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16. Abstract

The magnitude of potential highway user benefits and costs resulting from proposed highway improvements must be estimated with a reasonable degree of accuracy for highway agencies to make rational decisions in the public interest. The Highway Economic Evaluation Model (HEEM) has been developed for that purpose. One of the important aspects of the model is the assumed growth rate pattern which average daily traffic volume (ADT) will exhibit during the projection period under consideration. This study examines 18 case stydy areas in Texas, along with a detailed look at Dallas County, to determine the factors which significantly affect ADT growth rates for use in the HEEM. The factors include highway capacity, and different categories of land development. The accuracy of ADT projections in Dallas County, along with population and land use projections, are examined, as well as factors which seem to be influencing the size of the errors. Various alternative changes to the HEEM's traffic growth rate formulas are proposed, along with a simple multiple regression model to project ADT. The data are reported in narrative, graphic, and tabular form. Implementation of the findings and recommendations of this report should result in more accurate estimates generated from the HEEM at a lower cost of running the model.

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PREDICTING TRAFFIC VOLUME GROWTH RATES RESULTING FROM CHANGES IN HIGHWAY CAPACITY AND LAND DEVELOPMENT

by

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Research Report 225-23
Research Study Number 2-8-77-225
Economics of Highway Design Alternatives

Sponsored by the State Department of Highways
and Public Transportation

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PREFACE

The authors wish to express appreciation to those who have assisted in this study. Special acknowledgement is due Mr. James W. Barr and Mr. James R. Farrar of the Texas State Department of Highways and Public Transportation (SDHPT). Mr. Francis X. Fallwell and Ms. Miriam O. Grayson of District 18 of the SDHPT were very helpful in providing materials and data. Mr. Don Walden, Mr. Bill Bugleholl, and Mr. Arnold Breedon of the Dallas/Fort Worth Regional Planning Office of the SDHPT were also very helpful in providing information and data.

Mr. Dale Schafer, and his staff, of the Texas Transportation Institute, made a contribution to the study by performing some of the computer work. Mr. Eric Schulte skillfully prepared the map and graphs. Ms. Betty Benson and Ms. Sue Freedman receive special marks for typing the manuscript.

ABSTRACT

The magnitude of potential highway user benefits and costs resulting from proposed highway improvements must be estimated with a reasonable degree of accuracy for highway agencies to make rational decisions in the public interest. The Highway Economic Evaluation Model (HEEM) has been developed for that purpose. One of the important aspects of the model is the assumed growth rate pattern which average daily traffic volume (ADT) will exhibit during the projection period under consideration. This study examines 18 case study areas in Texas, along with a detailed look at Dallas County, to determine the factors which significantly affect ADT growth rates for use in the HEEM. The factors include highway capacity, and different categories of land development. The accuracy of ADT projections in Dallas County, along with population and land use projections, are examined, as well as factors which seem to be influencing the size of the errors. Various alternative changes to the HEEM's traffic growth rate formulas are proposed, along with a simple multiple regression model to project ADT. The data are reported in narrative, graphic, and tabular form. Implementation of the findings and recommendations of this report should result in more accurate estimates generated from the HEEM at a lower cost of running the model.

SUMMARY OF FINDING

Data collected from the 18 case study areas receiving highway improvements were aggregated to find what effect factors such as stage of area development and capacity changes have on traffic growth rate patterns and to compare these patterns with those assumed in the HEEM. Also data collected from 47 improved highway segments in Dallas County were aggregated to determine the relationships among ADT, land use, and population projections and to determine what changes should be made to the assumed ADT growth rate formulas in the HEEM.

The findings for the 18 case study areas are summarized as follows:

1. There is no clear distinction between the growth rates in developing areas as contrasted to developed areas. The assumption in the HEEM of a constant growth rate for developing areas and a particular declining growth growth rate for developed areas is not supported in this sample.
2. Improvements of primary routes in developing areas in this study significantly affect traffic growth rates, but that effect diminishes rapidly over time. The effect is much smaller in developed areas.
3. The number of lanes added to capacity also seems to be a significant factor in the 18 case study areas. In general, the greater the capacity change, the larger is the initial impact on ADT, but that effect on the growth rate diminishes over time.

4. Improvements along primary routes affect growth rates for both parallel routes and intersecting routes within the study areas, with a relatively greater impact on the parallel routes. The effect is most pronounced in developing areas, but the impact on the ADT growth rate diminishes over time and almost disappears four (4) years after construction began on the primary route improvement.

