CONTRACT RESEARCH
GDOT RESEARCH PROJECT NO. 7005
FINAL REPORT

DEVELOPMENT OF AN URBAN PEAK-HOUR TRAFFIC MODEL BASED ON THE 1970 CENSUS AND CONCURRENT GROUND COUNTS PHASE II

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This research project has been conducted by the Georgia Institute of Technology, School of Civil Engineering. Dr. Donald Covault, Professor, is the Principal Investigator. He and his two assistants, for purposes of this report are considered the Research Team. Likewise, the opinions and conclusions expressed or implied in this document are those of the Research Team. They are not necessarily shared by the sponsors of this project.

I. INTRODUCTION

This research project, "Development of an Urban Peak-Hour Traffic Model Based on the 1970 Census and Concurrent Ground Counts - Phase II", is the second phase of the project started in 1970. The first phase gathered 24-hour volume data at 140 roadway locations. Available volume data were also gathered for 123 locations from State files. In total, the Phase I tabulated 263 volume counts which are used as the concurrent ground counts for the Phase II research effort.

The Phase I project also investigated the 1970 Census Urban Transportation Planning Package (UTPP). In the form that the UTPP file was received, it was concluded taht it was unsatisfactory to use for trip assignment. The Phase I report described alternative approaches to use the UTPP file for traffic assignment.

The primary objective of the Phase II research is the development of a peak-hour model for the Atlanta SMSA using the 1970 Census UTPP file that is applicable to long-range planning and to Transportation System Management (TSM) requirements. In conjunction with this objective, a special research project for a Master Degree in CE at Georgia Tech has been undertaken to develop a methodology to estimate peak-hour factors. A secondary objective is an evaluation of the transportation related questions contained in the 1980 Census Instrument.

The purpose of this report is to describe in sufficient detail the research procedures used and the conclusions derived. Each of the research objectives are considered separately in the report. In addition, a number of technical memorandum have been prepared during the project.

A summary description of these memorandum are included in the report and where applicable the reader is referred to the particular document for further information.

BACKGROUND

Great efforts have been expended in the Atlanta Region on the development of a rational and balanced transportation program. Past studies have concentrated on comprehensive, cooperative, and continuing plan development. On a continuing basis, the transportation plan must be monitored and updated to account for urban growth and change. Plan revisions are especially important in the short range to achieve the optimum utilization of existing facilities. Consistent with this attitude and in an attempt to replace the need for origin-destination studies, the U. S. Department of Transportation in cooperation with the U. S. Bureau of Census collected work trip information in the 1970 Census Instrument. Sample size for these data is approximately 15 percent.

Of particular concern and interest is the tabulation of work trips be made between the zone of residence and the zone of employment (the destination). The Bureau of Census has coded these trips by traffic analysis zone and furnished this information to the Georgia Department of Transportation as the 1970 Census Urban Transportation Planning Package (UTPP).

In 1970, the Georgia Department of Transportation (GDOT) in cooperation with the Federal Highway Administration engaged the Georgia Institute of Technology to conduct research using the UTPP file. The objective of the research (Project Number 7005-Phase I) was the development of a peak-hour, work-trip oriented forecasting model for the Atlanta SMSA area. The model was intended to give the planner an analysis tool to assess the transportation conditions of an urban area.

The UTPP file was received by GDOT in May, 1974. After a detailed review, it was concluded by GDOT that the work trip table developed by the census was unacceptable for traffic assignment. The primary reason was the manner in which the Bureau of Census geocoded the work trip destinations. Specifically, respondents were asked to provide an explicit street address for their place of work. An address coding guide (ACG) was then used to code that trip. Unfortunately, the ACG did not cover the entire Atlanta SMSA; it was limited to the area contained inside the perimeter. Hence SMSA residents whose place of work was not within the ACG description had their work trip destination coded to a zip code number (ZC), an enumeration district (ED), or a universal area code (UAC). Respondents who did not provide an adequate or complete work address were coded with undesignated destinations using a dummy number equal to 99998. Thus, the primary deficiency of the Atlanta UTPP file is that only 56 percent of the work trip destinations are coded to traffic analysis zones. The remainder are coded to either ZC, ED, UAC or to 99998.

Similar difficulties were encountered in other urban areas. In the Delaware Valley Planning Region only 35 percent of the region's nearly 2 million work trips were coded to traffic zones. Albuquerque, New Mexico reported 64 percent, Wilmington, Delaware reported 55 percent, and California averaged 57 percent for 14 SMSA's. Because of the inadequate coding, the Tri-State Regional Planning Commission abandoned their attempt to use the UTPP data and requested the Bureau to generate a worker file.

At that time Project Number 7005-Phase I was terminated because of the poor geocoding of the work trip data. It was concluded that the UTPP file did not provide the desired level of data.

Between 1974 and the early part of 1976 no work was accomplished on the UTPP file. Then in 1976, GDOT requested Georgia Tech's Dr. Covault to take another look at developing a peak-hour model using the UTPP file. The present contract (7005-Phase II) was consumated from these renewed interests.

REPORTS

A number of technical memoranda have been prepared by the Research Team during the project. These memoranda have a specific topic and have been used to inform the Georgia Department of Transportation of project progress and findings. The following is a brief description of the various memoranda.

WORK PLAN: Development of an Urban Peak-Hour Model Based on the 1970 Census and Concurrent Ground Counts, Phase II; February 22, 1977 (1)

This memorandum describes in detail the proposed research. It delineates the project stages and the tasks associated with each stage. The detailed work plan has been accepted by the Georgia Department of Transportation and the Federal Highway Administration.

EXECUTIVE SUMMARY: April 7, 1977 (2)

The summary deals with the conclusions and findings of the Phase I portion of the project. Additionally, the memorandum describes the findings from the comprehensive literature search.

Interim Report: Status of the 1980 Census Instrument, May, 1977. (3)

The report addresses two topic areas:

1. The Research Team's preliminary findings and status of the 1980 Census Instrument. It recommends that if the State of Georgia desires to suggest changes to the Instrument questions, the State should move quickly because the Instrument will probably be finalized by the summer of 1977.
2. The Research Team has developed a questionnaire to determine the interest in tranportation information being collected through the Census. The findings and conclusions of the questionnaire are summarized in the report.

