6
164 < t ≤ 172	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	4
172 < t ≤ 180	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	9
180 < t ≤ 188	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	7
188 < t ≤ 196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
196 < t ≤ 204	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
204 < t ≤ 212	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
212 < t ≤ 220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
220 < t ≤ 228	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	2
228 < t ≤ 236	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	3
236 < t ≤ 244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
244 < t ≤ 252	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
252 < t ≤ 260	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	3
260 < t ≤ 268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
268 < t ≤ 276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
276 < t ≤ 284	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3
284 < t ≤ 292	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
292 < t ≤ 300	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
over 300	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	19	24
	7	8	8	9	7	8	8	3	4	4	3	4	7	0	4	3	1	2	0	38	42436

no trip interchanges by the gravity model is only about eight percent of the 42,436 total possible zone-to-zone interchanges. Conversely, 38,795 (42,436 minus 3,641) or 92 percent of all zone pairs have one or more trips by the gravity model. Thus, the gravity model distributed one or more trips between the vast majority of possible zone pairs. It seems unrealistic to suppose that anything approaching this dispersion of travel ever occurs in the real world.

Figure 1 shows the distribution of zone interchanges that were over and underestimated by the gravity model. For example, this figure shows that about four percent of the interchanges between zone pairs were underestimated by 15 trips and nearly three percent were overestimated by 15.

Fratar expansion, on the other hand, only expands the trip volume between zone pairs for which trip interchanges were observed in the survey data or for which a "pattern of trips" has been developed. The procedure involved in developing the "pattern of trips" is very time consuming. A process that would involve a method to control the zone pair combinations that are allowed to enter into the distribution process was suggested. It was further suggested that such a process should not be so restrictive as to limit the distribution to only those zone pair combinations having trip reports in the survey data nor should it allow as liberal involvement as the gravity model does. The battery of computer programs which were developed as the Texas Trip Distribution Package accomplishes this goal.

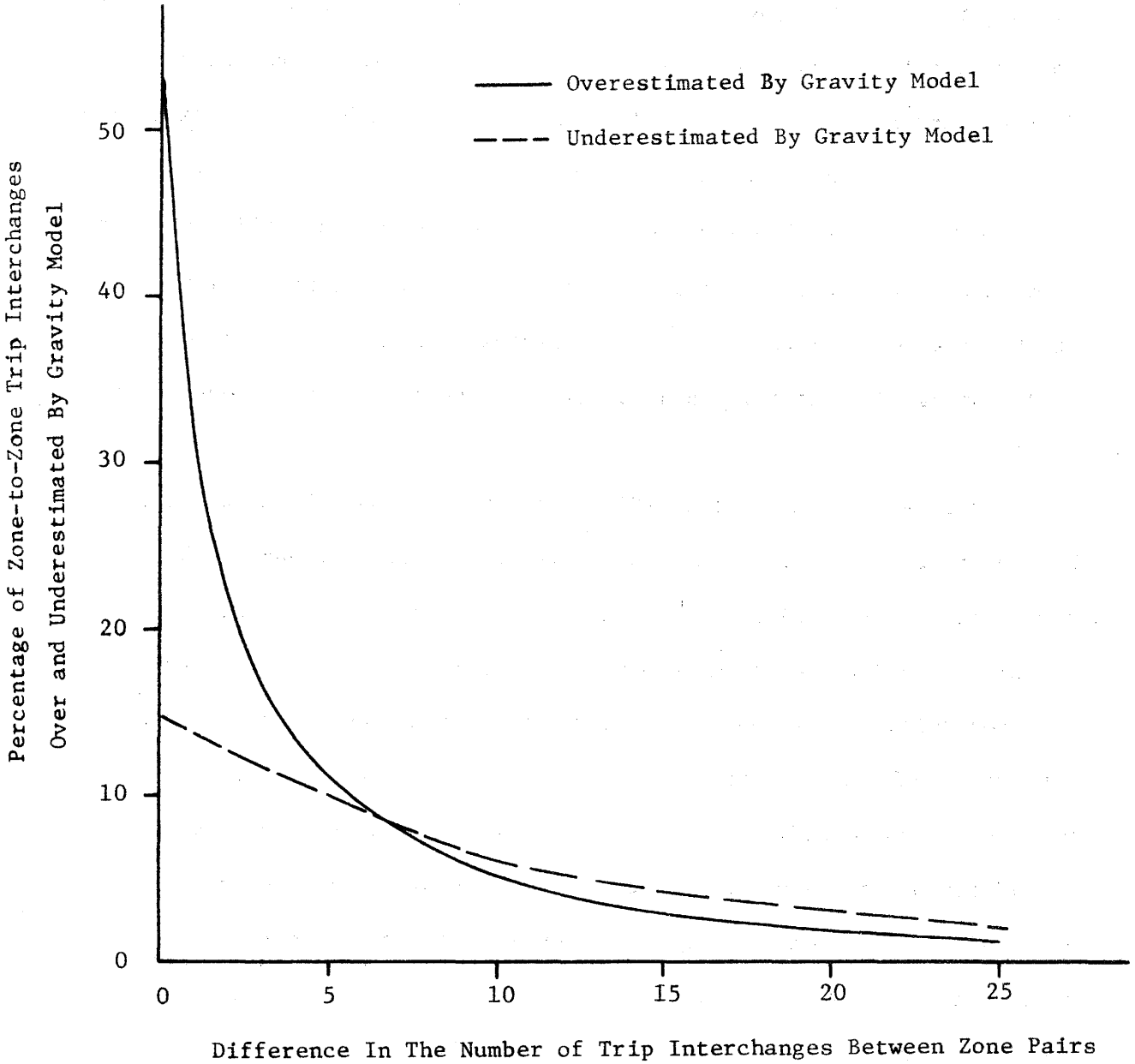


Figure 1: DIFFERENCES IN ZONE INTERCHANGES BETWEEN D.U. SURVEY AND GRAVITY MODEL

Texas Trip Distribution Package

The Texas Trip Distribution Package is a collection of computer programs having considerable flexibility in performing trip distributions. The methods range from directionally expanding existing trip matrices to new totals, to performing synthetic distributions using a constrained interactance model.

The basic interactance model applies trip lengths directly in the distribution process and, consequently, needs no calibration. Other properties of the interactance model are similar to a gravity model without 'F-factors'. By applying a constraint, derived from a concept related to intervening opportunities and supported by analysis of interchange propensity, only selected zone pairs enter into the distribution rather than all possible zone pair combinations as with the gravity model. This limit function is the essential element that differentiates the Texas trip distribution procedure from the conventional gravity models in concept.

A sector structure may be imposed to permit a statistical analysis for, and correction of, sector interchange bias created by socio-economic-topographical travel barriers. Movements having external terminals may be processed simultaneously with the synthetic distribution of internal trips.

The Texas Trip Distribution Package is designed to interface with the Texas Small and Large Network Traffic Assignment Packages. It has been prepared for an IBM 360 computer system, but is programmed almost entirely in FORTRAN (except for an entry into the system sorting

program) and, therefore, is not highly machine dependent. The coding in the programs has been optimized for processing efficiency in order to minimize execution time. For benefit of the user, simplicity and ease of operation have been emphasized rather than superflexibility due to its accompanying operational complexities. However, a feature has been provided to permit the exercising of options to satisfy abnormal flexibility needs.

The package is capable of accommodating trip tables having up to 4800 zones using a computer with 512,000 bytes of core storage available. By making a simple change, the capacity can be varied to conform to any partition or region size in excess of about 110,000 bytes.

Completion of this research activity was carried over on Study 2-10-71-167 which is the sequel to Study 2-10-68-119. Operating instructions for the Texas Trip Distribution Package was published as Research Report 167-1; internal documentation will be reported in Research Report 167-2.

Other Computer Programming

Adoption of the IBM 360 computer by both the Texas Highway Department and Texas A&M University, of course, required that the computer programs used in Urban Transportation Planning be rewritten. In addition to the substantial programming effort required to develop a small and large traffic assignment packages, an unusually large programming

effort was required to maintain operational capability. This unusually large required programming effort was due to the fact that numerous versions of the IBM 360 Operating System were adopted during the course of study no. 2-10-68-119. These changes of the Operating System frequently required the complete reprogramming of the small and large traffic assignment packages. The changes in the operating system caused an even greater repeat of programming effort for the Trip Distribution Package since this package was in the development stage. It is estimated that over two man years was expended in regaining operational capability on the three program packages.

Accuracy of Employment and Non-Home Trip Ends from Home Interviews

Comparisons were made of employment as estimated from the home interview survey data with the reported employment obtained by field listing (interview) of each employer in the study area. A comparison was also made for non-home trip ends for six selected zones in the McAllen-Pharr Urban Transportation Study area where manual cordon counts were made.

Study Area

The McAllen-Pharr Urban Transportation Study was conducted by the Texas Highway Department in 1968. The study area was roughly rectangular with sides six and twelve miles in length and included the towns of Mission, McAllen, and Pharr. The total population of the study area was estimated at 79,400; of these, 70,800 persons were over five years of

age. In addition, there are an estimated 300,000 persons living in the surrounding area including the city of Reynosa, Mexico.

Data Collection

The data involved in this report were collected by the Planning Survey Division of the Texas Highway Department during the data collection phase of the McAllen-Pharr Urban Transportation Study. The number of employees who worked in a particular zone was determined by contacting each employer within the study area. These employers were asked for the total number of persons he employed full-time (three or more days per week) and part time at that particular work site. These employment data were collected at an average cost of 0.31 man hours per employer. No information was obtained on domestic employees.

The total number of vehicles which entered each of the six zones was obtained by manual cordon counts. These counts were made by hourly periods beginning before the morning peaks and continuing until the traffic had subsided that evening. The six survey zones were chosen because there were no dwelling units in these zones and the internal street pattern prohibited through trips.

Data Compatibility

Table 5 lists the employment data totals for the study area as tabulated from the data tape and before any adjustments for absenteeism were made to the Type 2 and Type 3 card data.

In order to use the external data as a guide to the number of employees who cross the study area cordon, some adjustment must be made for the absentee rate. If it is assumed that this rate is the same

TABLE 5

EMPLOYMENT TOTALS BEFORE ADJUSTING
TYPE 2 AND 3 CARD DATA FOR ABSENTEEISM

(all survey data expanded to population)

Source			Number of Employees
Employer Survey			16,910
Dwelling Unit Survey:			
Employment Report (Type 6 card):			
Total Employed Labor Force			20,415
Total Labor Force, worked on previous day			17,334
Internally Employed Labor Force			16,963
Internally Employed Labor Force, worked on previous day			14,616
Trip Report (Type 2 card):			
First Work Trip			17,475
External Data (Type 3 card):			
a) Live out of area	Entering to work	3,736	Avg. 3,628
	Leaving from work	3,520	
b) Live in area	Entering from work	4,128	Avg. 4,054
	Leaving to work	3,979	

for employed persons residing outside the study area as it is for those employees residing inside the study area, the information on the Type 6 cards, Employment Report, may be used as a basis for estimating absentees for the Type 3, External Survey cards.

The number of employees in the total employed labor force (that is, those persons who live within the study area and are employed) is 20,415 persons. Of this 20,415 persons, only 17,334 reported having gone to work on the interview day. This indicates an absentee rate of 14.7 percent; calculated as follows:

$$\frac{20,415 - 17,334}{20,415} \times 100 = 14.7 \text{ percent absent.}$$

The number of persons working within the area and living outside was extracted from the Type 3, External Survey cards. It was necessary to assume that the trip purpose of all passengers was the same as that of the driver. Any adverse affect of this assumption should be minimal since the occupancy of vehicles entering the area to work was only 1.4 persons.

The employment from the Type 3 cards was obtained by multiplying the expansion factor (24-Hour Factors) by the number of persons in the car for each Type 3 card with one trip end "home" or "serve passenger" and the other "work" and summing the resulting product for each zone of employment. For purpose of a check, the data were tabulated as sub-totals by zones of employment for persons entering the area to work, leaving the area from work; and leaving the area to work and entering the area from work. No significant difference was found in the inbound and the outbound

volumes.* Consequently, the average was used in the analysis. It was necessary to assume that all persons who left the area from work within the area lived outside the area. Because of the rigid grid street arrangement, this appears to be a reasonable assumption.

Estimation of Internal Employment

Three different approaches were taken in order to obtain an estimate of the number of persons employed within the study area. These methods were:

method 1: estimate from total employed labor force: The total employed labor force obtained in the home interview survey includes all persons who claim to be employed regardless of place of employment. Therefore adjustments must be made for persons who live in the area and work outside as well as those who live outside of the area and work within the area. The calculations involved in this adjustment are as follows:

Total Employed Labor Force (from Type 6 card)	20,415
Entering area to work (from Type 3 card) = +3,628	
Adjusted for absentees = $\frac{3,628}{100 - 0.147}$ =	+ 4,241
Leaving area to work (from Type 3 card) = -4,054	
Adjusted for absentees = $\frac{-4,054}{1.00 - 0.147}$ =	- 4,759
Estimated Internal Employment	19,897

method 2: estimate from internally employed labor force: The internally employed labor force data as determined from the Type 6 card, Employment Report, reflect the number of employees who live and work within the study area. Therefore, in order to establish a total which could be

*A sign test was conducted on the inbound employees as listed by zone of employment. From this test it was concluded that there is no statistical difference in the average inbound or outbound trips. However, the reader might notice that the totals are lower for trips from work. This is to be expected due to after work shopping trips.

compared to the employer survey, the number of employees entering the area to work was added to the number of persons employed in each zone as obtained from the internally employed labor force data.

Internally Employed Labor Force (Type 6 card)	16,963
Entering Area to Work (Type 3 card) +3,628	
Adjusted for absentees = $\frac{3,628}{1.00 - 0.147}$	+ 4,241
Estimated Internal Employment	21,204

method 3: estimate from first work trip: The first work trip data provide an estimate of the total of the employees who went to work on an average day regardless of the location of their employment. In order to get an estimate of the total employment from this, the number of persons who enter the area to work must be added and the number persons who leave must be subtracted. The total, factored for absentee persons, becomes:

First Work Trip (Type 2 card)	17,476
Entering Area to Work	+ 3,628
Leaving Area to Work	- 4,054
	17,050

Estimated Internal Employment, Adjusted for Absentees

$$= \frac{17,050}{1.00 - 0.147} = 19,988$$

Comparisons of Estimates: It should be noted that in the "estimate from the total employed labor force" and in the "estimate from the first work trip", the external survey data are used to estimate both the number

of persons leaving and entering the area to work. In the "estimate by the internally employed labor force", the number of persons leaving the area to work is estimated by the dwelling unit survey.

The final estimates of internal employment differ by about 1300 employees, with the estimates from the total employed labor force and the first work trip about the same and the estimate from the internally employed labor force higher. After considering the possible sources of error in data collection as well as the assumptions in each of the estimates, it is concluded that method 2 is potentially the most reliable. Therefore, the estimate from the internally employed labor force was considered the best estimate of the employment in the McAllen-Pharr Study; this estimate was 21,200 employees.

The employment found from the employer survey was 16,910 employees. The obvious discrepancy of nearly 4,300 more employees is probably due to several sources. The major portion of this difference is believed to be the domestic personnel not reported in the employer survey and for which no estimate is possible. Other sources which might contribute to the difference are persons who claim to be employed, but who, in truth, are not employed; employers who do not report all of their employees because some are Mexican nationals working illegally; and problems of obtaining detailed information, without misunderstanding, in any external survey.

comparison of employment estimates by smaller geographical areas

Comparisons of employment estimates were performed by zones, districts, and census tracts. As a basis of comparison, the employer survey was

assumed as the standard to which the zone by zone data based on the internally employed labor force are compared. Again, one should realize that the employer survey does not include domestic help. Consequently, if there was any domestic employment in a particular zone, the employer survey would underestimate the employment for that zone. Further, the employment estimate from the home interview should be expected to exceed that from the field listing of employment (employer survey) since the total estimates of the employment from the O-D Survey are greater than the employment from the employer data. In no case should the employment estimate from the home interview be expected to be less than that obtained by the employer survey.

Similar adjustments were made to the data by zones, districts, and census tracts, as were made to the totals in the preceding section.

serial zones: There are 363 serial zones in the McAllen-Pharr study area; a scatter diagram of the data is shown in Figure 2. This plot indicates substantial variation between the O-D Survey data and the employer survey data. The distribution of error (employer survey minus O-D Survey) is shown in Figure 3. Zones which had zero employment from both the O-D Survey and the employer survey are not shown in this graph. As discussed above, these differences are expected to be zero or positive but not negative. However, Figure 3 shows that a number of zones (113) which are estimated to have fewer employees by the O-D Survey data than by the Employer Survey. This raises a question as to the reliability of using home interview data to estimate activities of the non-home end.