The findings for ADT growth rates of the improved highway segments in Dallas County are as follows:

1. ADT projections prepared by the SDHPT have an average error of .2870 in this study. The average error is influenced by a number of factors.
   a. The average error declines from .3266 to .1515 if the projection was made after the improvement had been completed.
   b. The average error goes down as the time the projections were made approach the present. The average error for projections made in the 1950's is .3385, compared to .1629 for projections made in the 1970's.
   c. The stage of commercial and industrial land use also is significant with an average error of .3213 for developed areas, compared to an average error of .2770 for developing areas.
   d. The year the projection was made, the stage of

commercial/industrial land use, and the time of the projection in relation to completion of the highway project, can explain 24.5% of the variation in the ADT projection errors.

2. Population and land use projections are, in general, not very accurate. Population projections have an average error of .4658, and the land use projections have an average error of .8371.
   a. The average error for both population and land use projections declines somewhat if the projection was made after completion of the highway project.
   b. The average error drops in developed areas for both population and land use projections.
3. Overall, very little relationship is observed between errors in ADT projections, land use projections, and population projections. However, there are significant relationships in some categories of the projection errors.
   a. There is a significant positive correlation between errors in population and land use projections for total developed areas and for projections made before completion of the highway project in developed areas.
   b. There is a significant negative correlation between

errors in ADT projections and land use projections for projections made after completion of the highway project in developing areas.

4. The declining growth rate formula in the HEEM is deficient in a number of aspects.

    a. The large number of iterations currently required in calculating the declining growth rate formula can be reduced to a single iteration by using the formula presented in this study.

    b. Multiple projections currently cannot be incorporated into the HEEM. Two alternative declining growth rate models are presented in this study which can incorporate any number of projections and retain the feature of an assumed terminal growth rate.

    c. Use of an assumed terminal growth rate and arbitrary selection of a constant growth rate formula or a declining growth rate formula based upon stage of development does not seem appropriate. A superior method would allow the HEEM to choose from a variety of growth patterns the one which most closely fits available historical ADT data.

5. A multiple regression model for projecting ADT is presented which takes into account historical ADT data,

stage of development, and the effects of a capacity change. The model increases the accuracy of ADT projections, reducing the average error in this sample from .2222, with the SDHPT projections, to .1857, a reduction of about 16%, using the model presented in this study.

IMPLEMENTATION STATEMENT

This report relates the findings of an aggregative study of 18 case study areas and a separate study of Dallas County to determine the factors affecting traffic growth rate patterns. Alternative formulas are proposed to improve the current growth rate formulas used in the Highway Economic Evaluation Model (HEEM). The findings can be implemented immediately to improve the accuracy of estimates generated from the HEEM and reduce the computer time costs of running the model.

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INTRODUCTION

Purpose and Objective of Study

The near completion of the Interstate Highway System and the increasing shortage of funds for future highway construction have caused state highway agencies to concentrate on upgrading and increasing the capacity of existing streets and highways. Much research has been done in the past concerning the impacts of new highway construction, but little has been done to examine the effects where an existing highway is upgraded. In order to optimize net public benefits, highway agencies need information of this type to help predict the effects from an improvement on an existing facility.

Studies have been made in 18 different areas to determine the effects on land use and traffic volumes where an existing highway or street has been improved. This study aggregates the findings of these 18 individual case studies and looks at the effects those improvements have had on traffic growth patterns. The aggregated effects on land use are presented in Research Report 225-22 [19].

An important aspect of traffic growth rates is their use in the Highway Economic Evaluation Model (HEEM) to calculate the Economic Measure of a highway project. This study examines several highway projects in Dallas County in order to determine the suitability and possible improvements of the assumed HEEM growth rate formulas.

Objectives:

(1) To determine traffic volume changes resulting from various types of improvements.

(2) Develop a more accurate procedure for determining corridor traffic growth rates to be used in the HEEM that take into account changes in vehicle volume, vehicle capacity, abutting

land uses, and population experienced in the study corridor and highway system of which the corridor is a part.

Contents of Report

The report consists of two major sections. The first section includes an aggregative analysis of 18 case study areas [1-18]. This section covers several areas, including alternative functional forms for ADT, analysis of land use and capacity changes on traffic growth patterns. This section also examines the effects on parallel and intersecting routes from a capacity change on the primary route.