Technical Report for Stage C: Status of Transportation Questions on the 1980 U. S. Census, March 20, 1978 (4)

This report presents a summary of the status of the 1980 Census Instrument. It discusses the pretests that have been held in 1977 and the proposed pretests scheduled for 1978. The report also states that the 1980 Instrument is in final form and will be presented to Congress for approval which normally is a formality.

Report to the Project Advisory Committee, March 22, 1978 (5)

The report presents the minutes of the meeting held on February 21, 1978 between the Project Advisory Committee and the Research Team. The significant conclusion of the meeting is that the research project should be terminated. The justification and rationale for this termination is discussed in Chapter 2 of this report.

Technical Report for Stage B: Research Methodology, May, 1978 (6)

The report presents a summary of the methodology utilized in the project. It is in sufficient detail so that the reader can achieve an understanding of the procedure. Weaknesses of the procedure are pointed out to alert other researchers of potential problem areas.

II. METHODOLOGY

The Phase II research project has two distinct components. The first was the development of a peak-hour methodology for the Atlanta SMSA based on the 1970 Census journey to work trip information. The second component was a review with recommendations of the transportation related questions to be included in the 1980 Census Instrument. This chapter is divided into two sections with the first addressing the peak-hour methodology and the second discussing the 1980 Census questions.

PEAK-HOUR METHODOLOGY

A library search has been conducted early in the project. Numerous techniques employed by other researchers have been reviewed. Two research efforts are reported in sufficient detail to explain the technique employed and the conclusions derived. The first report is Travel Demand Forecast Models, Phase 2 [7], and the second one is The Use of Census Data for Updating Urban Transportation Studies [8].

The Travel Demand Forecast Models, Phase 2 report describes the results of calibrating a peak-hour model for the St. Louis, Missouri area. The model that has been developed in St. Louis is based on the postulation that a relationship exists between 24-hour, home-to-work travel and total peak-hour travel. The model also postulates that travel varies as a function of zone-to-zone travel time and the employment density at the attraction zone. Based on the number of attributes, i.e., high percentage of work trips during the peak-hour and the stability of the home-to-work trip, the report concludes that the home-to-work travel is a good determinant of peak travel.

Two models, one for auto drivers and one for transit, are considered. The general conclusion is that the models over-estimate actual trips by 17.8 percent. This slight over-estimate is concluded to be reasonable. Further the report concludes that good correlation exists between the 1965-66 Origin and Destination Study and the Census work trip frequency distribution.

The methodology that has been developed in St. Louis is not used directly in this research approach. However, the report has been used as a continual reference because of its excellent summary of model methodology and the adjustments required to the Census data. The reader is directed to the Executive Summary prepared by Georgia Tech in April, 1977 for further details.

The second report which is directly applicable to this research is the Use of Census Data for Updating Transportation Studies. For purposes of this report, this study will be considered the Comsis Report. The Comsis Report describes the adequacy testing of three methods of forecasting average daily traffic volumes in the State of Rhode Island. Comsis Report Method 3 is considered most applicable to the present research. Briefly stated, this method is:

> "Determine the accuracy of average daily auto driver link volumes developed by estimating average daily trip productions and attractions as a function of the primary work trip productions and attractions and other socio-economic variables that are reported in the Census documents" [8]

Method three is based on the assumptions that a relationship exists between average-daily and primary work trip productions and attractions. Given this relationship, i.e, primary work productions and

attractions from the Census journey-to-work trip information and a calibrated distribution and assignment model, it follows that ADT link volume estimates can be developed. This technique has been used by Comsis and they have reported approximately a 3 percent under-estimate when compared to ground count information. Again the reader is directed to the April, 1977 Georgia Tech Executive Summary.

Based on the Library Search and discussions with the sponsoring agencies, the Research Team has developed a set of hypotheses to research the possible development of a peak-hour model for the Atlanta SMSA. These hypotheses include:

- A relationship exists between 24-hour journey-to-work trips and all-purpose peak-hour trips. (All purpose is defined to include home based work, shop, social, recreation, school, and other as well as non-home based travel.)

- A mathematical proportioning technique founded on employment distribution can be developed and used to allocate undersignated work trips in the Census journey-to-work file.

- The traditional planning techniques using calibrated models, i.e., gravity, logit modal split and assignment, which have been developed by others can be used to generate an all-purpose link volume.

- The 1970 historical record (HR) network can be used to assign the all-purpose trip table.

- A peak-hour factoring methodology stratified by socio-economic parameters can be developed so that the by-purpose trip tables can be converted from 24-hour to peak-hour and then merged.

- Generalized peak-hour factors can be developed and applied to 24-hour assigned link volumes.

- An evaluation analysis can be developed that uses the 265-ground count data collected in Phase I of this project.

It should be noted that there are two distinct methodologies suggested in the hypothesis statement. The first method factors the by-purpose trip tables and then merges these factored tables into an all-purpose peak-hour trip table. This all-purpose trip table is then assigned to the HR with the end results being synthesized peak-hour link volumes. These volumes can then be compared with the 265-ground count locations and accuracy of the methodology can be ascertained. The second procedure uses an all-purpose 24-hour trip table for the assignment. The 24-hour link volumes are factored to represent peak-hour flow for evaluation with the 265-ground count locations. This second procedure is the traditional approach that is often used in the 3-C transportation planning process. In Atlanta, the standard FHWA peak-hour factors have been augmented where possible with data collected in 1972.

At the beginning of this research project, the Research Team was prepared to develop the necessary analytical techniques to test and evaluate both of the procedures. It was anticipated that one of these techniques would yield a useful product for the Atlanta SMSA. It was further anticipated that the selected methodology would be directly transferable to other SMSA's in Georgia.

In 1972, Georgia Department of Transportation/Atlanta Regional Commission (GDOT/ARC) conducted a half of one percent origin-destination survey in the Atlanta SMSA seven county area. The sample consisted of 2851 dwelling units which represent 18,527 all-purpose trips. Additionally, studies were made to estimate special generator trips, truck travel and external trips. The traditional transportation planning process followed this work.