Figure 4 shows the distribution of the number of zones with a given percent error for different zone size groups. This figure indicates

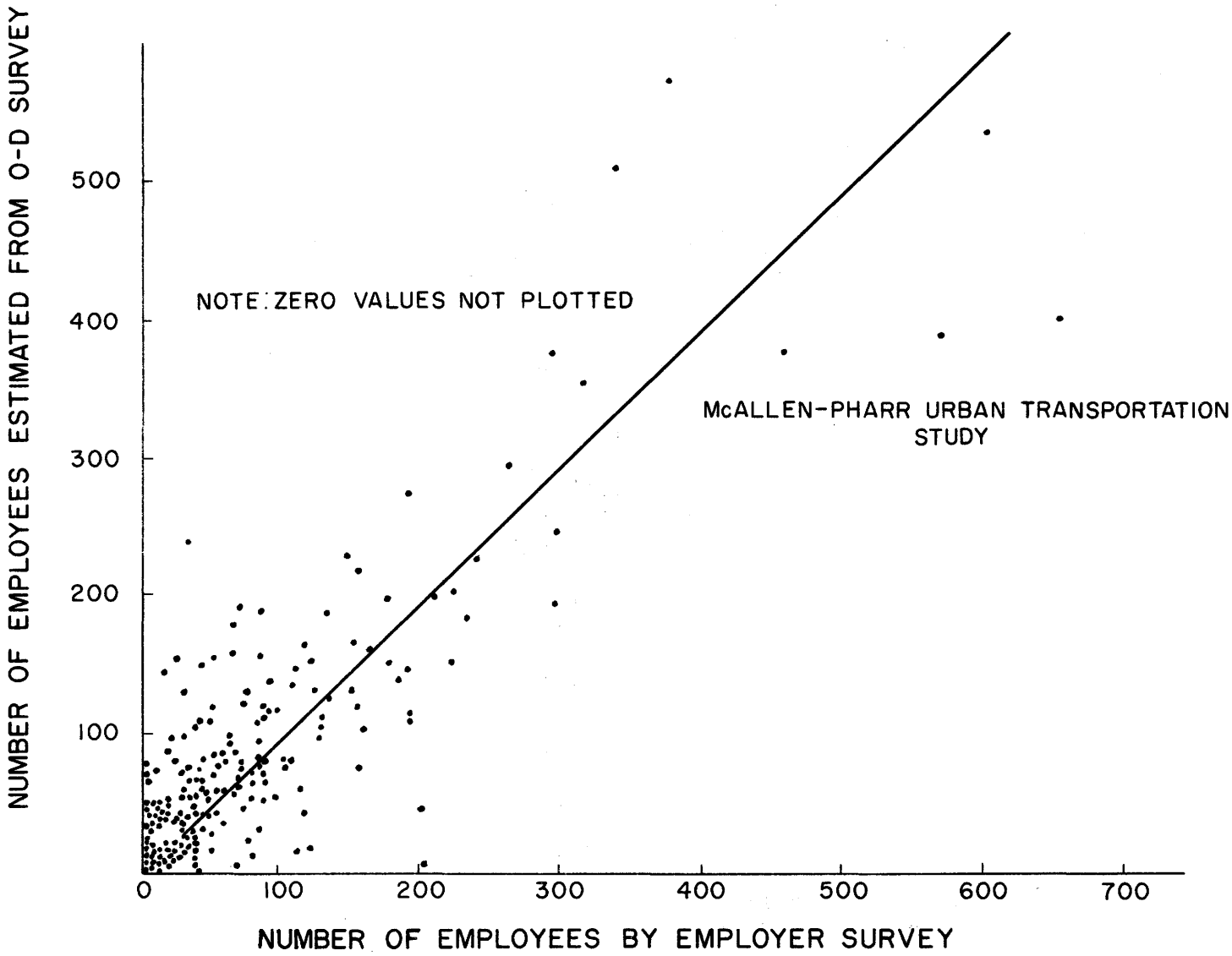


FIGURE 2. SCATTER DIGRAM OF ESTIMATED EMPLOMENT VERSUS EMPLOYER SURVEY

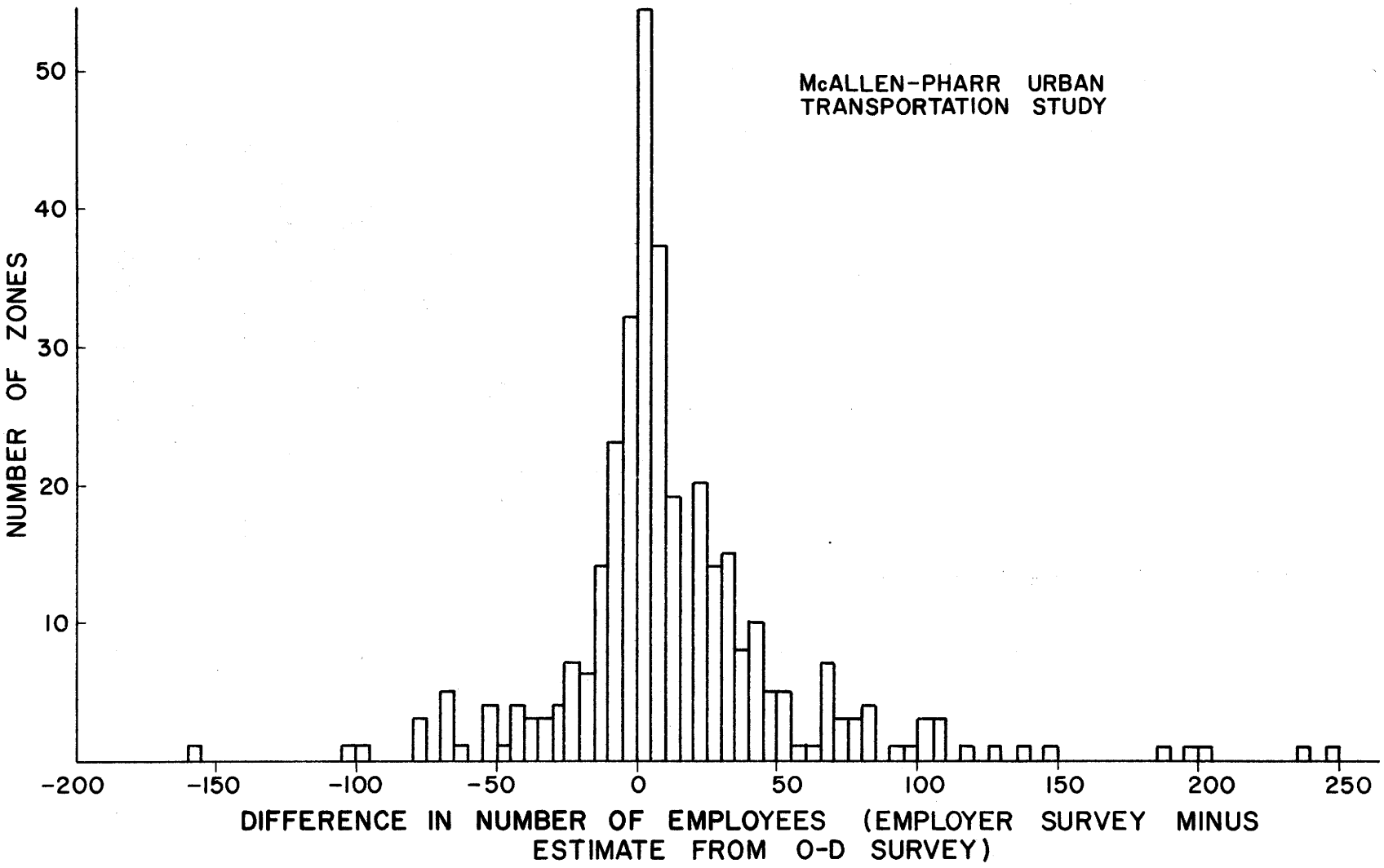


FIGURE 3. DISTRIBUTION OF ERROR IN ESTIMATED EMPLOYMENT BY SERIAL ZONES

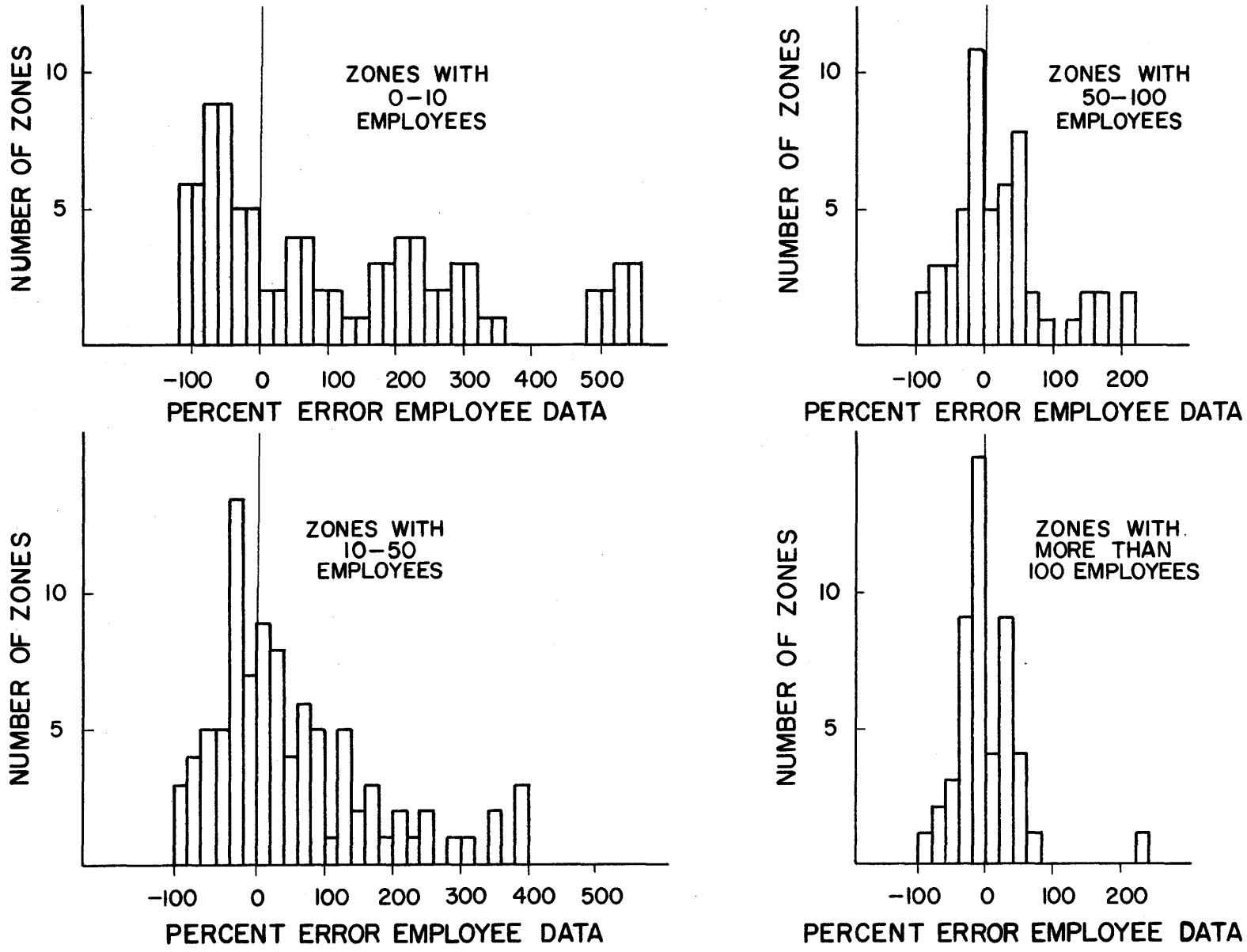

ZONES WITH
0–10
EMPLOYEES
NUMBER OF ZONES
10
5
-100
0
100
200
300
400
500
PERCENT ERROR EMPLOYEE DATA
ZONES WITH
50–100
EMPLOYEES
NUMBER OF ZONES
10
5
-100
0
100
200
PERCENT ERROR EMPLOYEE DATA
ZONES WITH
10–50
EMPLOYEES
NUMBER OF ZONES
10
5
-100
0
100
200
300
400
500
PERCENT ERROR EMPLOYEE DATA
ZONES WITH
MORE THAN
100 EMPLOYEES
NUMBER OF ZONES
10
5
-100
0
100
200
PERCENT ERROR EMPLOYEE DATA

FIGURE 4

that the O-D Survey data tend to underestimate the employment in serial zones, regardless of zone size. More significantly, the employment estimates from the O-D Survey data have a high percentage error even in the larger zones (over 100 employees).

It is concluded that acceptable estimates of employment by serial zones are not provided by the O-D Survey for the size zone used in the McAllen-Pharr Urban Transportation Study.

districts: An analysis similar to that for serial zones was also made for districts and census tracts in order to evaluate the effect of larger aggregations. Figures 5 through 7 present a summary of the employment comparisons by the 102 districts.

As expected, the O-D Survey does a better job of estimating employment at district level than it does at the serial zone level. However, it is concluded that the O-D Survey data do not yield acceptable estimates of employment for districts of the size used in the McAllen-Pharr Study.

census tracts: Results of the comparison of estimated employment and that obtained from the employer survey for the 20 census tracts which are partially or wholly within the study area are given in Figures 8 through 9.

It is concluded that the origin-destination survey does not yield an acceptable estimate of the employment by zones, districts, or census tracts.