The second major section examines ADT growth rates in Dallas County. The accuracy of ADT projections are examined, along with the factors affecting the projection errors. The accuracy of land use and population projections are also examined, along with the relationship between the errors. The HEEM declining growth rate model is examined and alternative declining growth rate formulas are presented. In addition, a simple multiple regression model to project ADT is presented which slightly lowers the average projection errors.

Sources of Data

Data for the 18 Case Study Areas were taken from the individual reports on each area. The original data sources for each study are published separately in these reports [1-18].

Data for the Dallas County highway projects came from a variety of sources. Information on the improvement projects within Dallas County came from the District 18 Office of the State Department of Highways and Public Transportation (SDHPT).

ADT historical data came from the SDHPT's Planning and Research Division RI-2-T-Log and District Highway Traffic Maps. Projected ADT figures were taken from various reports prepared by the SDHPT's Planning and Research Division.

Historical land use and population data were obtained from a computer tape prepared by SDHPT's Dallas-Fort Worth Regional Planning Office. Projected land use and population figures were obtained from the Regional Transportation Study (RTS), Volume 2, prepared by the SDHPT [22], and unpublished raw data used in preparation of the RTS, for individual survey zones within Dallas County.

AGGREGATIVE ANALYSIS OF 18 CASE STUDIES

The location of the 18 case study areas are presented in Table 1. The 18 areas were broken down into a developing or developed category. The developed category is defined as 80 percent or more of the land not vacant within the study area. A particular count station was selected which most closely reflected the change in average daily traffic (ADT) volume along the study route, and for which the greatest amount of data were available.

Table 1 also presents the parallel routes and intersecting routes selected for use in this study. Each route and the count station associated with that route were selected based upon its location within or proximity to the study area and the availability of ADT data. In general, much less data were available for parallel routes and generally even less for intersecting routes. This restricted the accurate estimation of growth rates along those routes and would indicate a need for more frequent ADT counts along these less traveled routes, especially those off of the state or federal systems. The historical ADT data used in this study for aggregating the 18 case study areas are presented in Appendix A, Tables A2, A7, and A10.

Functional Form for Projected ADT

In any study concerned with forecasting or projections, the functional form of the dependent variable and its rate of change or growth rate is of prime importance. The Highway Economic Evaluation

Table 1

Study Areas, Parallel Routes, and Intersecting Routes

Study Area Number	Name of Road and City Location	Type of Study Area [a]	Study Period	Length of Period (Years)	Location of Traffic Count Station	Parallel Route	Location of Traffic Count Station	Intersecting Route	Location of Traffic Count Station
1	SH 30, College Station	1	1968 - 1977	10	E. of Texas Ave.	Dominik St.	E. of Texas Ave.	Texas Avenue	S. of FM 2818
2	Texas Ave.S., College Station	1	1968 - 1977	10	S. of SH 30	Glade St.	S. of Holleman	FM 2818	W. of Texas
3	29th Street, Bryan	2	1958 - 1977	20	NW of Haswell, SE of Coulter	Carter Creek Parkway	SE of Texas NW of Coulter	Coulter Dr.	SW of 29th
4	Texas Ave. N., Bryan	1	1958 - 1977	20	NW of Stevens	Old Hearne	N. of N. Texas	SH 21	NE of N. Texas
5	West 43 St., Houston	2	1962 - 1978	17	W. of Shepard	Pinemont [b]	W. of N.Shepard	North Shepard	N. of W. 43rd.
6	Gessner Rd., Houston	1	1962 - 1978	17	N. of LongPoint	Witte Rd. [b]	at Long Point	Long Point Rd.	at Gessner
7	Antoine Dr., Houston	2	1964 - 1978	15	at Katy Freeway	Wirt Rd. [b]	at Katy Freeway	Long Point Rd.	at Wirt
8	FM 157 #1, Arlington	1	1964 - 1978	15	N. of Brown	SH 360 [b]	N. of IH 30	Lamar Blvd.	W. of FM 157
9	FM 1093, Westheimer #1, Houston	1	1962 - 1978	17	at Briargrove	San Felipe [b]	at Sage	Fondren Rd.	at Westheimer
10	Collins St., Arlington	2	1969 - 1978	10	N. of Spur 303	Cooper Street [b]	S. of Spur 303	Spur 303	at Center St.
11	FM 1093, Westheimer #2, Houston	1	1962 - 1978	17	at Hillcroft-Voss	Richmond [b]	at Fondren	Hillcroft-Voss	at Buffalo Bayou
12	FM 157 #2, Arlington	1	1963 - 1978	16	N. of U.S.80	SH 360 [b]	N. of US 80	US 80	W of FM 157
13	FM 1093, Westheimer #3 Houston	1	1962 - 1978	17	at Gessner	Memorial Dr. [b]	at Benigus	Fondren Rd.	at Buffalo Bayou
14	SH 352, Dallas	1	1958 - 1979	21	W. of Don	Military Parkway	E.of St.Augustine	Sam Houston	S. of SH 352
15	SH 356, Dallas	1	1958 - 1978	21	E. of Trinity	John Carpenter Freeway	W. of Regal Row	Mockingbird Lane	S. of 356
16	W. Berry St., Ft. Worth	2	1964 - 1978	15	Univ.and Forest Parkway	Seminary Dr. [b]	McCart and James	University	W.Berry and Park Hill
17	Vickery St., Ft. Worth	1	1964 - 1978	15	Montgomery and Hulen	Camp Bowie [b]	Halloran and Horn	Montgomery	Lovell and Locke
18	Pipeline Rd., Hurst	2	1963 - 1978	16	E. of Precinct	SH 183 [b]	E. of Norwood	Precinct Line Rd.	at Pipeline Rd.