Of particular importance to this research project is the calibrated models and the trip tables for truck and external travel. These data are used as the foundation for the Census file analysis and the development of a peak-hour model. From the time that this project was formulated, the Research Team has presumed that the use of these data provided the most expeditious utilization of previous projects. This assumption has proven to be a major weakness in the research methodology. For a detailed explanation and analysis of the GDOT/ARC transportation planning process methodology the reader is directed to the document Atlanta Region Transportation Planning Models[9]

The following portion of this section is devoted to a detailed description of the steps undertaken during the research project. Each step is written as a separate entity; however, there are many avenues of feedback that have been dropped for clarity. The University of Georgia at Athens IBM 370/158 MVS computer facility has been used for processing the FHWA Transportation Planning Battery of programs and the numerous Research Team developed programs. All of the programs developed by the Research Team are written in Fortran IV and are available to the sponsoring agencies.

Step One - Development of an Equivalence File

In recording the journey-to-work trip data, the Bureau of Census has used traffic analysis zone information furnished by the Georgia Department of Transportation. Where it was impossible for a variety of reasons to code the work attraction end of the trip, the Bureau has used dummy codes supplied by GDOT that represent zip codes, enumeration

districts, universal codes and undesignated destinations.

The traffic analysis zones given to the Bureau of Census are made up of 1548 zones that correspond to the zoning system used prior to 1970. These zones are nonsequentially numbered Ø to 8994. Based on the Research Team's investigation, this numbering system does not violate Census Tract boundaries and corresponds directly to the 525 zone system that has been developed since 1970.

It should be recognized that the two traffic analysis zone systems (1548 zones and 525 zones) represent the same study area. Thus on numerous occasions, the 525 zone system is composed of more than one zone from the 1548 system. In essence, the 525 zone system is a aggregation of zones into more homogeneous units at a higher degree of manageability.

To code work trip destinations to zip codes, universal area codes and enumeration districts, the Bureau of Census has used the GDOT furnished dummy numbers. The dummy number equivalence for each of these designations is:

Designation	Dummy Number Range
Zip Codes	9001-9451
Universal Area Codes	9452-9480
Enumeration District	9481-9621

By subtraction, it is obvious that there are 620 additional designations that must be converted to traffic analysis zones.

It is cautioned that this conversion is not a straightforward matter. The Georgia Department of Transportation does not have complete files as to what particular areas within the study area are represented by the dummy codes. Further, much of the data concerning the dummy

numbers is conflicting. The dummy numbers have presented an enigma which in many cases has been solved by engineering judgement.

Some of the problems associated with using the dummy numbers are:

- Zip codes and universal area codes violate census tract boundary; they do not conform uniformally to traffic analysis zones.
- Enumeration districts are numbered to correspond to the County in which they are located. For example, the same enumeration district number can appear in more than one county.
- Dummy numbers do not conform to a rational geographic representation of the area. For example, it is common to have dummy numbers represent a particular area which is geographically impossible.
- The postal service does not have a comprehensive zip code map so that a rational geographic boundary can be associated with a zip code.
- A zip code is not an appropriate surrogate descriptor because the place of work is not indicated by the zip code. Employees of the Gulf Oil, for example, work south of the CBD but the zip codes associated with Gulf Oil in the main Post Office is in the heart of the CBD. This is not a unique occurrence but instead it is a typical situation for the large corporation located in the Altanta SMSA.

Because of these associated problems with zip codes, universal area codes and enumerations districts and their related dummy numbers, the Research Team urges the Bureau of Census not to use these surrogate descriptors.

Recognizing the above problem, the Research Team has proceeded in the development of the equivalence file. A member of the Research Team has interviewed the Public Relations Director at Atlanta's Main Post Office to resolve zip code conflicts. The Director, in turn,

has discussed the boundaries with many of the postal staff, especially the mail carriers. At the beginning of this conversion effort, the Research Team used a zip code map prepared by ARC. However, this map has been found in error. Thus, the Research Team has concluded that the discussions with the postal staff are the highest level of reliability possible, to determine zip code boundaries

In a similar manner, a member of the Research Team has interviewed the local Bureau of Census in defining the boundaries of enumeration districts. Again, this process has proved to be tremendously subjective and relied heavily on the local knowledge of the Bureau of Census staff.

For both zip codes and enumeration districts, the Research Team has equated the appropriate zones from the 525 zone system. The Universal Area Code work trips have been distributed using a calibrated gravity model. This process is discussed later in this report.

In summary, a subjective analysis has been devised to equate dummy descriptions used in UTPP file to the 525 zone system. In a non-statistical subjective manner, the Research Team estimates that the use of this type of engineering judgement has caused approximately a plus or minus 30 percent error in the completed equivalence table. However, it has been further concluded that this approach is the best possible without attempting to re-do the work previously undertaken by the Georgia Department of Transportation and the Bureau of Census. It is also suggested that a complete revision of the UTPP file by the Research Team is not possible because of anonymity problem and the associated cost.

Step Two - Development of Equivalence Computer Program

Once the equivalence table was complete, a computer program has been developed to convert the UTPP file into the 525 zone system. In its original form, the UTPP file contains 51,751 records. A record in this context represents a zonal "i-j" pair with "x" journey-to-work trips associated with that pair. It should be recognized that the UTPP file represents the 24-hour home-to-work trip pattern. The UTPP file does not contain any data concerning the work-to-home trip. This is an important consideration because in Atlanta the highest peak hour occurs in the PM when the work trip is predominantly work-to-home.

When the UTPP file is investigated in detail, the following statistics are readily apparent:

Work Trip Destinations Allocated to	Number of Trips	Percent of Total
1548 Nonsequential Zones	328,168	56.5%
Zip Code Designations	161,958	27.8%
Enumerations Designations	216	0.1%
Universal Area Code Designations	38,003	6.5%
Not Allocated	53,148	9.1%
Total Trips	581,943	100.0%

It is interesting to compare the work total trips (expanded) from the UTPP file and the work total trips estimated by GDOT/ARC. In comparison,

UTPP Work Trips = 581,943
GDOT/ARC Work Trips = 1,045,422
Difference 463,479 or (-44.3%)

The UTPP expanded files underestimates the GDOT/ARC estimate by 44.3 percent. The logical question to ask is which estimate is correct. UTPP estimate has a high degree of intuitive appeal because it is derived from approximately a 15 percent sample. However, the GDOT/ARC estimate has undergone an accuracy check and their estimate satisfies the limits of tolerance. The question remains unanswered as to which estimate is correct. Perhaps when the U. S. Bureau of Census Housing Survey becomes available, the work related questions in that survey will shed some information concerning the order of magnitude of the number of work trips.