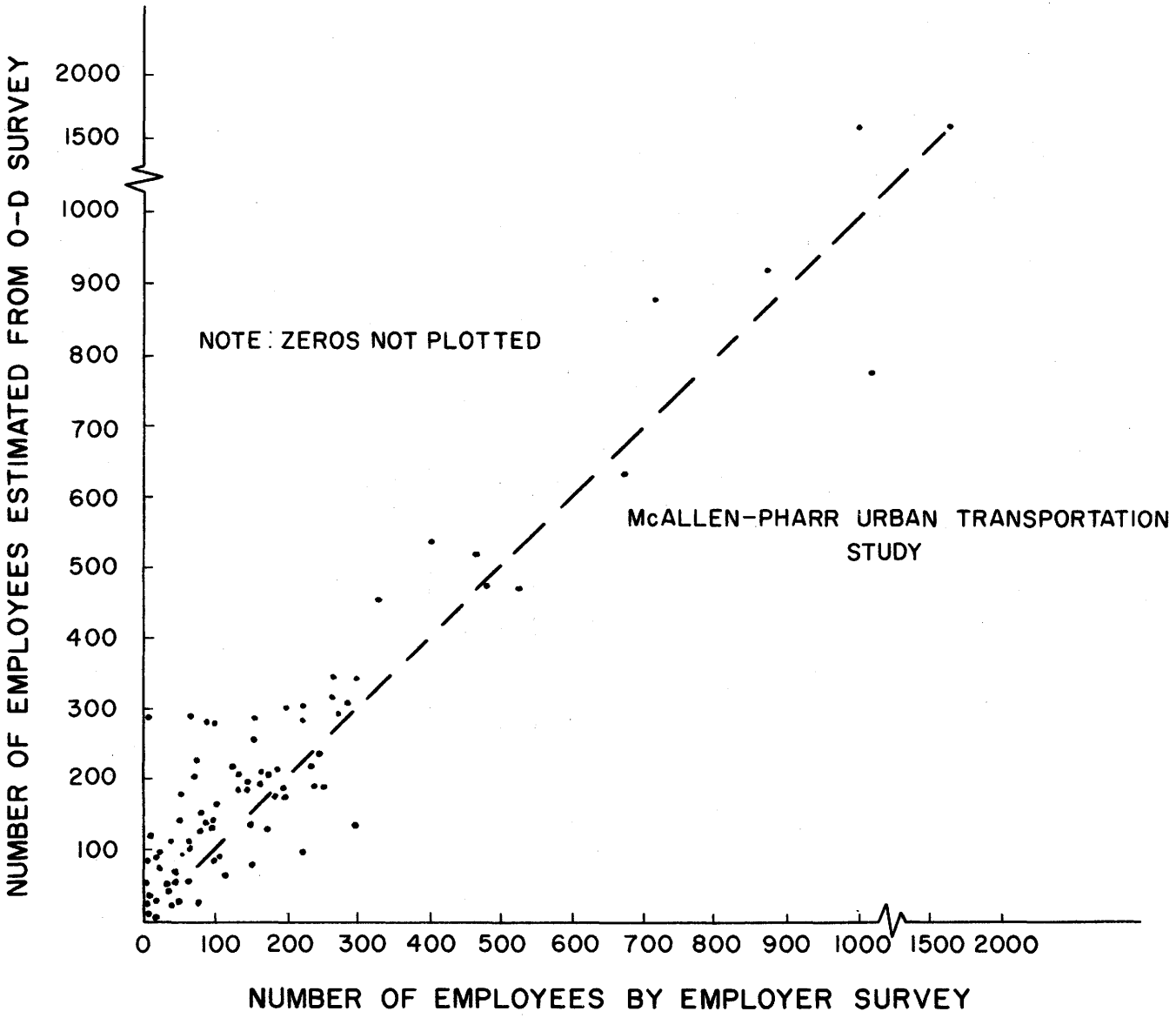


FIGURE 5. SCATTER DIAGRAM OF ESTIMATED EMPLOYMENT VERSUS EMPLOYER SURVEY BY DISTRICTS

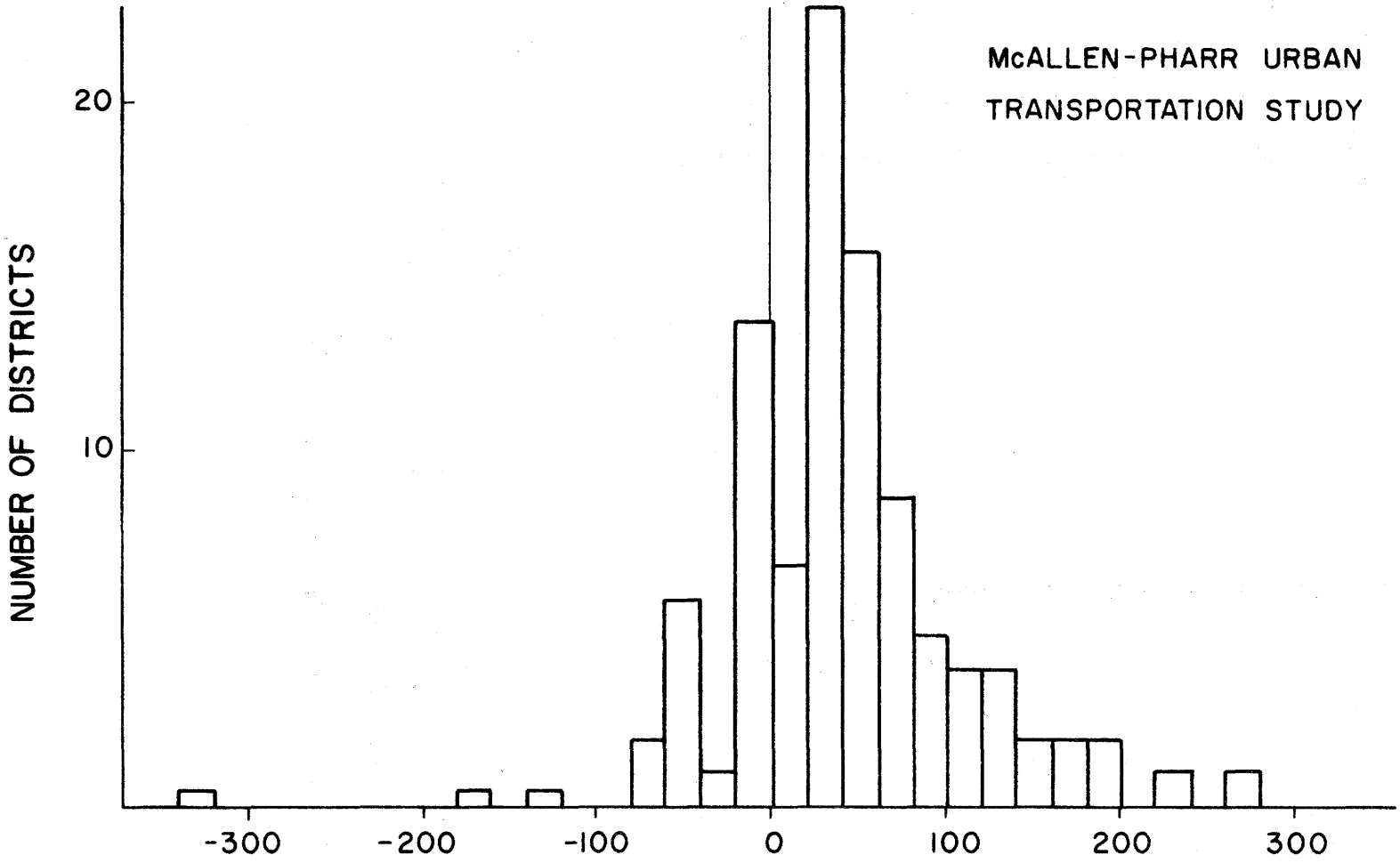


FIGURE 6. DISTRIBUTION OF ERROR IN ESTIMATED EMPLOYMENT BY DISTRICTS

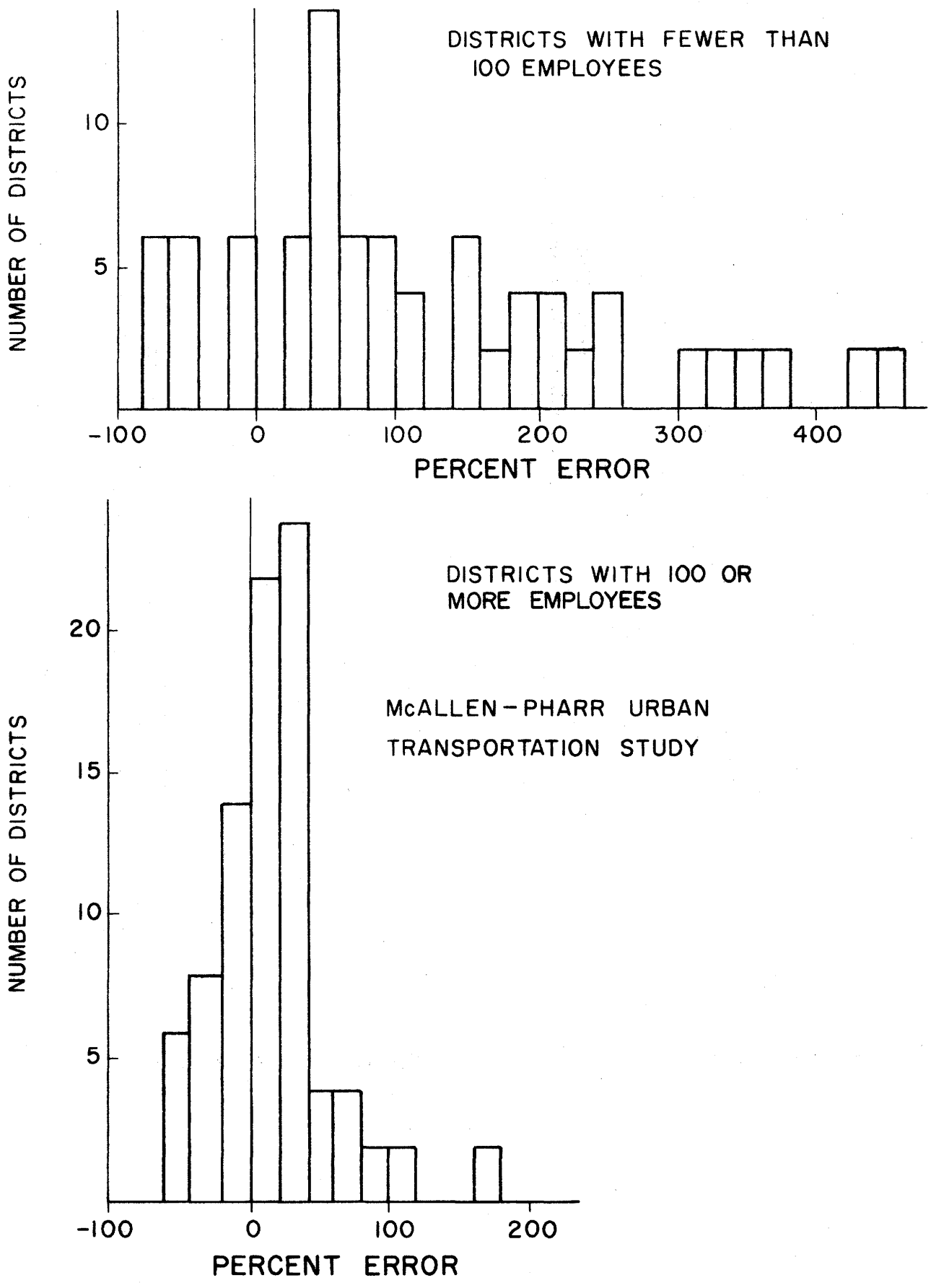


FIGURE 7. DISTRIBUTION OF PERCENT ERROR FOR DISTRICTS

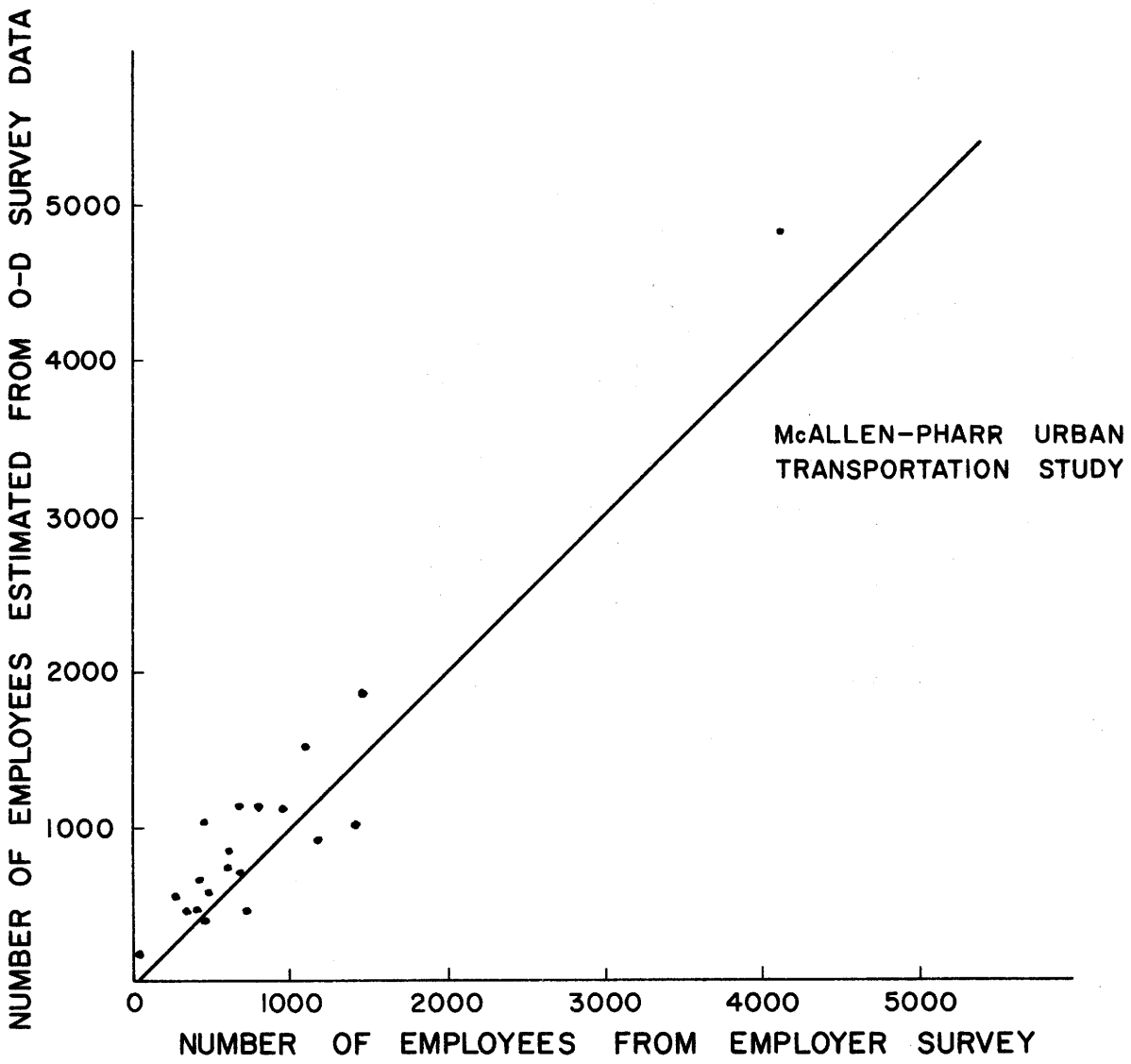


FIGURE 8. SCATTER DIAGRAM OF ESTIMATED EMPLOYMENT VERSUS EMPLOYER SURVEY BY CENSUS TRACTS

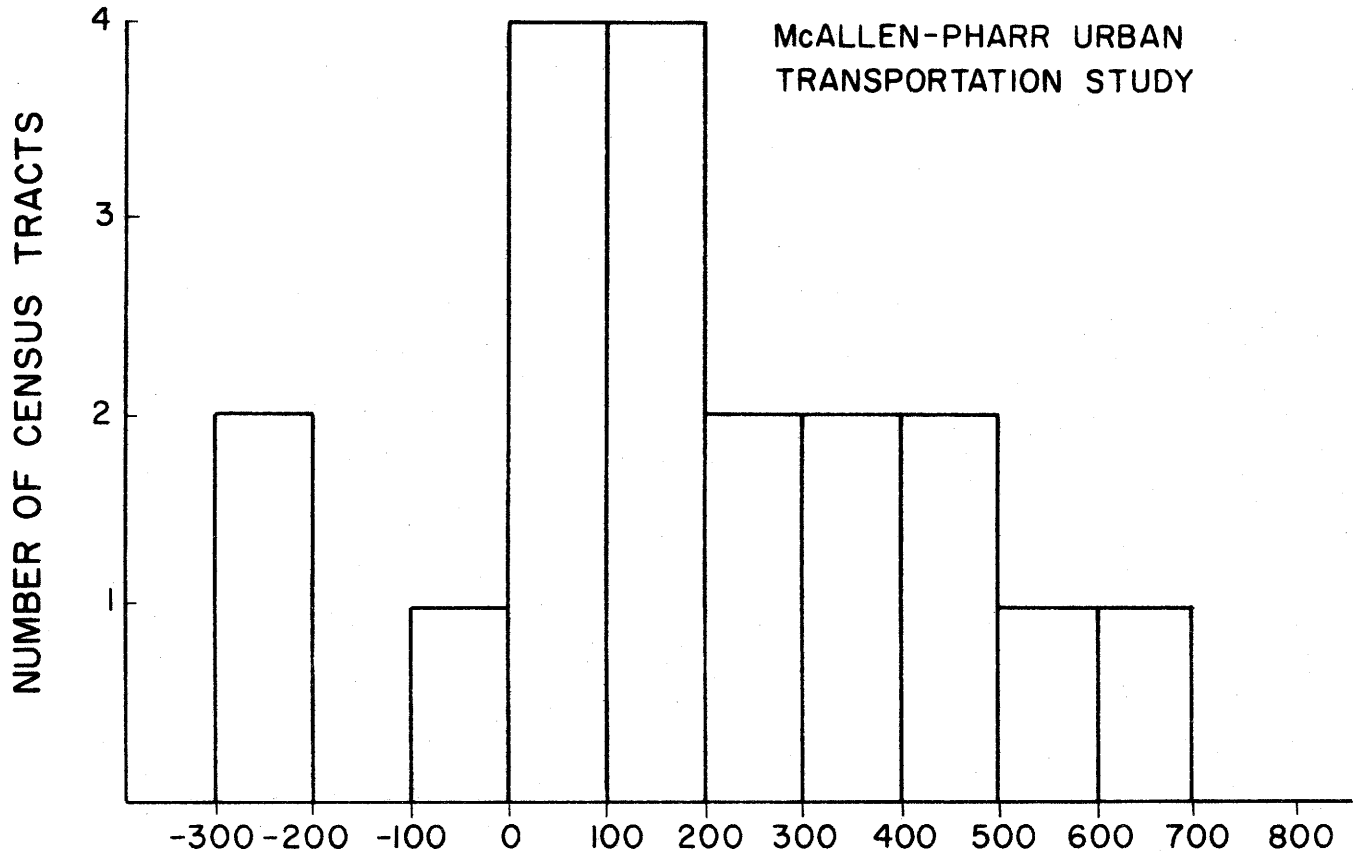


FIGURE 9. DISTRIBUTION OF ERROR IN ESTIMATED EMPLOYMENT BY CENSUS TRACTS

conclusions: The following conclusions are drawn from these analyses:

(1) The O-D Survey data did not provide acceptable estimates of employment by zone, district, or census tract. It is hypothesized that equally unacceptable estimates are likely to be obtained in other small urban areas.

(2) The data do not provide a basis of evaluating how large (in terms of employment) an area must be in order to obtain an acceptable estimate. However, inasmuch as districts and census tracts having employment as high as 1000 were not adequately estimated from the home interview data, the analysis indicates that the minimum is larger than 1000 employees. It also suggests that it is not possible to delineate zones of a sufficient size so as to yield acceptable estimates of employment from the O-D Survey data in small urban areas.

comparison of trip end totals: For purposes of comparing trip attractions as estimated by the O-D Survey with the number of attractions obtained by manual cordon counts, trips with a reported starting time ten minutes before the beginning or end of the ground count period were tabulated for comparison with the ground counts.

Table 6 summarizes the comparison of the Special Count Data and the O-D Survey data. The difference in the number of trip ends estimated from the ground counts and from the O-D Survey data is considered to be within reasonable limits for only one of the six zones (survey zone 215).

There does not appear to be any particular pattern to the under or overestimate. Of the three largest zones, each having over 2400 trip ends, one was overestimated and one was underestimated by the O-D Survey as compared to the ground counts, and one compared within acceptable limits.