a 1 = Developing Area
2 = Developed Area

b = Not in Study Area

Model (HEEM) uses two functional forms, depending on the stage of development in the area. One is a constant growth rate, which is to represent a typical developing area. The other is a declining growth rate where the terminal growth rate must be specified, which is to represent a typical highly developed area. Due to the specification of the model, the parameters of the second function must be iterated.

A more detailed look at the HEEM growth rate models is presented in the last section of this report, but it is sufficient at this time to mention that the functional form of the HEEM declining growth rate model prevents it from being used in a linear regression model to estimate growth rates of historical ADT data.

In addition, it is certainly not obvious that one particular functional form is applicable in all cases where the growth rate happens to be declining. Table 2 presents five different models of ADT as a function of time. Each can be estimated with a simple least-squares regression technique. In addition, the ADT growth rate is presented which is associated with each functional form. The first one has a constant growth rate, the other four have declining growth rates, with each one in general having a different rate of decline. The relative relationship of the models is presented in Figure 1, where ADT is assumed to increase from 10,000 to 20,000 in 20 years.

The selection of these five particular functional forms was arbitrary in the sense that there are virtually an infinite number to choose from. However, these five offer the advantages that their coefficients are easily calculated or estimated, as the situation warrants, and they offer a relatively wide range of variability in the