Considering the summary table above, the computer must convert the unallocated trips (approximately 44 percent) to the 525 zone system. In addition, the 1548 nonsequential zones must be converted to the 525 zone system. Finally, the program must merge all of these trips together into a Census journey to work trip table in terms of the 525 zone system. Theoretically, this trip table is a 525 x 525 matrix.

Specifically, the program accomplishes the following tasks:

- Assign the residential zone (1548 nonsequential) on a zone by zone basis to the 525 zone ststem.
- Check the destination end of the "i-j" pair to determine if it is a nonsequential zone, a zip code, a universal area code, an enumeration district or an unallocated destination.
- If it is a nonsequential zone, assign it directly to the appropriate zone in the 525 zone system.
- If it is a zip code or enumeration district, distribute the trip to the dummy destinations using the formula

$$t_j = T_j \frac{e_j}{E_j}$$

where:

T_j = number of trips calculated for the individual dummy zone

e_j = the number of employees in that dummy zone

t_j = the total work trips associated with the dummy description

E_j = the total number of employees in the dummy description

(Note: The above formula was derived by the Comsis Corporation and reported in their study The Use of Census Data for Updating Urban Transportation Studies.[8] A detailed explanation of the rationale of the formula is contained in the Georgia Tech Executive Summary).

- After the journey-to-work trips are proportioned among the zones in the dummy descriptions, the dummy zones are assigned directly to the appropriate zone in the 525 zone system.
- If it is a universal area code or an unallocated dummy description, the program generates a separate file and assigns and totals the number of trips to the appropriate origin zone.
- After considering all 51,751 records, the program stores two files, i.e.,
  1. allocated UTPP trips in terms of the 525 zone system.
  2. unallocated UTPP trips by zone of origin.

From the GDOT/ARC data, the Research Team has obtained the work related friction factor (F_{ij}'s) file. This file in conjunction with the FHWA Battery program "GM" and the unallocated UTPP trips are processed to generate a trip table that distributes the UTPP trips and the trip interchanges from the GM procedure to yield a composite trip table. In summary this trip table represents the trip interchanges as

reported in the 1970 Census Instrument modified to account for the various aberrations described above. The remainder of this report will refer to this product as the UTPP trip table. The reader is reminded that it is modified and subject to all errors associated with engineering judgement, dummy descriptors and the proportioning technique to allocate trips.

Step 3 - Development of All-Purpose Trip Generation Models

An agreement of the research contract is that the Research Team will make maximum utilization of existing GDOT/ARC data base. Included in this agreement is all of the previous transportation planning effort accomplished by the participating agencies. In particular, the Research Team agreed to utilize the existing data base and the available models where appropriate in the research application.

Two models that are not available are the trip generation models for all-purpose productions and attractions. To build these models, the Research Team has used the GDOT/ARC data base. Thus, the models derived reflect the same level of data accuracies as the GDOT/ARC models.

To derive an all-purpose home-based trip productions model, the Research Team has used the GDOT/ARC cross-classification matrices. For each stratification, the by-purpose trip production rates are cummulated to give an all-purpose home-based trip production matrix.

For further clarification the reader is directed to Exhibit 1. This Exhibit, Home Based Work Trip Productions is reproduced from the ARC publication Atlanta Region Transportation Planning Models;[9]

EXHIBIT 1

HOME BASED WORK TRIP PRODUCTIONS

Persons Per Household	Automobiles Per Household		
	0	1	2^+
1	0.600	0.896	1.714
2	1.000	1.600	2.300
3	1.417	2.250	2.750
4^+	1.850	2.000	2.900

SOURCE: Atlanta Region Transportation Planning Models Technical Documentation, Atlanta Regional Commission, December, 1976.

also, the document that provides a detailed explanation of the by-purpose cross-classification matrices. The stratifications of the matrix are persons per household vs. autos per household. To find a particular rate, all one needs to do is to select the correct row and column and read the trip rate at the intersection of the row and column. For example, with 2 persons per household and 1 auto per household, the home-based work production rate is 1.600.

The next table , Exhibit 2, is the all-purpose home-based trip production matrix. In a similar manner, to select a particular rate, determine the appropriate row and column and read the rate at the intersection. In this case, 2 persons per household with 1 auto per household has an all-purpose home-based trip production rate of 4.672. With this stratification, the average household on the average makes approximately one out of three trips to or from work.

To relate this all-purpose matrix to the UTPP file, the all-purpose matrix has been made a function of the work trip production and is illustrated in Exhibit 3. This is accomplished by dividing each cell of the matrix by the corresponding work trip rate. Using the same example, the all-purpose productions (4.672) divided by the work productions (1.600) yield a value of 2.920. This value is interpreted as the all-purpose productions divided by the work purpose productions. Literally, it has the same definition as above, the average two member household makes approximately one out of three trips to or from work.

The second model that has been derived is the trip generation for all-purpose attractions. This includes the home-based and the non-home-

EXHIBIT 2

ALL-PURPOSE HOME-BASED PRODUCTIONS

Persons Per Household	Automobiles Per Household		
	0	1	2+
1	1.751	2.316	3.573
2	1.998	4.672	5.453
3	3.550	6.110	8.250
4+	5.494	8.100	12.350

EXHIBIT 3

ALL-PURPOSE PRODUCTIONS/WORK PURPOSE PRODUCTIONS

Persons Per Household	Automobiles Per Household		
	0	1	2^+
1	2.918	2.585	2.084
2	1.998	2.920	2.371
3	2.505	2.716	3.000
4^+	2.970	4.05	4.258

based attractions. Multiple regression techniques using the Biomedical Computer Program BMD02R [9] are used to build the model. This computer program generates a sequence of multiple linear regression equations in a stepwise manner. At each step, one variable is added or deleted to the regression equation. The variable that is added is the one which makes the greatest reduction in the error sum of squares. Equivalently, it is the variable which has the highest partial correlation with the dependent variable partialed on the variables which have already been added.

In the particular analysis, the dependent variable is "y" all-purpose trip attractions. Generally, the expected multiple linear regression equation has the form:

$$y = B_o + B_1x_1 + B_2x_2 + ... + B_nx_m + e$$

where:

y = the dependent variable all-purpose trip attraction

x_1-x_n = the independent variable which are discussed below

B_o-B_n = the regression weights

The first attempt to develop a regression equation used six independent variables which are:

x_1 = total autos

x_2 = total population

x_3 = total employment

x_4 = employment land-use

x_5 = school enrollment

x_6 = work attractions

The GDOT/ARC Zap file of socio-economic data has been utilized as the base for the multiple regression analysis. The Research Team has expanded the Zap file by adding GDOT/ARC developed information concerning trip generation data. No modifications or alterations have been made to these data.