TABLE 6

COMPARISON OF TRIP ATTRACTIONS ESTIMATED BY O-D SURVEY AND GROUND COUNT

McAllen-Pharr Urban Transportation Study

Survey Zone	Description	Ground Count	O-D Survey			O-D Survey as a percent of Ground Count
			Auto Drive	All Other	Total	
58	Community Shopping Center location U. S. 83 Business Mission	1316	717	117	834	83
215	Discount Store location 10th Street South U. S. 83 McAllen	2498	1798	721	2519	105
224	Area Shopping Center location U. S. 83 Business McAllen	2719	1238	464	1792	66
236	Professional Center location 10th Street North of U. S. 83 McAllen	1036	528	132	660	64
237	Community Shopping Center location 10th Street North of U. S. 83 McAllen	2479	2918	180	3098	125
252	Industrial with some commercial wholesale location U. S. 83 Business McAllen	403	42	65	107	26

Although a small number of zones were included in this study, it is believed that the data are sufficient to indicate that trip attractions are not estimated with an acceptable degree of accuracy by the O-D Survey for the size of zone that must be used in small urban areas.

The Accuracy of All-Or-Nothing Assignments In Estimating Turn Movements

The accuracy of the traffic volume estimates resulting from traffic assignments has been considered sufficient for system planning purposes. However designers, confronted with a need for design data, have also employed these results. As turning movements are furnished as a routine portion of traffic assignment output, these results have been considered a logical source of turning volume estimates for proposed transportation facilities. The adequacy of assigned turning volumes is cause for concern if these estimates are to be employed in design.

A preliminary analysis of turn movements was performed as a satellite to the study on the effect of network detail on the all-or-nothing traffic assignment using information from the Waco Urban Transportation Study.

Comprehensive turning movement count data for the express purpose of detailed analysis of turn movements was not collected during the origin-destination survey. Hence, there were only 25 intersections, scattered throughout the study area which could be included in the

analysis using all three coded networks. These three networks were:

- The operational (E-2) network having 410 nodes.
- An intermediate density network with 1930 nodes.
- A detailed network with 5629 nodes.

The following count data were available for the 25 intersections.

(1) A.M. peak period count.

(2) P.M. peak period count.

(3) One hour off-peak count, usually 10-11 A.M.

Twenty-four turn movement counts, however, were not available for the same 25 intersections for which there were counts for peak and off-peak periods. Thus, the short period counts had to be expanded to twenty-four hour estimates for comparison with the twenty-four traffic assignment results.

This was accomplished by adding the two peak period counts to sixteen times the off-peak hour count on the assumption that turns, in percent of approach volume, remains constant throughout the day. The expansion factor of sixteen was selected based on an analysis of volumes of all roadway sections in the study area with both peak period, off-peak period and twenty-four hour counts.

An expansion factor was calculated for each of these roadway sections on the following basis:

$$\frac{\text{24 Hr. Count - (A.M. + P.M. Peak Period Counts)}}{\text{Off Peak Hour Count}}$$

The average value of the expansion factor was found to be approximately sixteen.

In order to obtain twenty-four hour turn volume estimates, the expansion factor was used in the following manner:

Estimated 24 hour volume = (Expansion Factor) (Off Peak Hour Count) + (A.M. + P.M. Peak Period Count)

The expanded counts were compared with the turning movements obtained from the assignment of the observed O-D trip matrix to the three coded networks. The assignments were made without turn penalties. The assigned values were first to be consistently below the estimated twenty-four hour volumes for all three degrees of network detail.

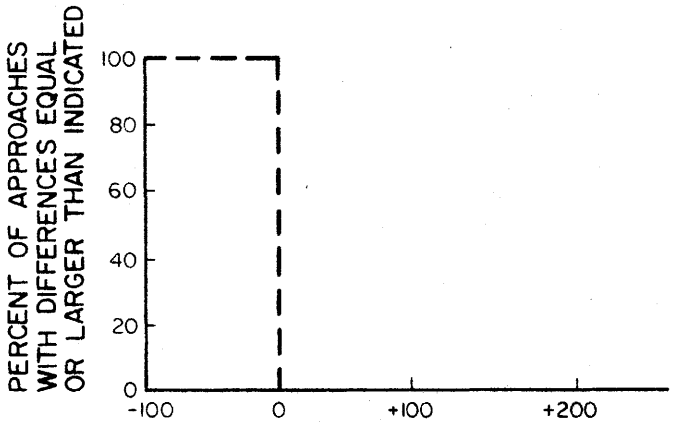
In an attempt to minimize any influence of the off-peak period expansion factor, the percent turning movements were compared. This was done because the percent turns are not as drastically affected by errors in estimating the expansion factor as are the actual number of turns.

Left turns, as a percent of approach volume, obtained from expanded peak period counts were plotted against assigned left turn volumes as a percent of total assigned approach volume for the 25 intersections for which there were turn movement counts available. This analysis suggested that the percentage of turns obtained through an all-or-nothing traffic assignment are approximately randomly distributed.

In an attempt to provide a comparative evaluation of the accuracy of turning assignment for different degree of network detail an accumulated frequency distribution of each of the three networks was prepared.

This was done by plotting the accumulated percent of approaches, for which there were data available, against the difference in percent between assigned and counted volumes. Percent differences were accumulated in the direction from large toward smaller algebraic values (i.e. any negative value is considered smaller than zero; the smallest difference was thus -100 percent for a turn movement with zero assigned volume). Only approaches where counts for through or individual turn movements exceeded 500 vpd. were included in the analysis.

The plots are shown in Figures 10, 11, and 12 for left turns, through movements and right turns respectively. A perfect agreement between assigned and counted volumes would produce a curve as indicated in the figure below.



$$\frac{\text{(Assigned Volume - Ground Count) x 100}}{\text{Ground Count}}$$

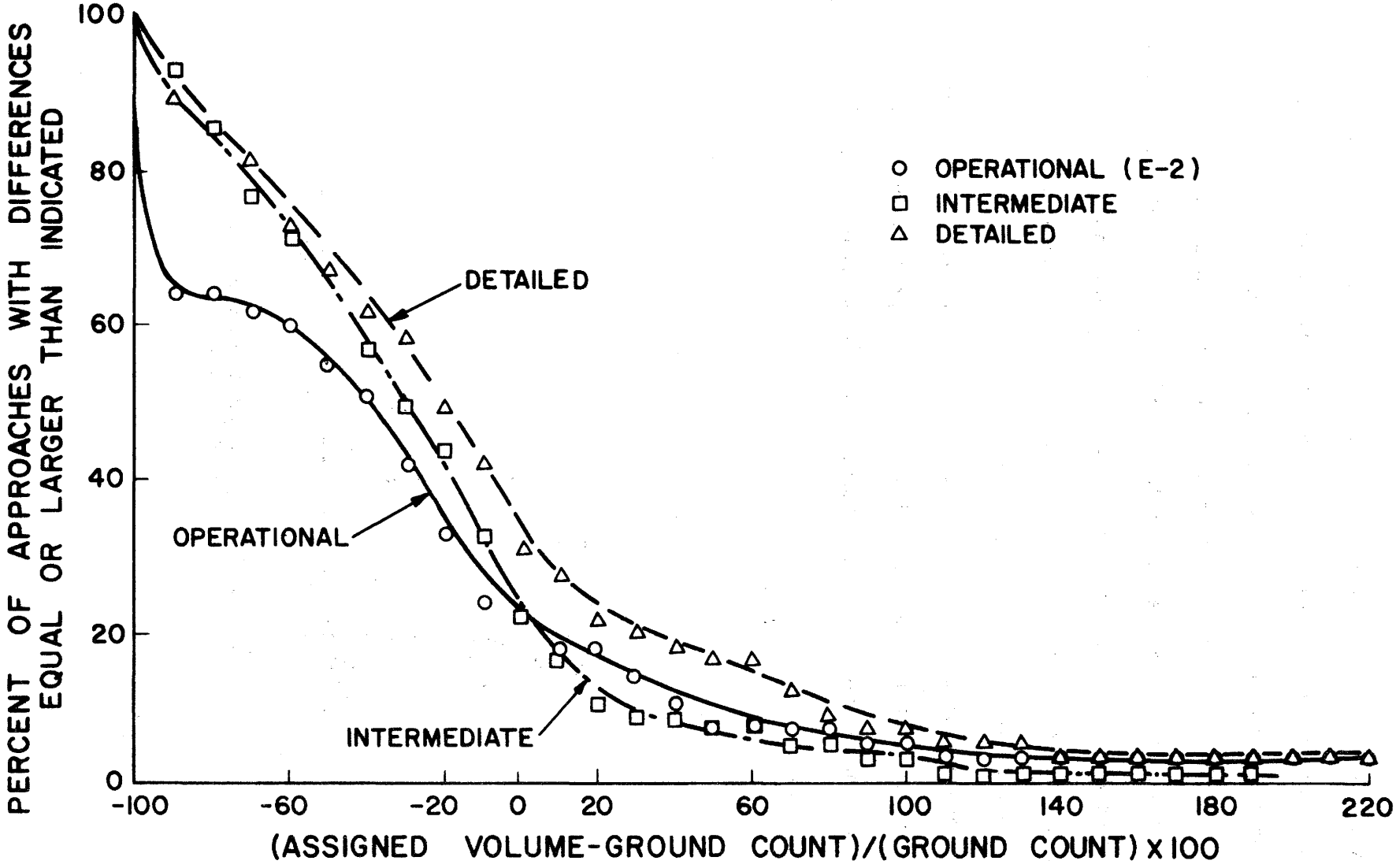


FIGURE 10. DISTRIBUTION OF DIFFERENCE BETWEEN ASSIGNED AND COUNTED LEFT TURN VOLUMES

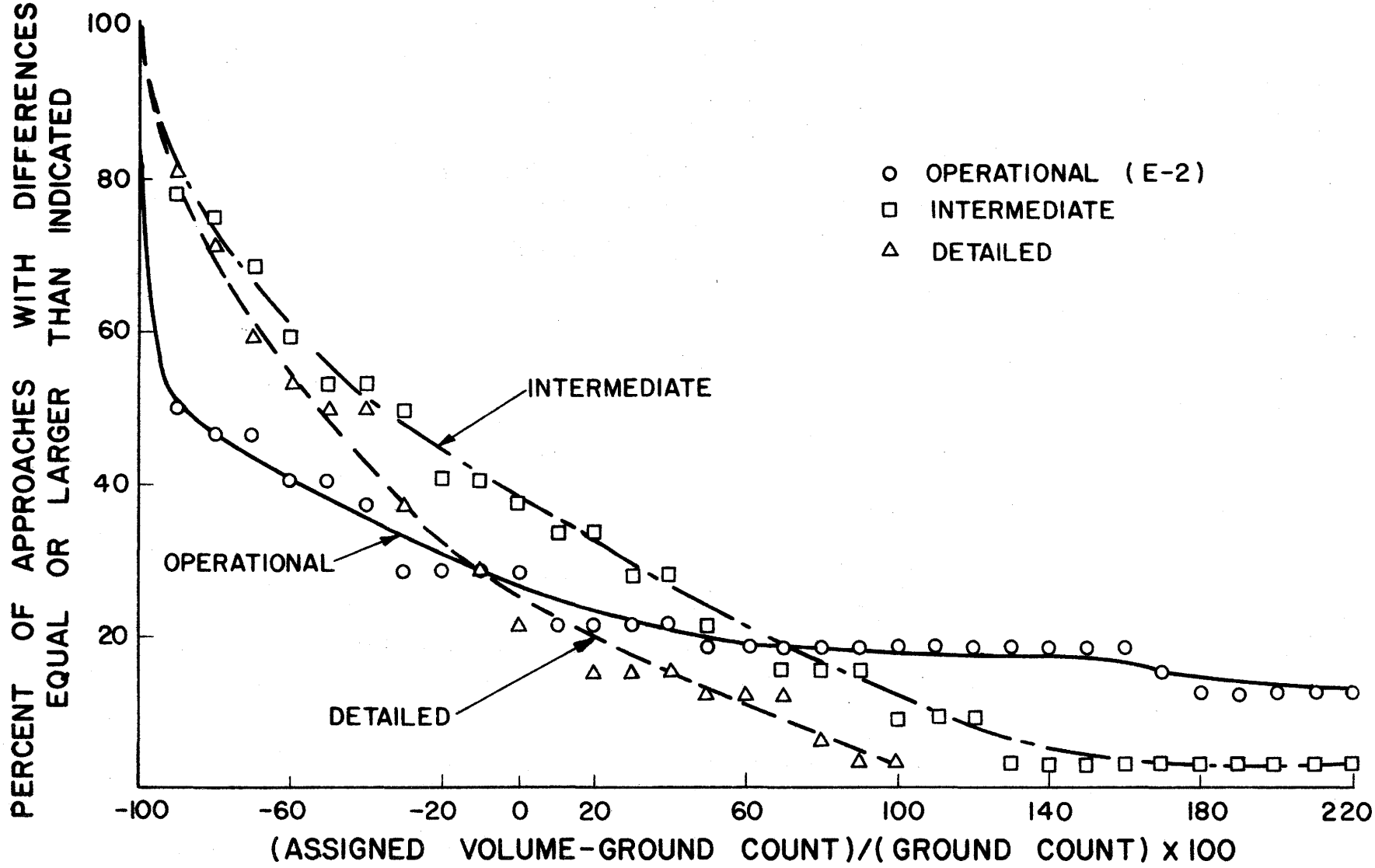


FIGURE 11. DISTRIBUTION OF DIFFERENCES BETWEEN ASSIGNED AND COUNTED THROUGH VOLUME

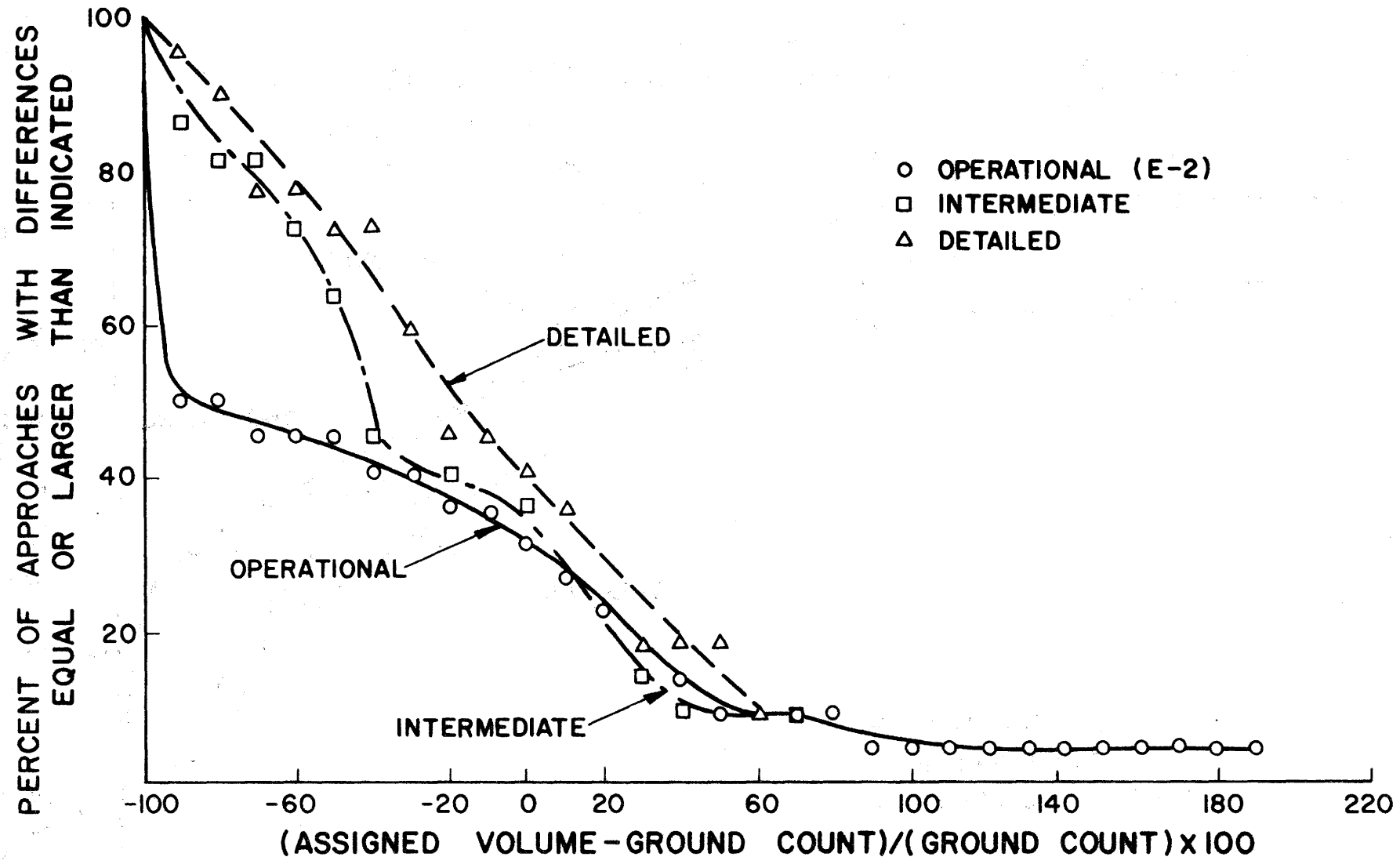


FIGURE 12. DISTRIBUTION OF DIFFERENCES BETWEEN ASSIGNED AND COUNTED RIGHT TURN VOLUMES

The resulting curves do not indicate any significant difference in accuracy of assignment of turn and through volumes between the three networks. More importantly, the relative difference in accuracy of the three networks is insignificant compared to the complete lack of correspondence between counts and assigned volumes.

conclusions & comment

The following conclusions are based upon the limited analysis that could be made with the data available.