Table 2 Functional Forms for ADT Models

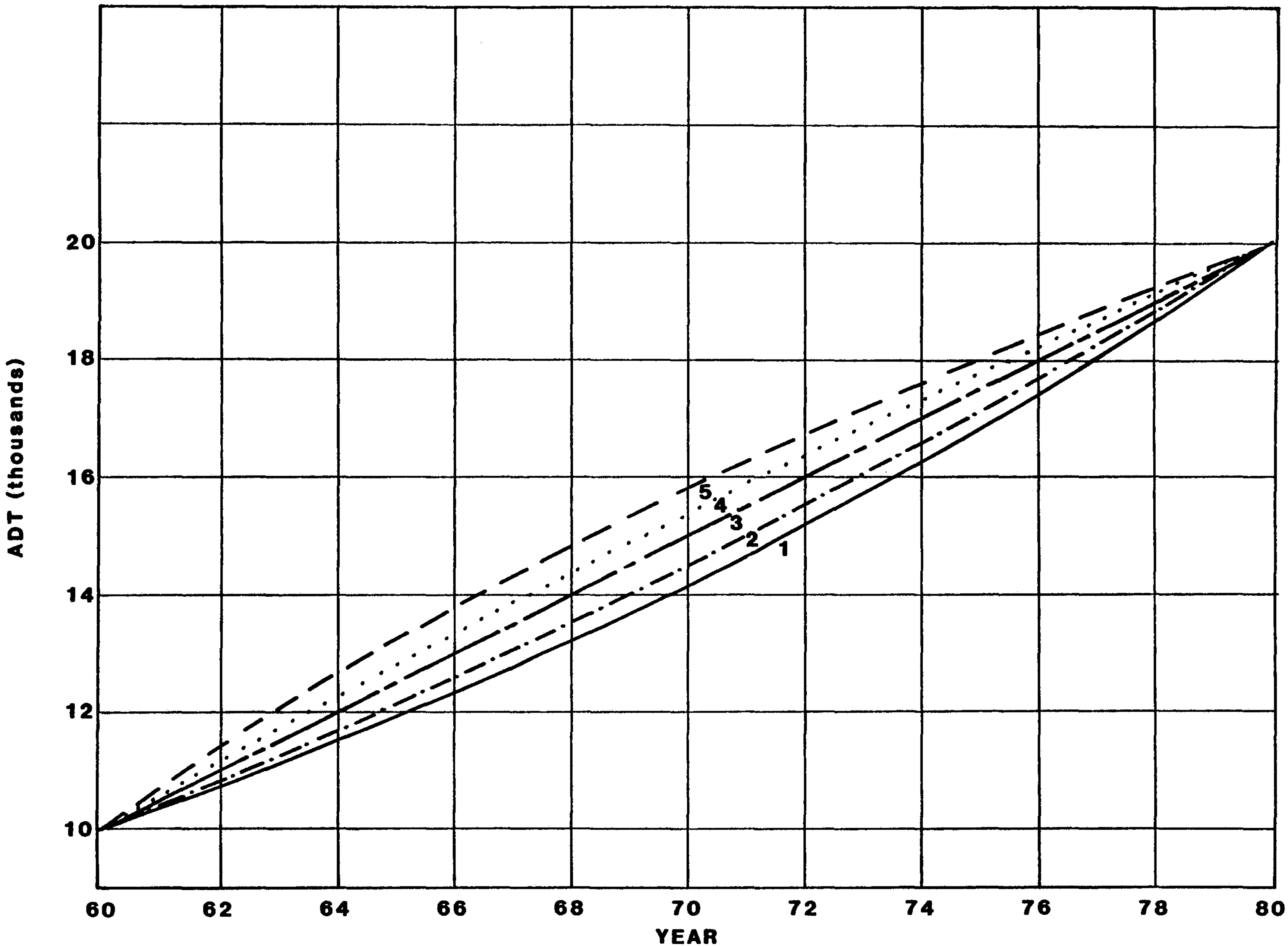
Functional Form	Growth Rate
1. $\ln ADT_t = a + b\,t$	b
2. $\ln ADT_t = a + b \ln t$	$\frac{b}{t}$
3. $ADT_t = a + b\,t$	$\frac{b}{a+bt} = \frac{b}{ADT_t}$
4. $ADT_t = a + b \ln t$	$\frac{b}{t(a+b\ln t)} = \frac{b}{t(ADT_t)}$
5. $\left(\frac{ADTt}{10{,}000}\right)^2 = a + b\,t$	$\frac{b}{2(a+bt)} = \frac{(5\times10^7)b}{ADT^2}$

Where: ADT = Annual Average Daily Traffic

t = Time Period (year)

a,b = Parameters

FIGURE 1 COMPARISON OF FUNCTIONAL FORMS FOR ADT MODELS



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estimated ADT values over the period under consideration. For example, in Figure 1, at the midpoint (1970), ADT varies by more than 1,500. (Table A1 in Appendix A gives the ADT figures for each functional form).

Ideally, the particular model or models selected would be based on some theoretical assumptions concerning the "true" relationship. In this case, no a priori information is available which would allow selection of one model versus another. However, their applicability to particular sample data can be observed, and for that reason the model with the highest R^2 value was used in this study to estimate the growth rate for a given set of historical ADT data.

Analysis of ADT on Primary Routes

The 18 case study areas were selected after a careful evaluation of a number of highway improvement projects. The 18 study areas were chosen based upon the following characteristics: (1) stage of area development; (2) type of highway or street; (3) predominate land use; and (4) type of setting (urban or suburban). In addition, each study area selected was required to have adequate historical experience after the improvement had been made.

As a result of this selection process, aggregating the study areas presented some difficulties. The case studies covered several different time periods (see Table 1) which includes varied study periods and length of periods. In addition, several gaps in the yearly ADT data are present.