A standard technique to select the variables that should remain in the multiple linear regression equation is plot a of R^2 multiple correlation coefficient for the number of variables. This plot is shown in Exhibit 4. It is evident from an investigation of the graph that the rate of change of R^2 becomes quite small after the inclusion of two variables. This indicates that the optimum number of variables to be included in the equation is two which are work attractions and total population. In addition, a detailed residual analysis has been conducted. It should be recognized that the square of the residuals divided by the degrees of freedom is an estimate of error. Consequently, if the residuals can be reduced in a rational manner, the error estimate will also be reduced.

In the development of a multiple linear regression model, a number of trial runs using the BMD02R program have been performed. A summary table of this analysis is shown in Exhibit 5. It indicates the variables that have been included in the equation, R^2 and the standard error. From the analysis, the equation that is selected for use in this research project is:

$$y = 45.47 + 1.808\ x_6 + 1.419\ x_2$$

Exhibit 4

Multiple Regression Analysis

R^2 Plot

First Attempt

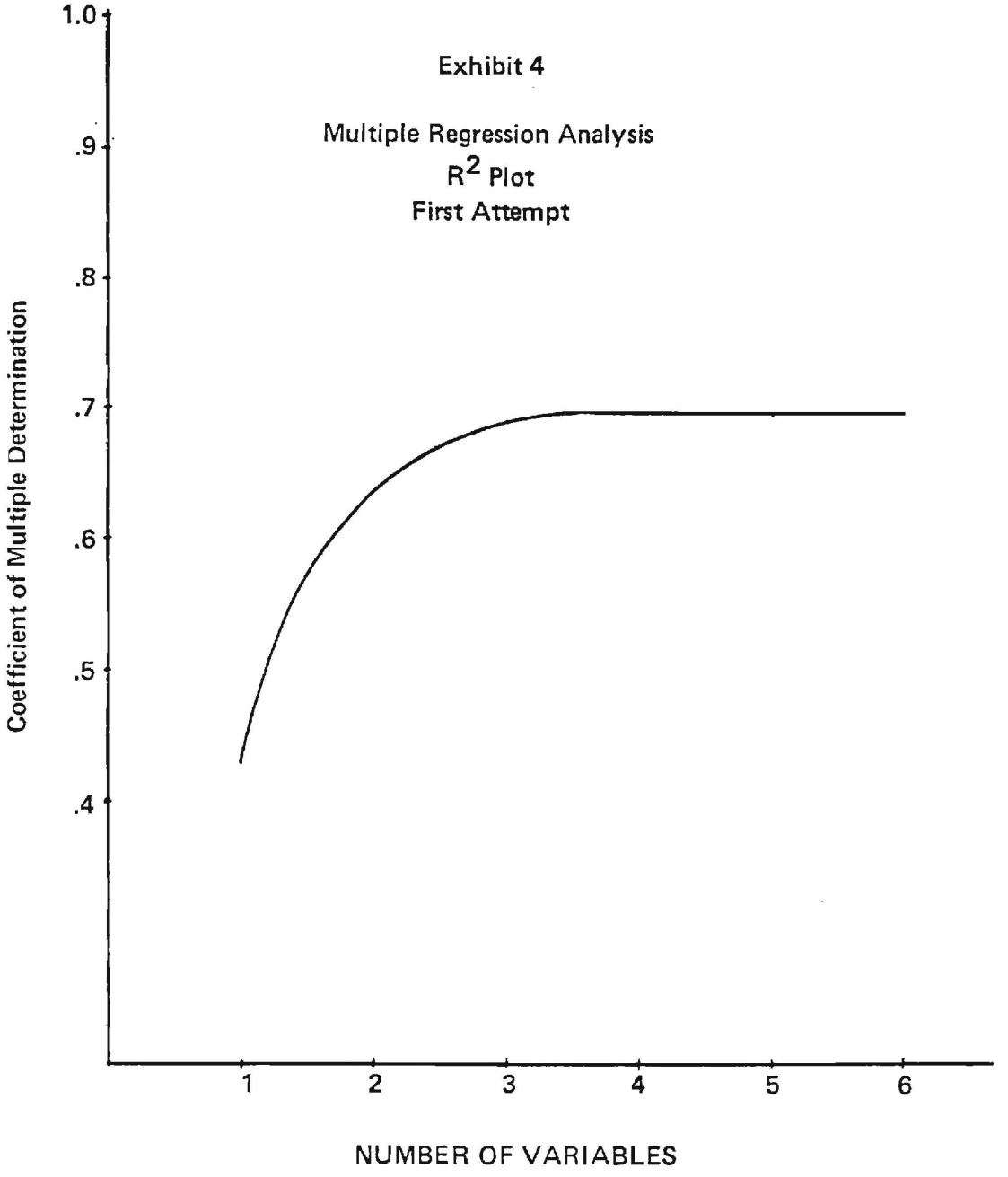

EXHIBIT 5

SUMMARY TABLE OF REGRESSION ANALYSIS

Run Description	Total Attr. Mean	Total Attr. S. D.	Constant	V1	V2	V3	R	R^2	R^2 Change	S. E.
AT TPOP TE ELU SCHL WKATR	9497	8756	4978.8	1.872 (WKATR)			.605	.367	.367	6977
			139.6	1.879 (WKATR)	3.598 (AT)		.778	.605	.239	5515
			47.8	1.790 (WKATR)	2.919 (AT)	137.581 (SCHL)	.814	.662	.057	5108
DELETE AT	9497	8756	4978.8	1.872 (WKATR)			.605	.367	.367	6977
			-222.3	1.899 (WKATR)	1.743 (TPOP)		.761	.579	.212	5698
			-42.8	1.806 (WKATR)	1.351 (TPOP)	135.554 (SCHL)	.795	.631	.053	5336
DELETE AT, TPOP	9497	8756	4978.8	1.872 (WKATR)			.605	.367	.367	6977
			3412.3	1.735 (WKATR)	214.478 (SCHL)		.725	.525	.159	6046
			3005.9	1.592 (WKATR)	200.452 (SCHL)	10.428 (ELU)	.732	.536	.011	5988
CONSIDER TP &				1.828						