1. The turning movement obtained through an all-or-nothing traffic assignment bears little, if any, direct relationship to the expanded counts.
2. There appears to be no tendency for improvement in the assigned turn movements with increasing volume.
3. There appears to be no significant improvement in the assigned turn movements with increasing degrees of detail in network representation.

It is believed that the differences are so gross that these conclusions are basically valid in spite of all weaknesses inherent in the limited analysis.

Even though there appears to be little or no direct comparison between assigned and counted turn movements, it is possible that the total number of, say, left turns along some reasonably long segment might compare reasonably well. The type of information needed to test such a hypothesis was not available from the Waco study.

One-Hundred Percent Home Interview Data

In conjunction with the San Antonio-Bexar County Urban Transportation Study, home interviews were conducted in 100 percent of the dwelling units in three adjacent zones located on the north-central side of the city. Interviews were completed with a total of 424 dwelling units. The selected zones appear to be homogeneous as to socio-economic characteristics and might be classified a middle-class residential. There was no commercial activity within the three zones.

The number of dwelling units together with number, mean, variance, and standard deviation of home-based person trips is given in Table 6.

TABLE 6

SUMMARY STATISTICS FROM
100 PERCENT INTERVIEWS FOR INTERNAL
HOME-BASED PERSON TRIPS

	ZONE 1922	ZONE 1923	ZONE 1924	AGGREGATE AREA
Number of units	96	164	164	424
Home-based person trips	860	1180	1180	3220
Average number of trips per unit*	9	7	7	8
Variance*	46	43	32	40
Standard deviation	6.807	6.571	5.628	6.309
Coefficient of variation	0.760	0.913	0.782	0.831

*Rounded to the nearest whole number.

As expected, the frequency distributions of the number of trip ends per dwelling unit (not shown in this report) were found to be highly skewed to the right. However, the means (average number of trips per dwelling unit from various samples) should be normally distributed because, as the sample size is increased, the mean of a random sample from any population with a finite variance tends to be normally distributed.[1]

A random number generator was needed to draw 500 samples for each of five sampling levels (5, 10, 20, 30, and 40 percent of the 424 dwelling units). The samples were selected with replacement studies. The samples were expanded to represent the population and the percent error $\left(\frac{\text{estimated - actual}}{\text{actual}} \times 100\right)$ calculated.

The resulting estimates indicating the deviation from true number of trip ends (3220) are plotted in frequency distributions presented in Figures 13 through 17.

Summary of Initial Findings

The Chi-Square test (5 percent level of significance) indicates that the distribution of the trip end estimates from the 5 percent samples is significantly different from a normal distribution; the distribution estimates from the 10 percent and higher sampling rate sample are not. Hence, statistical formulas based on the assumption of normality can be used to determine the reliabiiity of estimates based on sample means as long as the sampling rate is 10 percent or higher (42 dwelling units or more) using these data.

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[1] Snedecor and Cochran, Statistical Methods, (6th ed., 1968), p. 50.

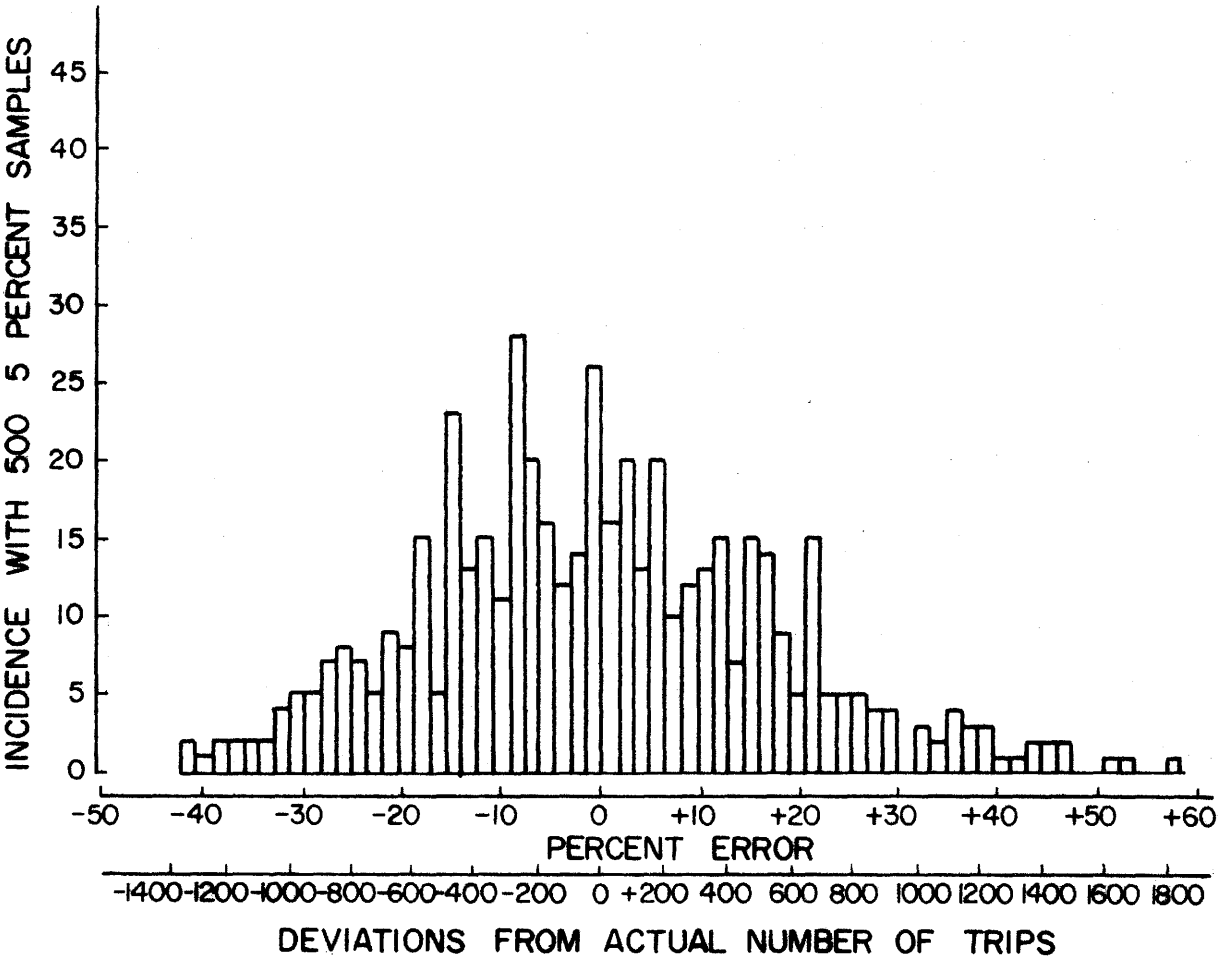

FIGURE 13. DISTRIBUTION OF PERCENT ERROR IN ESTIMATED HOME-BASED PERSON TRIPS AT 5 PERCENT SAMPLING RATE.

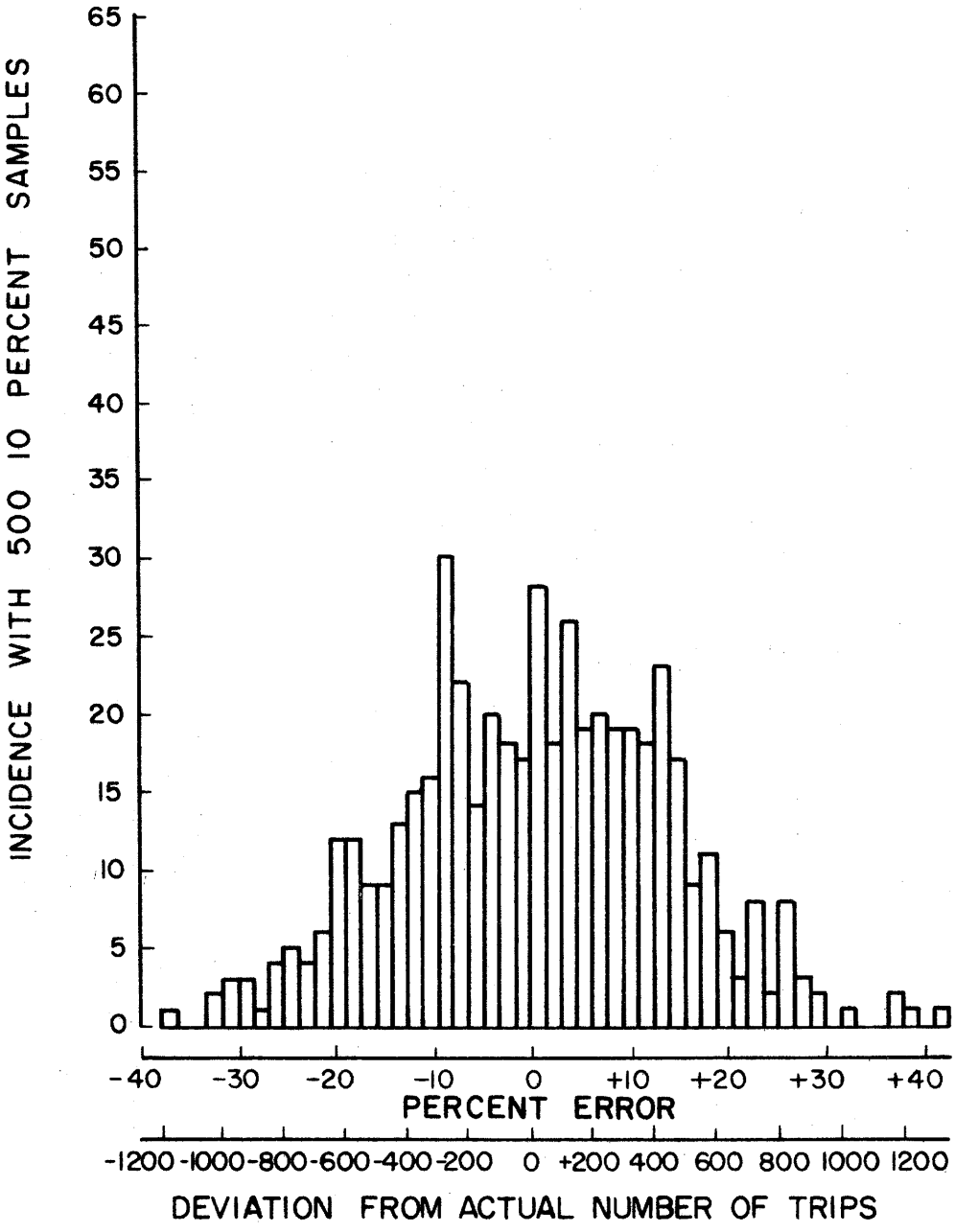

FIGURE 14. DISTRIBUTION OF PERCENT ERROR IN ESTIMATED HOME-BASED PERSON TRIPS AT 10 PERCENT SAMPLING RATE.

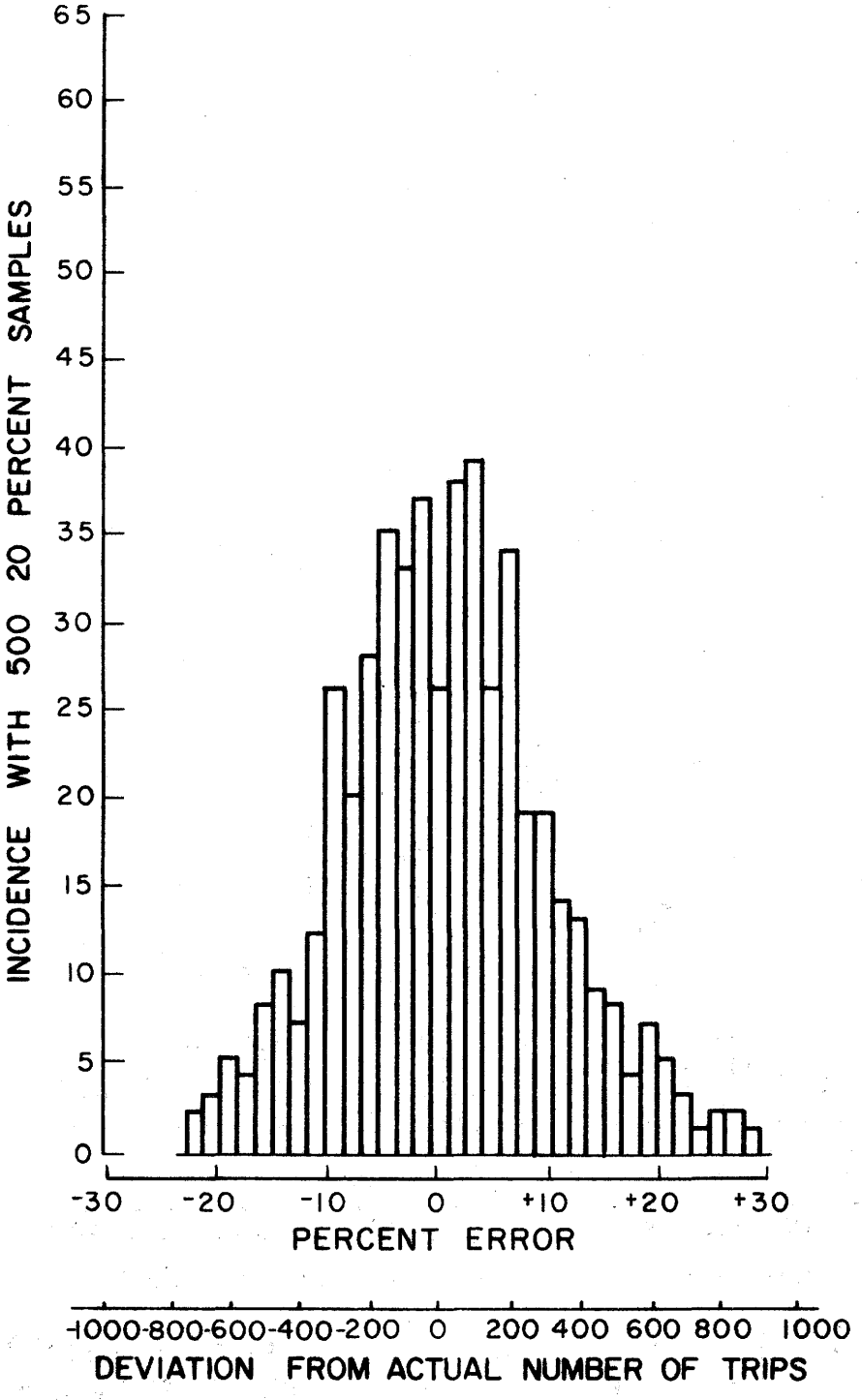

FIGURE 15. DISTRIBUTION OF PERCENT ERROR IN ESTIMATED HOME-BASED PERSON TRIPS AT TWENTY PERCENT SAMPLING RATE.