To resolve these problems and make the data comparable, the historical ADT figures for each study area were normalized, to cover a similar 15 year study period. Year five was used in each case to indicate the year before commitment was made to fund the project, final planning completed, and construction began. In that way, each study area would reflect the relative change in ADT resulting from the improvement during the same time frame and so that the 18 case study areas could be aggregated along with any subset of these areas.

The year when construction was completed could also have been used as the basis of comparison, but in most cases the construction period was relatively short (one or two years) and would not significantly affect the results. In addition, by using the year prior to the beginning of final planning and construction, it allows a clear comparison of time periods before and after improvements were made in order to examine the effects of these changes on the aggregated ADT figures.

Linear interpolation was used in most cases to fill in the gaps of the historical ADT figures for each study area. In the few instances where the normalized study period extended beyond available historical ADT figures, the estimated growth rate for the particular study area was used to estimate the required ADT figures (see Appendix A, Tables A3 and A4).

The aggregate ADT figures are presented in Table 3. These ADT figures represent an average of the ADT figures for each of the 15 years during the study period and are categorized by the previously described developed or developing areas and by all 18 study areas. The study areas in each category are listed at the bottom of the table.

Table 3 Primary Route Averaged ADT, Classified by Stage of Development

Year	Developing Areas [a]	Developed Areas [b]	Total Areas
1	8,970	8,550	8,830
2	9,580	8,350	9,170
3	10,820	9,100	10,250
4	11,380	9,970	10,910
5	12,070	9,790	11,300
6	12,620	9,580	11,610
7	13,110	10,030	12,080
8	14,060	10,140	12,750
9	16,310	10,550	14,390
10	18,750	11,110	16,200
11	20,660	11,830	17,720
12	22,360	12,510	19,080
13	24,600	12,400	20,530
14	26,170	12,950	21,760
15	28,290	13,690	23,420

a Areas 1,2,4,6,8,9,11,12,13,14,15,17.

b Areas 3,5,7,10,16,18

In addition, the entire study period was broken down into three segments. The first five years represent the period before final planning and construction took place. The second segment of five years represents the period of final planning, construction, and immediately following construction of the project. This period would capture the initial impact on traffic volume resulting from the improvement along the study route. The third segment represents the period after the initial impact has passed and after readjustments of traffic volume have occurred as a result of the improvement having taken place.

Figure 2 gives a graphical representation of the aggregated ADT figures. As would be expected, the developing areas show a much faster ADT growth than the developed areas. However, it is interesting to observe that the developed areas do not exhibit an obvious declining growth rate curve in this sample, which is assumed in the HEEM model. A larger sample size would be required to determine the exact relationship between stage of development and the pattern of ADT growth, and a longer sample period of 20 years may show a declining growth rate pattern for developed areas.

Calculation of Growth Rates by Stage of Development

Growth rates were then calculated for each of the three aggregated categories over the study period and are presented in Table 4. The actual growth rates are presented which represent the year-to-year change in the ADT figures. The growth rate was calculated using the