where:

y = the dependent variable - all-purpose attraction in each zone

x_6 = the independent variable - total work attractions in each zone

x_2 = the independent variable - total population in each zone

A logical comparison is to analyze this equation versus the various trip generation attraction equations developed by GDOT/ARC. An all-purpose multiple linear equation has intuitive appeal because it represents an aggregate rather than a stratified sample. In this particular comparison, the statistics do not support this hypothesis. If only the statistics are judged, the by-purpose regression equations appear to be better. However, the Research Team's opinion is that this comparison is inconclusive because the bias in the GDOT/ARC equation is unknown. Although the above equation does not have the desired statistics, it has been judged adequate for the development of a research methodology. This conclusion is especially consistent when it is realized that it is beyond the scope of this project to collect the necessary data to build a more precise model. The GDOT/ARC half of one percent origin destination survey is the best data available in the Atlanta region.

Step Four - Development of an All-Purpose Trip Table Using the UTPP File

This step involves the building of an all-purpose trip table using the modified UTPP file, the trip generation equations and the special generator information previously developed by GDOT/ARC. It is a straight-

forward procedure to combine these data and equations and build an all-purpose trip table. A computer program has been devised to perform this task. The 525 x 525 trip table matrix is stored on the Research Team's private disk at the University of Georgia computer site.

THE DICHOTOMY

The objective of this particular research is to develop a peak-hour model methodology using the 1970 Census UTPP file. To reiterate, the UTPP file is a description of the journey-to-work trip by mode of travel. In the case of Atlanta, approximately 56 percent of the trips have been coded to the traffic analysis zone system. The remainder have been coded to dummy numbers that describe a surrogate system.

Just prior to the development of the all-purpose trip table, an intense debate began among the Research Team. The debate centered on the validity of peak-hour model as a function of the UTPP file. All of the models that have been built as well as all work in support of the research effort is based on information developed in the GDOT/ARC transportation planning process. That is to say the peak-hour model developed from the UTPP data is directly dependent on the GDOT/ARC effort. The direction of the debate led the Research Team to re-examine the functional intent of the research effort. This analysis led to the basic conclusion that the UTPP data cannot stand alone but is dependent on calibrated models developed during the traditional transportation planning process. At least this is the case for the methodology pursued by the Research Team.

A point of the debate is that it is inconclusive to perform an

analysis of potential peak-hour model link estimates and actual ground counts. For example if the analysis showed no significant difference between the ground counts and synthetic volumes, it is not possible to discern if the peak hour methodology is adequate or if the traditional models used in support compensate for shortcomings. Likewise, the same inconclusive dilemma would occur if the comparison indicated a significant difference.

This is a perplexing situation since the work trip is well-defined and also a large proportion of these trips are made in the morning and evening peak-hour periods. Furthermore, the sampling rate of the UTPP file is approximately 15 percent, a much larger sample size than Atlanta 1970 half of one percent origin - destination survey.

Because of this reliance on existing models from the traditional planning process, the problems in geocoding the journey-to-work data and the necessary engineering judgement required to completely allocate the UTPP, one may wonder if the transportation questions asked in the Census Instrument are a substitute for the origin-destination study. The answer to this question is inconclusive. Based on the methodology that has been used by the Research Team, the answer would have to be that the UTPP file cannot be substituted for an origin-destination study. However, the Research Team has not examined an exhaustive set of methodologies that equate the journey-to-work trips with all-purpose trips.

This dilemma has been discussed with the Project Advisory Committee. The general consensus was that the project should be stopped without performing an assignment because the effort would not yield a useful result. The Research Team stopped further work on the project

and this report reflects the accomplishments of the project up to the point of termination. A set of recommendations have been developed and are included in the last section of the report. The fact still remains that a peak-hour model applicable to TSM procedures is a valuable tool to the practicing transportation engineer.

CIVIL ENGINEERING MASTER DEGREE SPECIAL RESEARCH PROJECT

The secondary element of this objective is the development of a peak-hour factor methodology that can be used with the traditional transportation planning process. This research is being conducted as a Special Research Problem by a Georgia Tech graduate student in partial fulfillment of a Master of Civil Engineering Degree. This research effort will continue and will not be effected by termination of the peak-hour methodology research.

There are two approaches for developing design hour volumes. The first is to assign ADT volumes to a network and the resultant "smoothed" assignments factored to produce peak-hour volumes. The second approach is to convert the ADT by-purpose trip interchanges in trip table format to peak-hour trip interchanges. After the peak-hour trip interchanges are obtained, they are assigned to the network and the resultant values are a peak-hour assignment.

The Special Research Project will assess:

(a) current methodology that is used in the Atlanta regional planning - Approach One

(b) by-purpose trip interchange peak-hour factors will be developed as a part of the research methodology - Approach Two

A brief description of the two approaches are:

Approach One - assess the design hour factor matrix employed in the Atlanta regional transportation planning process. The matrix which classifies the Atlanta highway sections by area and functional classification will be refined and supplemented with ground count data from Phase I of the present project and factors developed. The research will address the base year design hour factor matrix.

Approach Two - analyze the Atlanta by-purpose trip interchanges:

a. the 1972 home interview origin destination survey for work, school, shopping, social/recreation and non-home based trips.
b. the 1972 truck survey for trucks.
c. the 1972 external survey for internal-external trips.
d. from this analysis develop appropriate peak-hour factors.

The FHWA program PEAKHOUR will be used to process the survey trip records and stratify the data to obtain peak-hour factors. Factors will be established for person trips and auto driver stratified by all-purpose travel. Based on similar peak-hour studies completed in Baltimore, Maryland, the research will incorporate changes in the peak period travel based on regional socio-ecomonic parameters. Peak period travel by-purpose will be examined in terms of trip ends stratified by income, number os autos, employment density, residential density and geographical distribution. The research will attempt to account for variation in peaking characteristics as a function of trip end travel and a knowledge of zonal characteristics. Thirty-four geographical (super-districts) zones has been defined for this analysis. The super-districts will be aggregated if similar peaking characteristics are discovered among the super-districts.