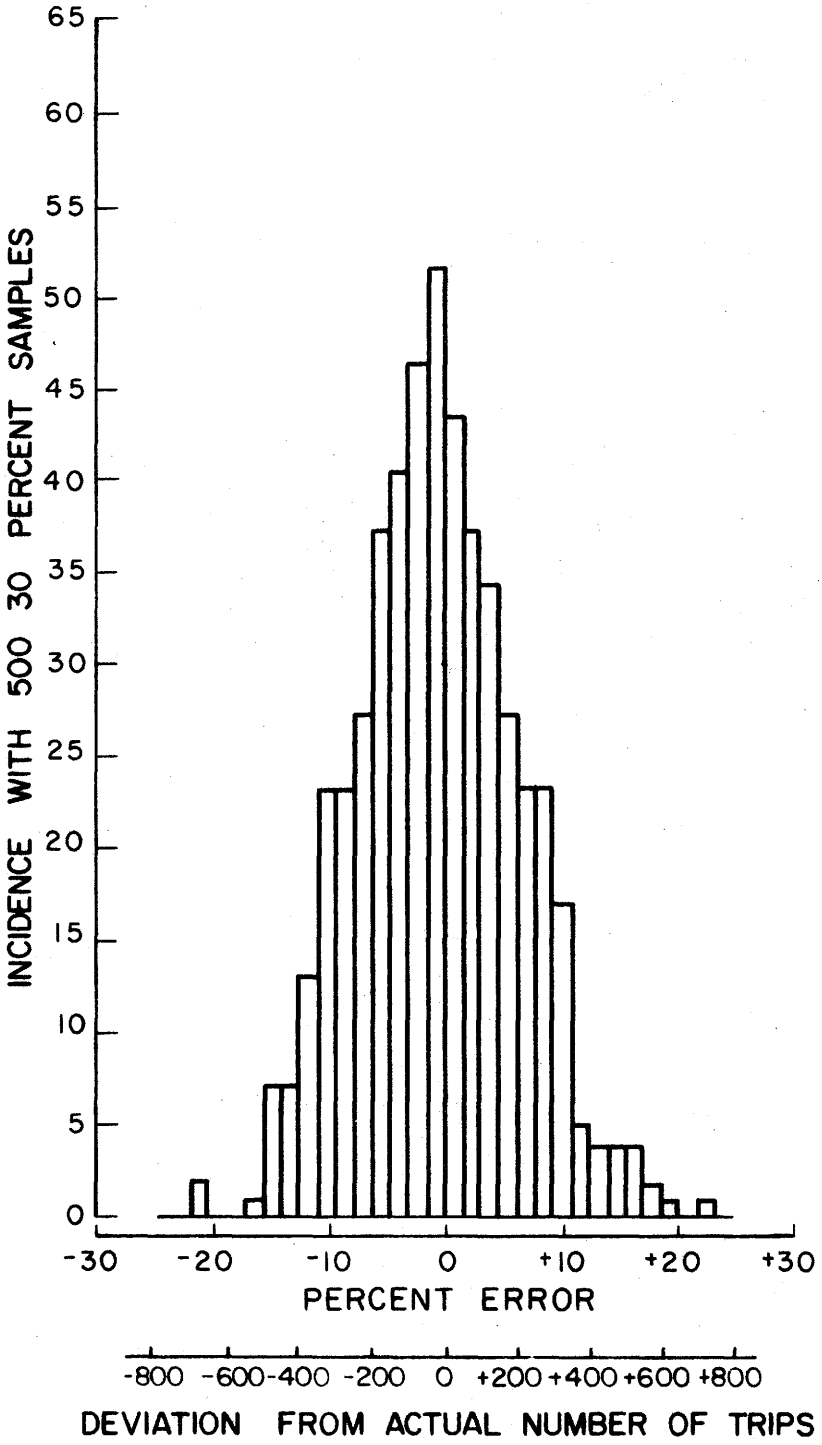

FIGURE 16. DISTRIBUTION OF PERCENT ERROR IN ESTIMATED HOME-BASED PERSON TRIPS AT THIRTY PERCENT SAMPLING RATE.

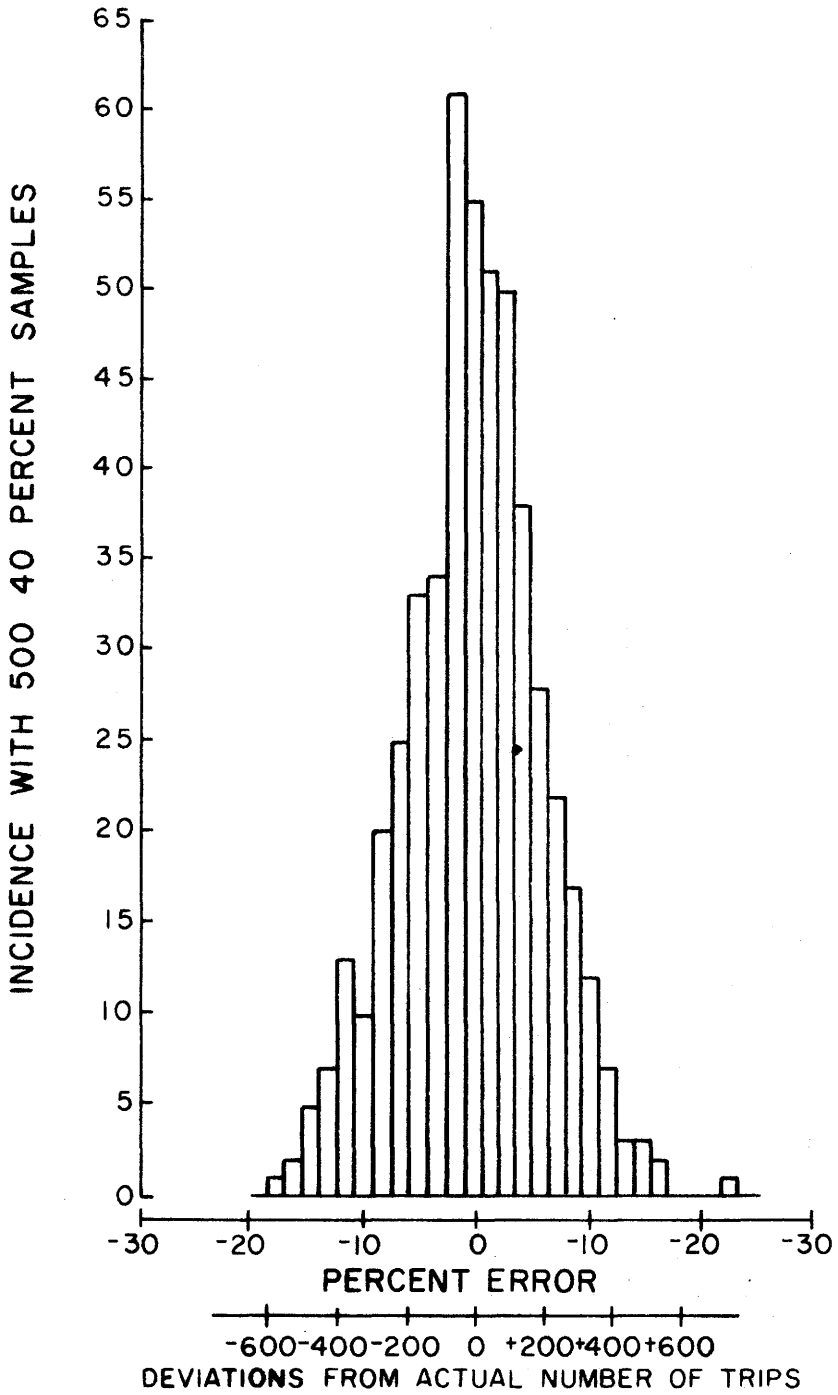

FIGURE 17. DISTRIBUTION OF PERCENT ERROR IN ESTIMATED HOME-BASED PERSON TRIPS AT FORTY PERCENT SAMPLING RATE

The hypotheses of equal means and equal variances for the three zones were also tested (home based person trips, home based auto driver trips, home based work auto driver, and home based nonwork auto driver). Statistical tests indicated that the hypotheses can be accepted and the 95 percent confidence level for all except the variances for homebased work auto driver trips.

Based on the assumption of normality, the following formulas[2] were used to calculate the sample size needed to accurately estimate the total number of trip ends:

$$n_o = \frac{(NtS)^2}{(d)^2} \qquad \text{and} \qquad n = \frac{n_o}{1 + \frac{n_o}{N}}$$

where, N = the size of the zone being sampled
t = the value from the normal table which corresponds to the desired level of confidence, eg., 1.96 for 95%
S = standard deviation
d = desired degree of accuracy, eg., ± 322 trips.
n_o = uncorrected sample size
n^o = sample size after correction

The second formula corrects for finite populations. The sample size needed to attain the desired degree of accuracy is given by n. For example, in order to be 95 percent confident that the estimated total number of trip ends will be within 10 percent of the actual number generated by the 424 dwelling units interviewed, a sample of 163 (40%) interviews would be needed.

$$n_o = \frac{(424 \times 1.96 \times 6.309)^2}{(322)^2} = 265$$

$$n = \frac{265}{1 + \frac{265}{424}} = 163$$

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[2] William G. Cochran, Sampling Techniques, John Wiler & Sons, 1963, p. 76.

Calculations were made for each of the zones and for the aggregate, at confidence levels of 95% and 80%; results are represented graphically in Figures 18 and 19 respectively. These figures indicate that unexpectedly high sampling rates would be needed in order to estimate the total number of trip ends with desirable accuracy. For example, a sampling rate of over 20 percent is required in order to estimate the total number of trip ends within plus/minus 10 percent at the 80 percent confidence level.

A similar analysis was performed for internal home based auto driver trips, internal home based work auto driver trips, and internal home based nonwork auto driver trips. Tables 7, 8, and 9 contain the summary statistics for these trips. Figures 20 through 26 illustrate the margin of error versus the sampling rate for these trips at confidence levels of 95% and 80%.

Again, these figures indicate that unexpectedly high sampling rates would be needed in order to estimate the total number of trip ends with desirable accuracy. For example, a sample of nearly 20 percent would be required to estimate the total number of home based auto driver trip ends within plus/minus 10 percent at the 80 percent confidence level. Likewise, with the desired accuracy of plus/minus 10 percent at the 80 percent confidence level, a sampling rate of just under 20 percent would be required to estimate the total number of home based work auto driver trip ends and the total number of home based nonwork trip ends.

It is interesting to note that a smaller sampling rate is required to estimate the home based auto driver trip ends than the home based

person trips. This indicates that, at any given sampling rate, the home-based auto driver trip ends can probably be more accurately estimated than the home-based person trip ends.

The sampling rates required for estimating home-based-work auto driver trip ends as compared to the sampling rates required for estimating home-based auto driver trip ends may be somewhat misleading. As can be seen from Tables 7 and 8, there are 2,090 home-based auto driver trips of which only 681 are home-based-work auto driver trips. Therefore, a plus/minus 10 percent error in home-based auto driver trips implies plus/minus 209 trips; whereas, with home-based-work auto driver trips, it implies plus/minus 68 trips. Since the size of the populations being estimated are so significantly different, it is interesting to compare the required sampling rates with a desired accuracy in terms of plus/minus a given number of trips rather than a given percentage of trips. For example, if the desired accuracy was plus/minus 200 trips rather than 10 percent of the trips, the following sampling rates would be required, at a confidence level of 80 percent, to estimate the four types of trips for the aggregated area:

Type of trips	Desired accuracy in number of trips	Desired accuracy in percent of trips	Required sampling rate
home based person trips	±200	± 6.2%	41%
home-based auto driver trips	±200	± 9.6%	19%
home-based work auto driver trips	±200	±29.4%	4%
home-based nonwork auto driver trips	±200	±14.2%	16%

A comprehensive analysis of the 100 percent data relative to both trip ends and travel patterns is continuing under study 2-10-71-167.

conclusion

The preliminary findings of the 100 percent interviews and other analyses suggest that the conduct of urban transportation studies might be made more cost effective through the employment of "synthetic" study techniques combined with data collection procedures designed to answer specific questions and/or to fill particular "data gaps". (Such an approach has been approved for and is being implemented with the Houston-Galveston Area Urban Transportation Study.)

TABLE 7

SUMMARY STATISTICS FROM
100 PERCENT INTERVIEWS FOR INTERNAL
HOME-BASED AUTO DRIVER TRIPS

	ZONE 1922	ZONE 1923	ZONE 1924	AGGREGATE AREA
Number of units	96	164	164	424
Home-based auto driver trips	563	764	763	2090
Average number of trips per unit*	6	5	5	5
Variance*	15	14	12	14
Standard deviation	3.911	3.760	3.500	3.723
Coefficient of variation	0.667	0.807	0.752	0.755

*Rounded to nearest whole number.

TABLE 8

SUMMARY STATISTICS FROM
100 PERCENT INTERVIEWS FOR INTERNAL
HOME-BASED-WORK AUTO DRIVER TRIPS

	ZONE 1922	ZONE 1923	ZONE 1924	AGGREGATE AREA
Number of units	96	164	164	424
Home-based-work auto driver trips	173	261	247	681
Average number of trips per unit*	2	2	2	2
Variance*	3	3	2	3
Standard deviation	1.708	1.712	1.429	1.608
Coefficient of variation	0.948	1.076	0.949	1.001

*Rounded to nearest whole number.

TABLE 9

SUMMARY STATISTICS FROM
100 PERCENT INTERVIEWS FOR INTERNAL
HOME-BASED-NONWORK AUTO DRIVER TRIPS

	ZONE 1922	ZONE 1923	ZONE 1924	AGGREGATE AREA
Number of units	96	164	164	424
Home-based-nonwork auto driver trips	390	503	516	1409
Average number of trips per unit*	4	3	3	3
Variance*	12	11	10	11
Standard deviation	3.427	3.301	3.109	3.275
Coefficient of variation	0.844	1.076	0.988	1.433

*Rounded to nearest whole number.

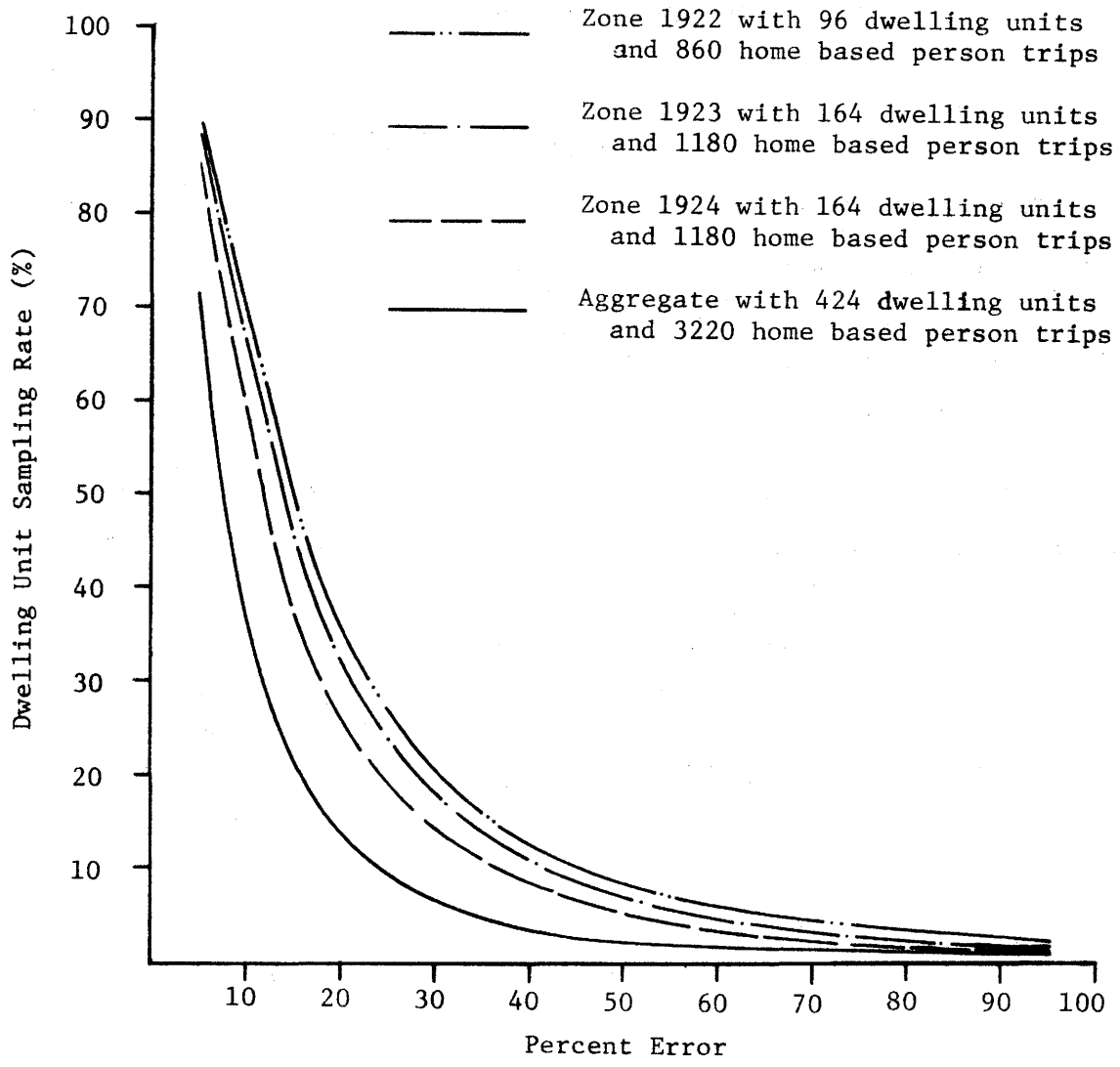

Figure 18: MARGIN OF ERROR VS. SAMPLING RATE WITH 95% CONFIDENCE FOR INTERNAL HOME BASED PERSON TRIPS

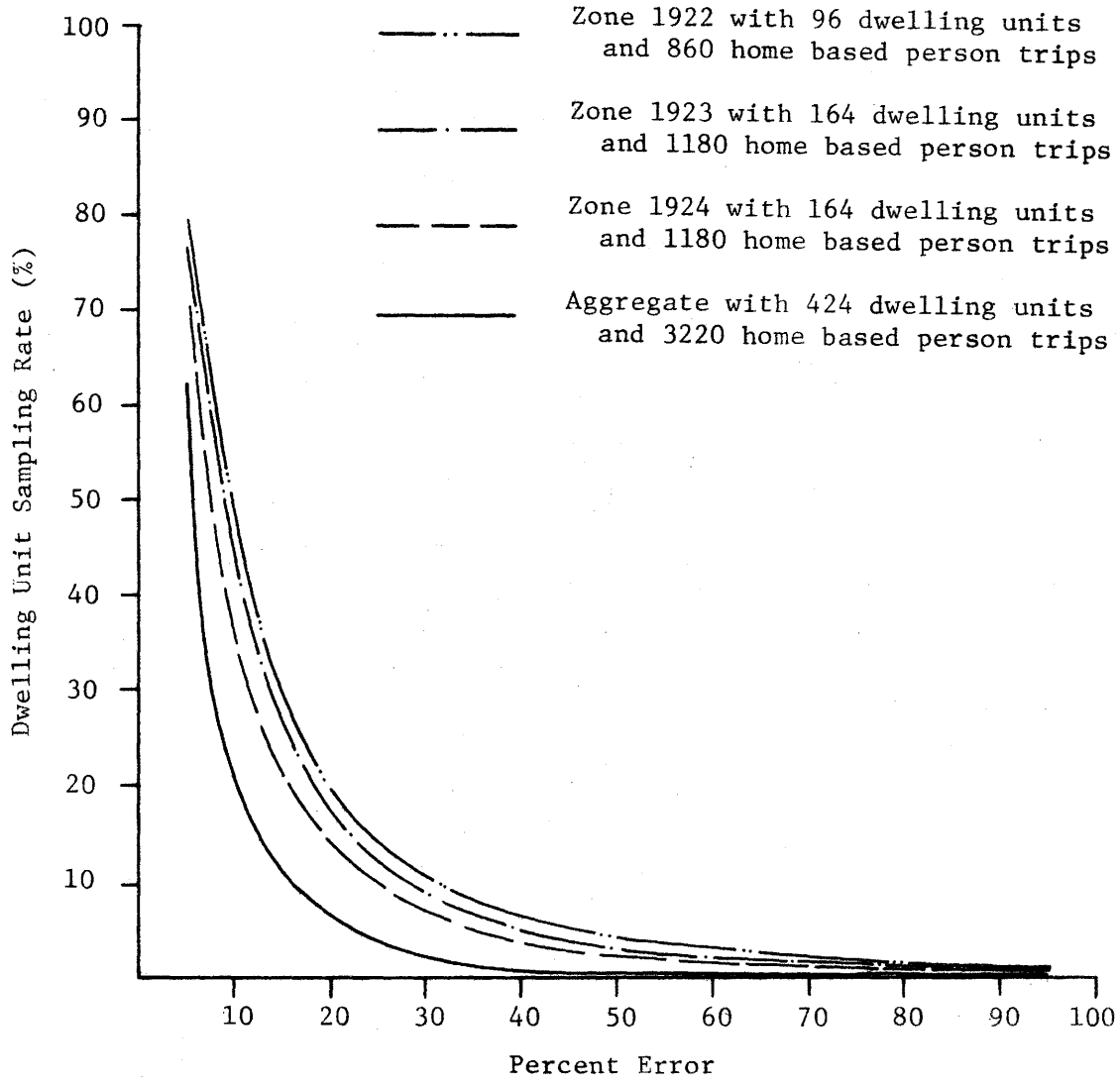

Figure 19: MARGIN OF ERROR VS. SAMPLING RATE WITH 80% CONFIDENCE FOR INTERNAL HOME BASED PERSON TRIPS

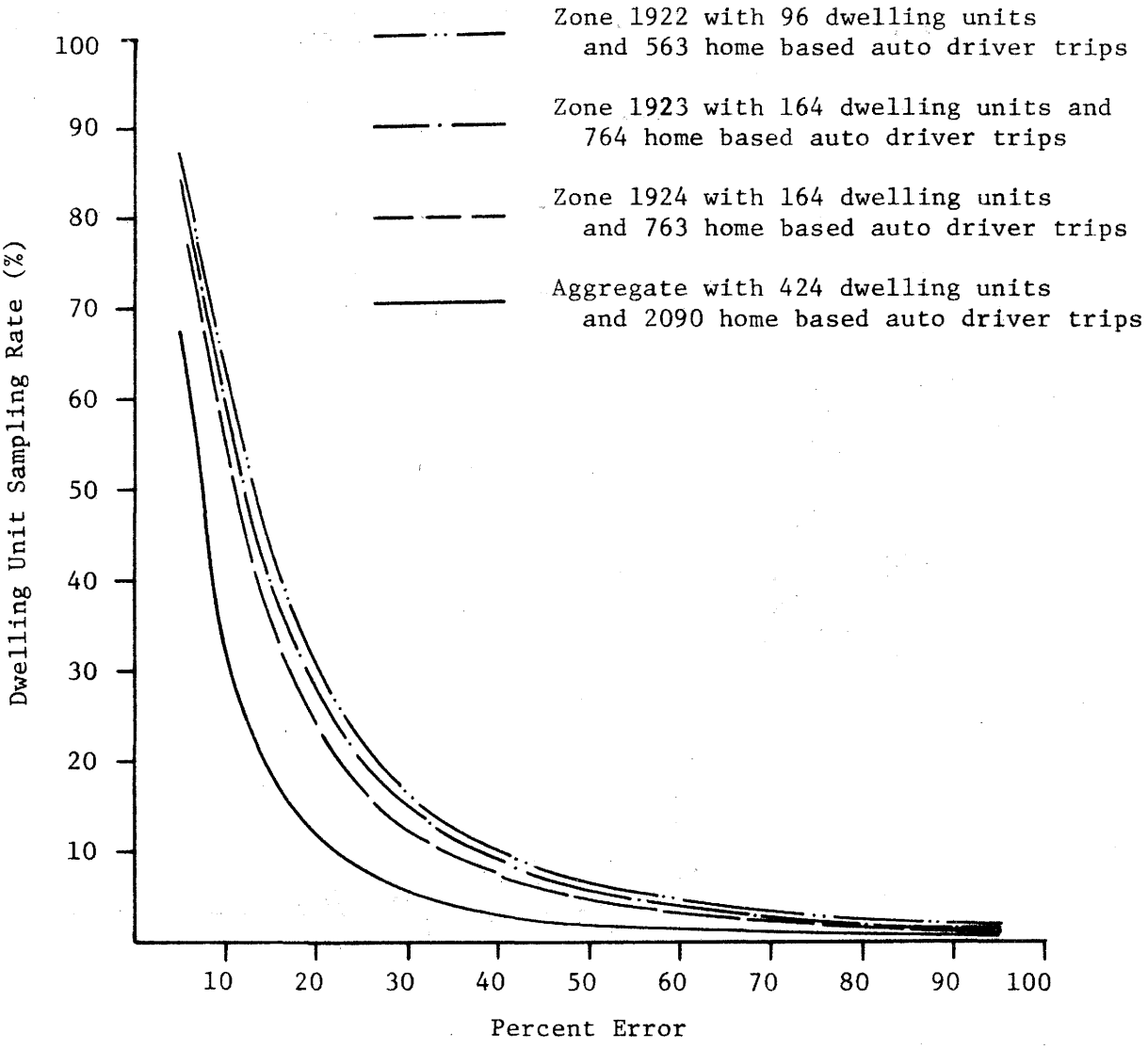

Figure 20: MARGIN OF ERROR VS. SAMPLING RATE WITH 95% CONFIDENCE FOR INTERNAL HOME BASED AUTO DRIVER TRIPS

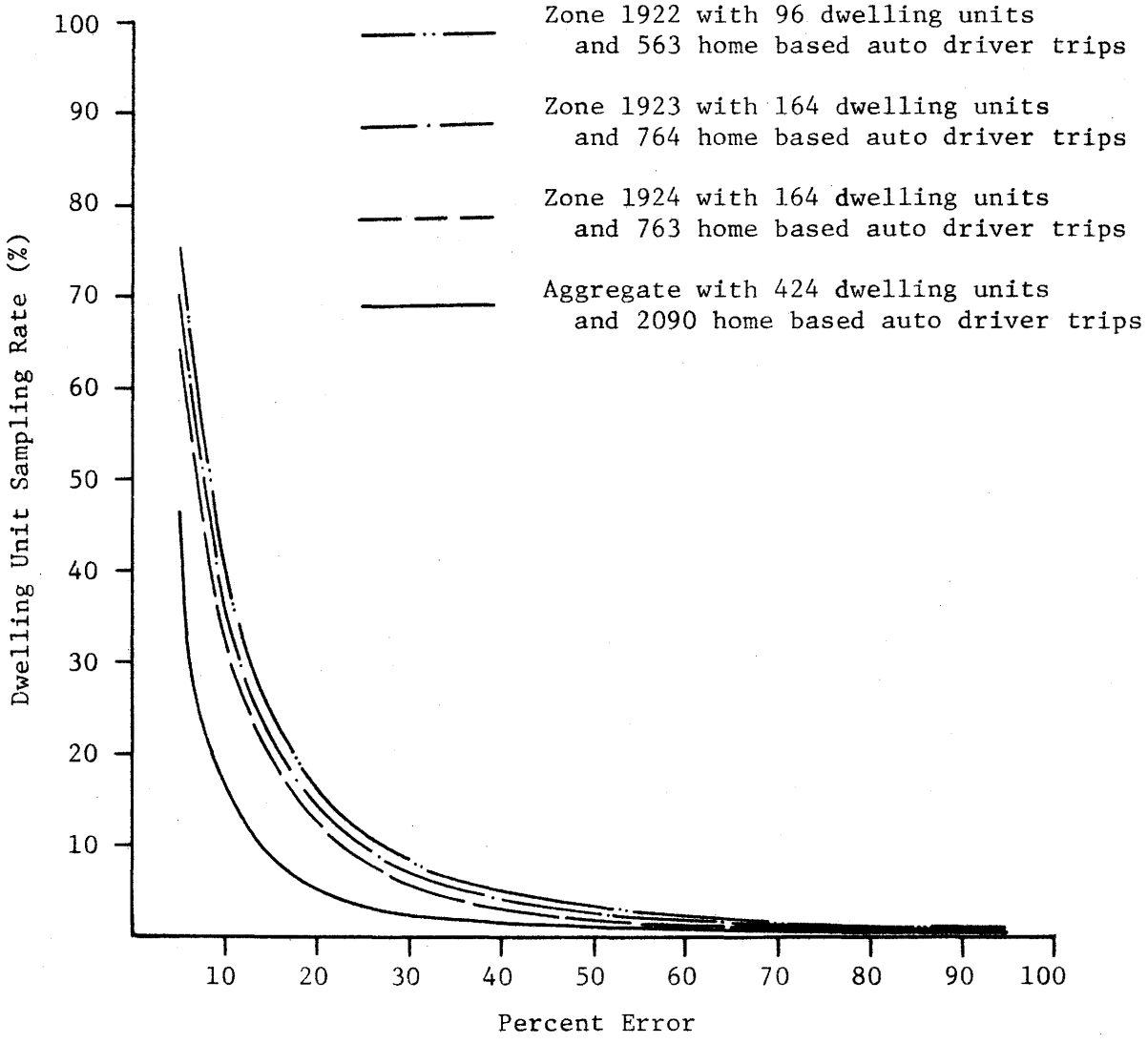

Figure 21: MARGIN OF ERROR VS. SAMPLING RATE WITH 80% CONFIDENCE FOR INTERNAL HOME BASED AUTO DRIVER TRIPS

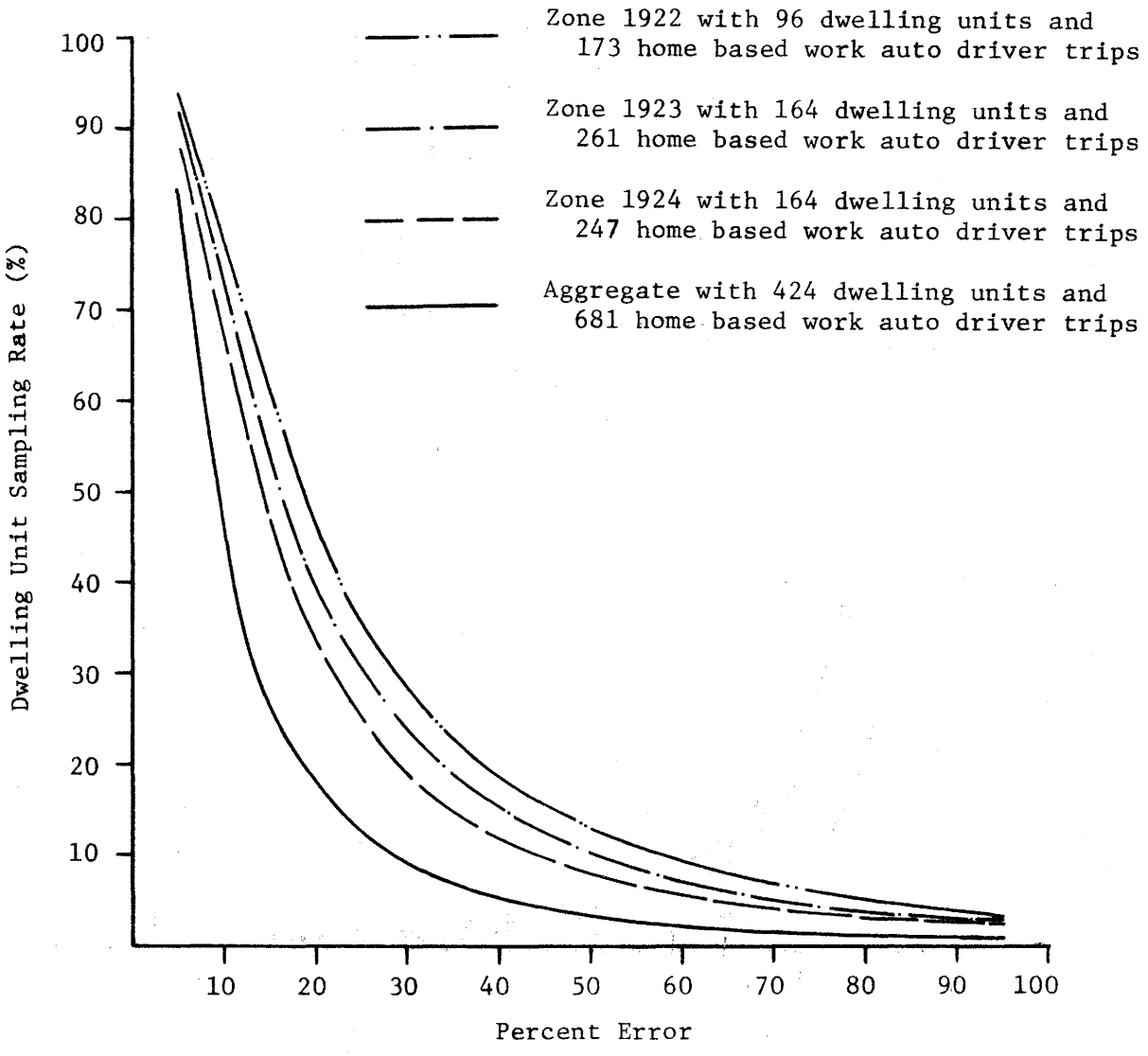

Figure 22: MARGIN OF ERROR VS. SAMPLING RATE WITH 95% CONFIDENCE FOR INTERNAL HOME BASED WORK AUTO DRIVER TRIPS

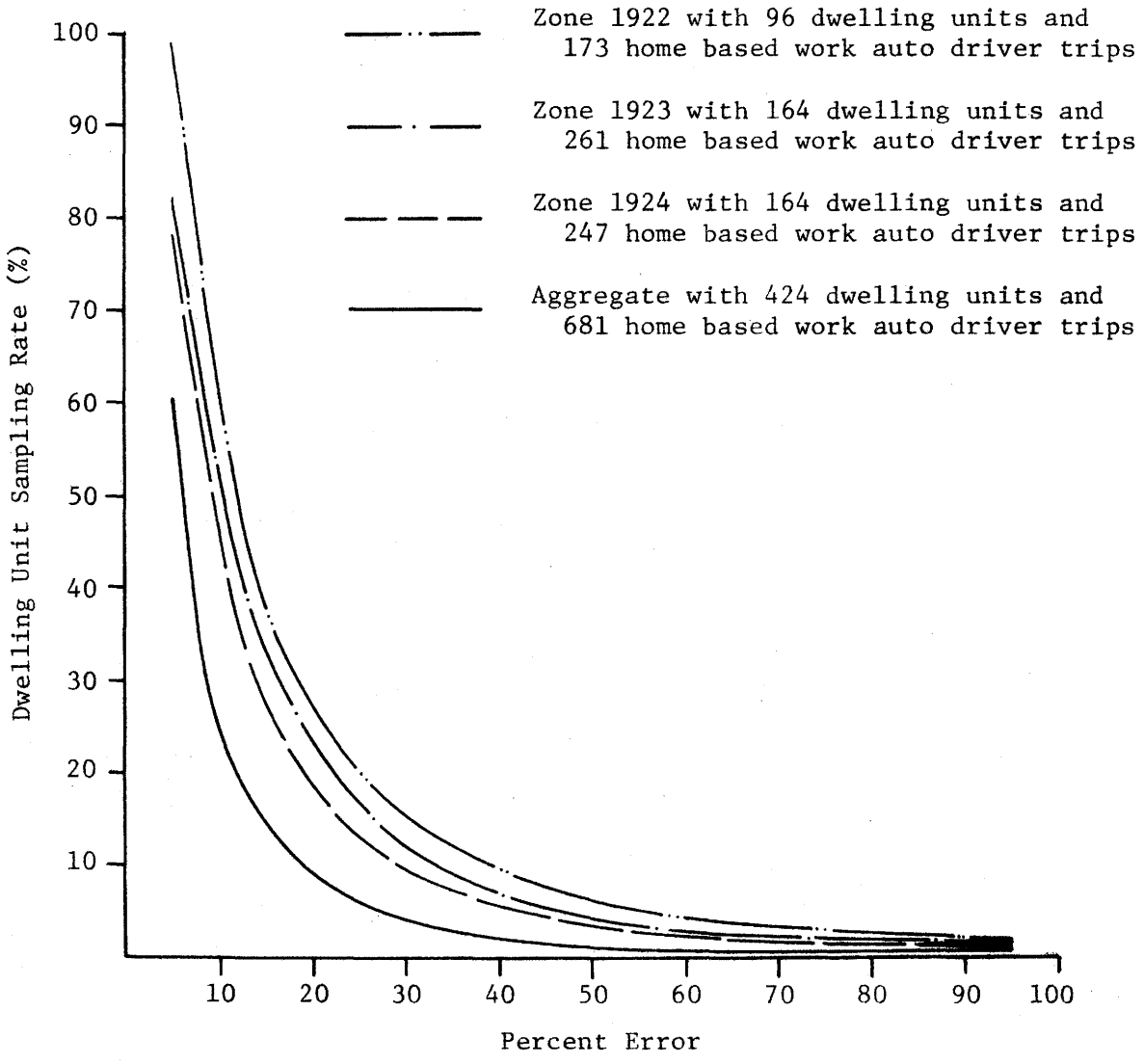

Figure 23: MARGIN OF ERROR VS. SAMPLING RATE WITH 80% CONFIDENCE FOR INTERNAL HOME BASED WORK AUTO DRIVER TRIPS

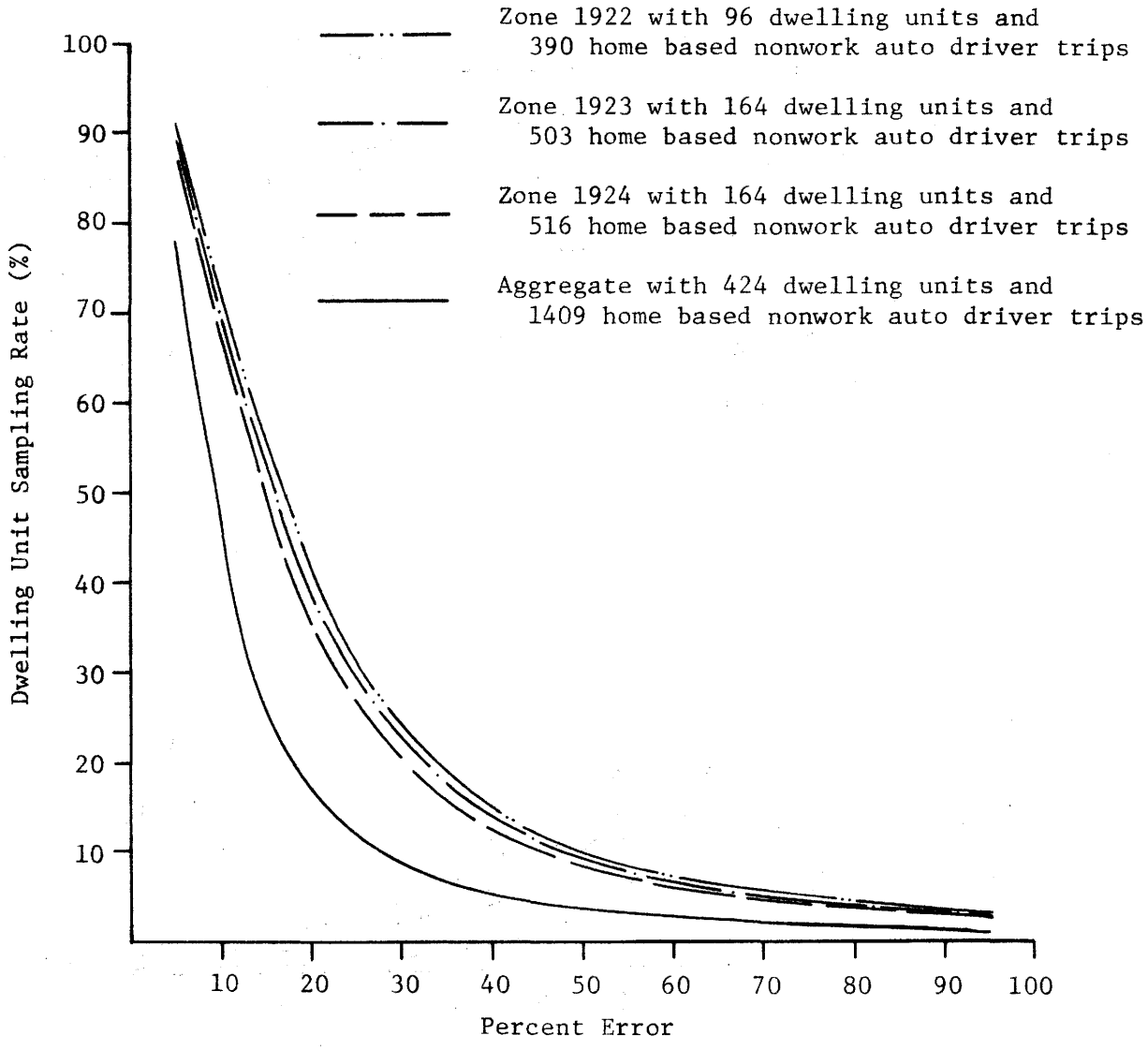

Figure 24: MARGIN OF ERROR VS. SAMPLING RATE WITH 95% CONFIDENCE FOR INTERNAL HOME BASED NONWORK AUTO DRIVER TRIPS

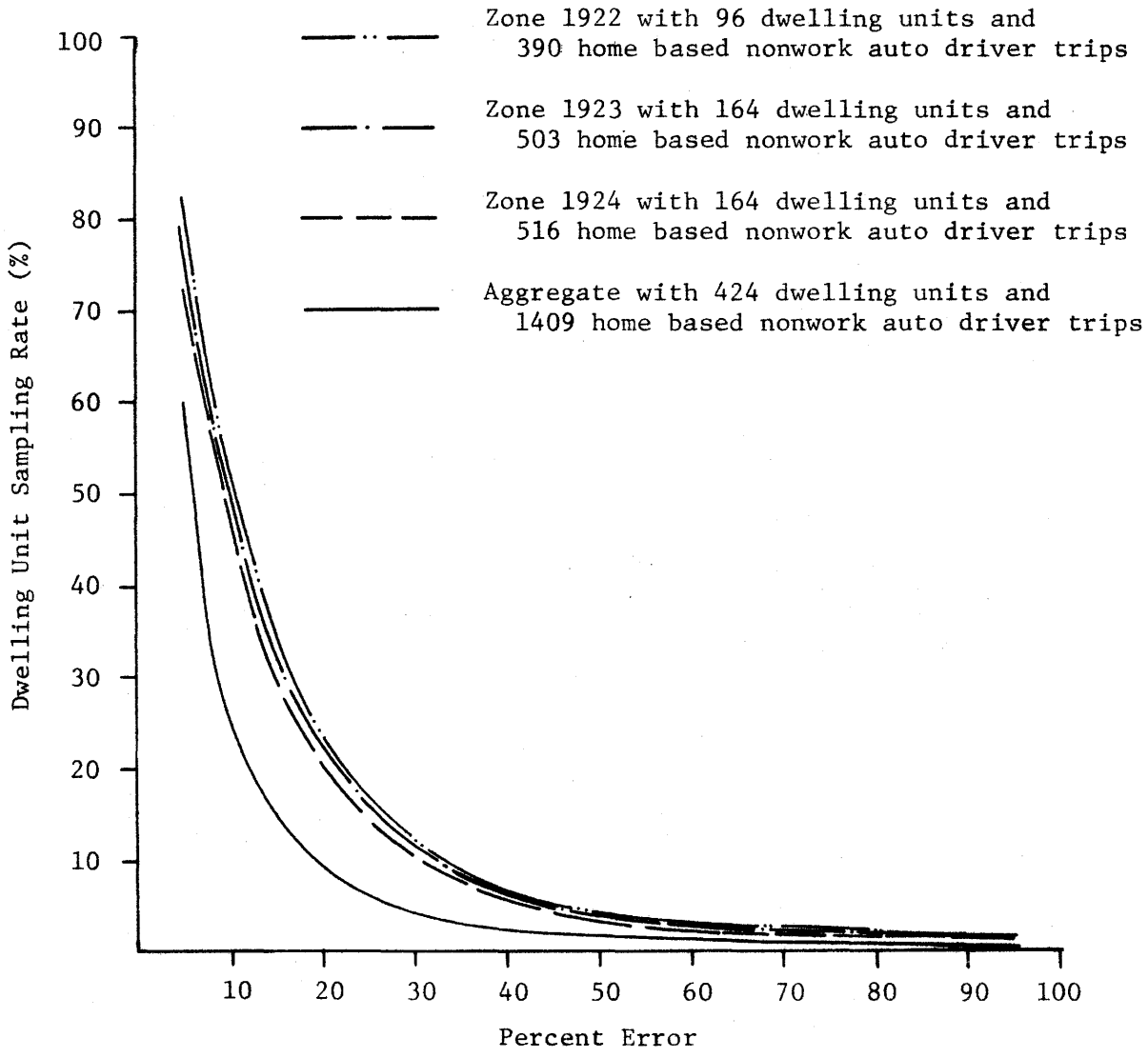

Figure 25: MARGIN OF ERROR VS. SAMPLING RATE WITH 80% CONFIDENCE FOR INTERNAL HOME BASED NONWORK AUTO DRIVER TRIPS

APPENDIX

Study Objectives and Summary of Accomplishments

The objectives of Study 2-10-68-119, are stated below together with a summary of the work accomplished and the status of each objective at the end of August, 1970.

OBJECTIVE #1: Investigate techniques and develop procedure for making Traffic Assignments to small portions of large networks for the purpose of evaluating alternative route locations and/or designs that are relatively localized in terms of the size of the entire study area.

Accomplishments/Status:

Work was initiated on this objective in the first year of the study (1967-68). The procedures and computer programs were based upon programs that were originally developed under research sponsored by the Bureau of Public Roads. These programs would assemble small coded areas (with the desired degree of detail in each) into an assignment network. However, work was temporarily halted shortly after initial conversion of the IBM 7094 programs to the IBM 360 System was undertaken. Decision to halt work was based on the fact that this program capability was not then essential whereas other computer program capabilities were immediately needed for the day-to-day operation of the Planning Survey Division. No work was performed on the objective in Fiscal Year 1968-69. During this time, analysis of the San Antonio and Houston/Galveston Transportation Network indicated critical problems in the establishment of partition lines necessary for small area coding in these two study areas. It was, therefore, agreed to permanently suspend work on this objective with the recommendation that the objective be officially terminated and removed from the scope of work.

Completion: The objective was terminated.

OBJECTIVE #2: Test and evaluate the capacity/volume restrained program developed under Study Number 2-8-63-60.

Accomplishments/Status:

The restrained assignment procedure was developed as a set of stand alone programs to facilitate development and testing independent of the assignment packages being used by the Texas Highway Department. Restrained assignment capability was added to the Small Network and Large Network Assignment Packages after the initial evaluation by the Highway Department indicated that the procedure provided acceptable and useful results. Two versions of the draft of the research report concerning the development of the restrained assignment procedure were reviewed by the Texas Highway Department Planning Survey Division. However, this report has not been finalized because substantial effort needed to be diverted to more critical problems relative to continued day-to-day operation of the Highway Department. Further, the documentation was not considered essential due to the fact that Highway Department personnel were familiar with the procedure by virtue of close liaison throughout the development.

First application of the restrained assignment procedure was made in conjunction with the McAllen-Pharr Urban Transportation Study.

Completion: Writeups for executing the restrained assignment procedure were incorporated in the operating manuals for the two traffic assignment reports (119-1 and 119-2). Documentation of the development and evaluation will be completed under Study Number 2-10-71-167.

OBJECTIVE #3: Program, Test, and evaluate the THD trip distribution forecasting procedure outlined under Study Number 2-8-63-60.

Accomplishments/Status:

The THD Trip Distribution Model was developed as a package of computer programs and subroutines. Initial use of the package by the Texas Highway Department led to a variety of modifications and numerous programming corrections. The McAllen-Pharr Urban Transportation Study was used as the primary basis for test and evaluation of the THD Trip Distribution Procedure. Satisfactory performance led to its general adoption by the Highway Department as the trip distribution procedure used in urban transportation studies in Texas and was first applied in an operational manner in the El Paso Urban Transportation Study.

Completion: A manual for executing the package together with a report concerning the development and testing of the procedure will be prepared under Study Number 2-10-71-167.

OBJECTIVE #4: Evaluate the accuracy of nonhome trip end (attraction) information.