The validity and adequacy of the two approaches will be assessed based on available data in the Atlanta region. A statistical or

graphical method will be employed to evaluate the approaches. When this research is complete, a copy of the final publications will be available to the sponsoring agencies.

To reiterate, this Special Research Project has been created to compliment the analysis of the Census journey-to-work research. Even though Model Development has been terminated, the peak-hour research will continue. The special research and, its findings will be applicable to the on-going transportation planning being conducted by GDOT/ARC.

REVIEW OF THE 1980 CENSUS INSTRUMENT

The second objective of the research has been the investigation of the potential impact that could be made to the transportation questions contained in the 1980 Census Instrument. As of July, 1977, it became highly unlikely that any revisions could be made. But, it is important to discuss the findings of the Research Team as reported in a number of technical memorandums. The following is a discussion of these memoranda.

Transportation related issues first appeared in the 1960 Census Instrument. Again in 1970, transportation questions were asked. Transportation related areas in 1970 dealt with:

(a) The place of work (the question contained the number and street name, name of city, town or village, county, state and zip code).

(b) mode of travel (the question contained the categories of driver private auto, passenger private auto, bus

or streetcar, subway or elevated railroad, taxicab, walked, worked at home and other).

A number of problems were incurred in reducing the 1970 Census data. Most of the problems are related to the difficulties of geocoding.

It is planned by the Bureau of Census to ask transportation related questions in the 1980 instrument. The sample rate will be 1 out of 6 or 16.7 percent. In anticipation of these questions and because of previous problems, extensive efforts have been or are being made to update the Area Coding Guide. If this is accomplished, the geocoding problems will be reduced to a minimum. Further, the Bureau has conducted pretest in Austin, Texas, Oakland, California, and Camden, New Jersey in 1977. In 1978, additional "Dress Rehersals" will be conducted in three cities prior to the actual census in 1980.

The 1980 instrument contains the following questions that are related to the journey-to-work:

(a) Work Location
(b) Modal Split
(c) Auto Occupancy
(d) One-Way Travel Time to Work
(e) One-Way Travel Distance to Work

A copy of the 1978 pretest questionnaire for Richmond, Virginia is attached to the March 20, 1978 technical memorandum. Mr. Turner of the Bureau of Census has indicated that the Richmond, Virginia "Dress Rehersal" format will be the questionnaire that will be submitted to Congress for approval. He implied that this approval is a formality. So it appears reasonable to assume that the 1980 instrument will be the same as the questionnaire used in the "Dress Rehersal".

Early in 1977, the Research Team sent a questionnaire[3] to a number

of individuals concerning the inclusion of the journey-to-work questions in the 1980 Census Instrument. A list of the individuals and a sample questionnaire are contained in the Appendix. The aim of the questionnaire was the determination of the prevailing opinion concerning collecting transportation data through the Census Instrument. A summary of responses is shown in Exhibit 6.

The Exhibit illustrates the question asked, the mode of the response, the inference and the current Bureau of Census Status. The information in the last category indicates whether or not the question area is included in the 1980 instrument. Generally, the Research Team Survey concludes that Census instrument should address question areas number one (destination), number 3 (modal split) and number four (occupancy). Question area number two (nearest intersection), number six (distance to work), and number seven (travel route) should not be included in the Instrument. No conclusions have been derived concerning area number five (travel time) and number eight (time of departures).

Three major conclusions are made in the Stage C Report, Status of Transportation Questions on the 1980 U. S. Census, March, 1978:

1. The final version of the 1980 Census Questionnaire has been set.

2. "Dress Rehersals" will be held on the "short forms" and "long forms" of the Census Questionnaire in three U. S. Cities during 1978.

3. "Great Concern" is the general mood of those who will be using the Census data for transportation planning. These persons are primarily concerned with the coding of the destination portion of the work trip. Previous efforts have been unsatisfactory in the validity and the amount of information provided by the coding effort.

EXHIBIT 6

SUMMARY OF RESPONSES TO WORK TRIP RELATED QUESTIONS FOR THE 1980 CENSUS*

Questions on Area of Interest	Mode	Inference	Current Bureau of Census Status
#1 Destination of Work Trip	Priority #5**	Should be included in Census Instrument	Included
#2 Nearest Intersection to Work	Priority #1	Should not be included in Census Instrument	Not Included
#3 Modal Split	Priority #4 & 5	Should be included in Census Instrument	Included
#4 Occupancy	Priority #4	Should be included in Census Instrument	Included
#5 Travel Time to Work	Priority #4 & 5	No Conclusion	Included
#6 Distance to Work	Priority #1	Should not be included in Census Instrument	Not Included (Could be Deleted)
#7 Travel Route to Work	Priority #1	Should not be included in Census Instrument	Not Included
#8 Time of Departure from Home	Priority #3	No Conclusion	Not Included

* Source: GDOT Report, "Status of the 1980 Census Instrument", May, 1977.

** Gradation as Follows: #1 Low Priority
#5 High Priority

III. CONCLUSIONS AND RECOMMENDATIONS

From an evaluation of the results of the research project in comparison to the detailed work plan, it is plainly obvious that the research goal has only been partially achieved. That is, the research effort did not yield a peak-hour model methodology to estimate design hour volumes applicable to TSM procedures. In fact, a peak-hour model as a function of the UTPP file has not been developed. There are a series of questions that must be answered to explain the rationale of the stated conclusion, i.e.,

- Why and what caused the research effort to fall short of the stated objective?
- Has the research effort been worth the expenditure of resources in terms of manpower and dollars?
- Can a peak-hour model be developed that is directly dependent on the UTPP file?

The remaining portion of this section is the Research Team's response to the above questions. Included in this response is suggested recommendations to continue the analysis and evaluation of the UTPP type data.

Question 1: Why and what caused the research effort to fall short of the stated objective?

To answer this question, it is necessary to regress and reconsider the status of the 1970 UTPP file when the research began. The UTPP file represents the estimate of all one-way journey-to-work trips. It has been developed by the Bureau of Census by expanding the 15 percent sample data collected in the 1970 Census Instrument. Approximately forty-four percent of the trip interchanges are not coded at the destination end of

the work trip. These trips are coded to dummy zones which are zip codes, universal area codes, enumeration districts, or not allocated. It should be noted that the surrogate descriptions do not necessarily coincide with the 525 traffic analysis zones. Consequently, the first problem and a potential source of error is to synthetically distribute the uncoded UTPP trips to the 525 zone system. This procedure is discussed in the body of the report. Since the research is considered an effort to develop a methodology, the possible error resulting from the synthetic distribution of UTPP trips is not considered a significant prohibition.