Accomplishments/Status:

The accuracy of nonhome trip information from the conventional O-D Survey was evaluated using data from the McAllen-Pharr Urban Transportation Study. The results and evaluation of the comparisons made were reported in a technical memorandum. It was further concluded that little, if any, benefit might be gained from more extensive work using additional data from other urban transportation studies, and that more valuable results might be obtained from other analyses such as that of the 100% home interview data collected in the San Antonio-Bexar County Urban Transportation Study.

Completion: Issuance of a technical memorandum entitled, "Accuracy of Employment and Nonhome Trip End Estimates From the Home Interview" dated 15 September 1969. Correspondence from D-8 Research dated 12 December, 1969 stated that the technical memorandum satisfactorily completed this objective and that no further report(s) was necessary.

OBJECTIVE #5: Investigate techniques for analyzing and/or statistically evaluating the data collection projection and assignment phases of transportation studies separately or in combination.

Accomplishments/Status:

At the outset of the research it was hopeful that statistical measurement techniques applicable to urban transportation studies might be developed from statistical theory. However, continued contact and inquiry with members of the staff of the Institute of Statistics at Texas A&M University failed to develop potentially successful avenues of research. It was therefore decided to discontinue further attempts in this direction and to concentrate on the application of existing statistical procedures. A variety of comparisons and applications of statistical tests were incorporated into the output of the Assignment Packages and the Trip Distribution Package. The potential value of this output is still in question and can probably be determined only through attempts at application in the day-to-day conduct of several urban transportation studies.

Completion: Agreement to not pursue the theoretical approach further and to incorporate routines to provide statistical summary data into the appropriate computer programs and packages developed under Objectives 3 and 6.

OBJECTIVE #6: Investigate and develop a partition - simultaneous tree building and network coding procedure.

Accomplishments/Status:

Two Traffic Assignment Packages were developed for the IBM 360 System for use by the Texas Highway Department. Both packages were designed to use input and provide output similar to that for the IBM 7094 Package previously used by the Texas Highway Department; problems that resulted from changing from the IBM 7094 to the IBM 360 System were therefore minimized. Development of what has become known as the Small Network Assignment Package was developed and tested by the end of December, 1967; this package was adopted as the Operational Traffic Assignment Program Package of the Texas Highway Department in January, 1968. This package of programs is for application with study areas having networks of less than 4,000 nodes; it uses a procedure whereby minimum paths are searched and the network is loaded simultaneously.

A battery of programs were then developed to enable the Texas Highway Department to continue making the necessary assignments to the Dallas/Ft. Worth Network. These programs were initially a conversion of the IBM 7094 programs together with a program required to assemble the four separately coded subnets into a single network. Continued revisions and modifications have led to a package of programs called the Large Network Assignment Package which is used by the Highway Department for all coded networks containing more than 4,000 nodes.

This objective also includes the provision of such report as may be required to maintain and improve the computer programs used by the Texas Highway Department. In the course of the project numerous changes in the several programs were required to either correct errors or problems found in the operational use of the programs or to regain operational capability which was lost due to changes in the IBM 360 Operating System. Reprogramming necessitated because of changes in the IBM 360 Operating System were especially troublesome and time consuming.

Completion: Adoption of the program packages by the Planning Survey Division of the Texas Highway Department for operational use; and, the preparation of an operating manual for each package (Research Reports 119-1 and 119-2).

OBJECTIVE #7: Supply computer programming and analysis support to the Texas Highway Department concerning procedures developed and/or evaluated on Study Numbers 2-8-63-60 and 2-10-68-119.

Accomplishments/Status:

This objective was added in the third and final year of the study and was directed towards the identification of alternatives and less costly study procedures with particular interest in application to small study areas. Prior to the termination of Study Number 2-10-68-119 the possibility of applying less costly study procedures in large urban areas was seriously considered by the Texas Highway Department. Particular interest and concern centered on the proposed Houston/Galveston Urban Transportation Study. The decision to proceed with a significantly revised study design for the Houston/Galveston Study led to the continuation and transfer of this work to Study Number 2-10-71-167.

Completion: Transfer and continuation as Objective #3 of Study Number 2-10-71-167