The major reason that the research effort falls short of the objective is the dependence the research methodology has on other sources of data and models. The UTPP file is solely in terms of the journey-to-work travel. If it is desired to forecast all-purpose trips, it is necessary to develop a technique in which work trips are the predictor random variable. To develop all-purpose travel, the Research Team has used the GDOT/ARC 1972 origin-destination data as the base. All-purpose trip generation technique using a cross-classification technique has been used to predict productions. Similarily, a multiple regression model has been developed to estimate attractions. Both of these models use the half of one percent origin-destination study and both have been generated so that travel to work is a predictor variable.

With the reliance on other data, especially the origin-destination survey, and the experience gained through working with the methodology, the Research Team began questioning the validity of the proposed methodology. The Research Team has argued that it is questionable if the research effort should be continued as a worthwhile investigation.

Consider for a moment how the detailed work plan proposed to evaluate the research results. In Phase I of the project 265 volume count locations are reported. These data would have been compared to the synthetically assigned link volumes. The basic question is how does this evaluation shed any light in recognizing the significance of the research results? If the synthetic and ground counts compared favorably, it could be concluded that methodology is an acceptable procedure. If on the other hand, the comparison is not favorable, it could be concluded that the procedure is not the optimum methodology from which a peak-hour model can be derived. Either conclusion is perhaps correct or erroneous depending on the importance given the UTPP file. In the opinion of the Research Team, the significant dependence GDOT/ARC data and the origin-destination survey prevents a true evaluation of the methodology and UTPP file.

With the research methodology used in the project, the UTPP file is a secondary source that is directly dependent on the previously developed models and data. If this is the correct interpretation of the research results, the UTPP file is supplemental data that is not directly applicable in the transportation planning process. If the research methodology is used, origin-destination data are needed to calibrate models. The UTPP data cannot replace the need for this survey. It can be argued that if origin-destination data are collected, then these data should be collected so that the data can be useful in aggregate or disaggregate procedures not to use the UTPP data. It may not be economically consistent to collect two data sources when the origin-destination data will suffice for the traditional transportation process. If the

disaggregate techniques are used, then that procedure may not need an origin-destination survey.

It should be realized that the arguments put forth in this paper should not be interpreted nor should a conclusion be made to abandon the gathering of the journey-to-work information through the Census Instrument. The total usefulness of the UTPP file has not been researched and the conclusions are limited to the scope of the project and the research methodology employed. The UTPP file provides a wealth of information concerning the journey-to-work trip. The 1980 transportation related information will be obtained from a relatively large sample (16.7%). In addition, the work trip represents a large number of well defined trips usually occuring during the morning and evening peak hours. Perhaps a methodology can be developed that negates the need for an origin-destination survey or the UTPP file can be used directly in disaggregate procedures. These potential uses of the UTPP file require further research so that maximum utilization of the Census data can be achieved.

Question 2: Has the research effort been worth the expenditure of resources in terms of manpower and dollars?

In the opinion of the Research Team, the answer to this question is a definite yes. It is suggested that the research methodology utilized in this project is not the correct method. It points out to other researchers that reliance on other sources of data are required and indicates the supplemental nature of the UTPP data. It also suggests to other researchers the potential pit-falls and troublesome areas that exist in the UTPP data. Some of these areas, particularly the problem with geocoding, may be avoided in the 1980 Census reporting.

If the UTPP file from the 1980 Census is going to be used as a substitute for an origin-destination survey, then a methodology must be

developed that is not heavily dependent on an origin-destination study. This particular research did not meet this particular criterion. It is suggested that further research is mandated if the UTPP file can be used to its fullest potential.

Question 3: Can a peak-hour model be developed that is directly dependent on the UTPP file?

The answer to this question is: "perhaps". However, the research methodology, in the opinion of the Research Team, is not the optimum direction to take. As a supplement product, the research has led to the development of a Special Research Topic for a graduate student at Georgia Tech.

The goal of this special research effort is to develop a set of peak-hour factors that can be used at the by-purpose trip table stage. It is hypothesized that peak-hour factors at this level are more sensitive to actual peaking characteristics. It is anticipated that the factors can be used with the traditional transportation planning process. The special research is an on-going effort. The reader is referred to the separately published report on this work to be made available about December, 1978.

As an overall conclusion, it is recommended that further research be devoted to investigating the uses of the UTPP file. This is especially important because the 1980 UTPP file is expected to be more complete than its predecessor, the 1970 file. It may be an erroneous decision to wait until the 1980 UTPP file has been completed by the Bureau of Census to start the research for an adequate methodology. Proceeding with research in advance of the 1980 Census may assist in shedding sufficient knowledge so that the 1980 Census can be immediately used upon availability. Many urban areas will be in the process of updating their transportation plan at approximately the same time that the 1980 UTPP file becomes available.

If an appropriate forecasting procedure that uses the Census travel data can be found, this information could be a valuable source to the transport analyst.

APPENDIX

RESEARCH TEAM QUESTIONNAIRE LIST

During the project, the Research Team developed a questionnaire to survey the prevailing attitudes concerning the importance of the transportation questions in the 1980 Census Instrument. The list of individuals in the appendix are those who received a questionnaire.

INDIVIDUALS THAT RECEIVED A RESEARCH TEAM QUESTIONNAIRE

AGENCY: Georgia Department of Transportation

Mr. Hugh Tyner
Mr. Dick Graves
Mr. Lamar Caylor
Mr. Robert Seago
Mr. Emery Horvath
Mr. Oscar Roberts
Mr. Robert Bowling

AGENCY: Federal Highway Administration

Mr. Kevin Heanue
Mr. George Schoener
Mr. Constantino Ben
Mr. Glen Price
Mr. James Cooley
Mr. Grover Bowman

AGENCY: Atlanta Regional Commission

Mr. Joel Stone
Mr. John Wilson

AGENCY: Bureau of the Census

Mr. Marshall Turner
Mr. Edward Elam

AGENCY: East-West Gateway Coordinating Council

Mr. Shoab Rana

AGENCY: Comsis Corporation

Mr. Martin Fertal

AGENCY: Metropolitan Washington Council of Governments

Mr. George Wickstrom

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