FIGURE 2 **PRIMARY ROUTE AVERAGED ADT, CLASSIFIED BY STAGE OF DEVELOPMENT**

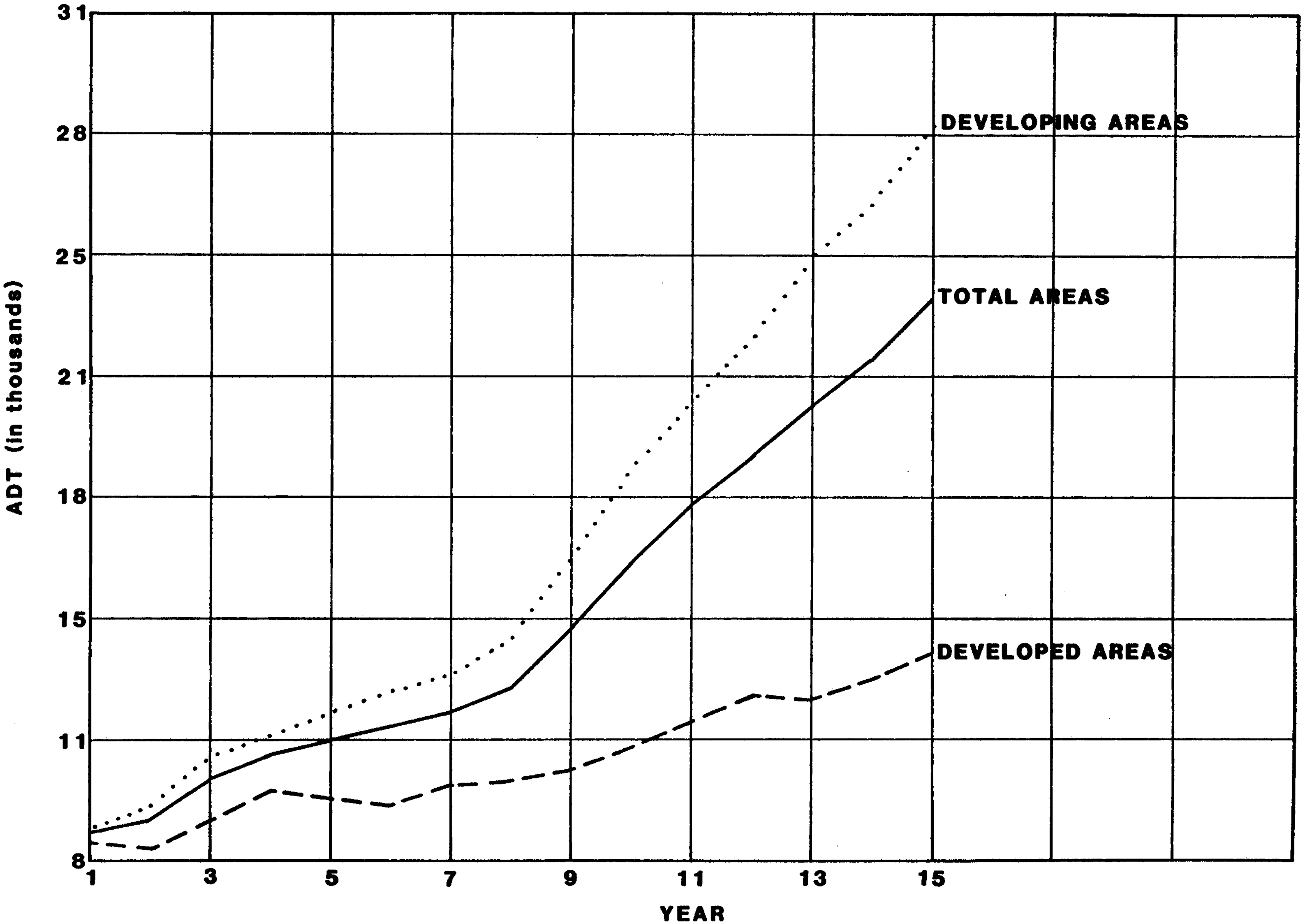


Table 4 Primary Route Growth Rates (%)

Year	Actual Growth Rates			Overall Calculated Growth Rates			Divided Segments Growth Rate		
	Developing	Developed	Total	Developing	Developed	Total	Developing	Developed	Total
1	.0680	-.0234	.0385	.0839	.0332	.0711	.1045	.0444	.0862
2	.1294	.0898	.1178	.0839	.0332	.0711	.0916	.0444	.0799
3	.0517	.0956	.0644	.0839	.0332	.0711	.0718	.0444	.0640
4	.0606	-.0201	.0357	.0839	.0332	.0711	.0649	.0444	.0564
5	.0456	-.0194	.0274	.0839	.0332	.0711	.0577	.0444	.0526
6	.0388	.0470	.0405	.0839	.0332	.0711	.1010	.0347	.0841
7	.0725	.0110	.0555	.0839	.0332	.0711	.1010	.0347	.0841
8	.1600	.0404	.1286	.0839	.0332	.0711	.1010	.0347	.0841
9	.1496	.0531	.1258	.0839	.0332	.0711	.1010	.0347	.0841
10	.1019	.0648	.0938	.0839	.0332	.0711	.1010	.0347	.0841
11	.0823	.0575	.0767	.0839	.0332	.0711	.0923	.0327	.0689
12	.1002	-.0088	.0760	.0839	.0332	.0711	.0853	.0327	.0689
13	.0638	.0444	.0599	.0839	.0332	.0711	.0775	.0327	.0689
14	.0810	.0571	.0763	.0839	.0332	.0711	.0729	.0327	.0689
15	-	-	-	.0839	.0332	.0711	.0674	.0327	.0689

following formula:

$$g_t = \frac{ADT_{t+1} - ADT_t}{ADT_t}$$

where: g_t = growth rate in year (%)

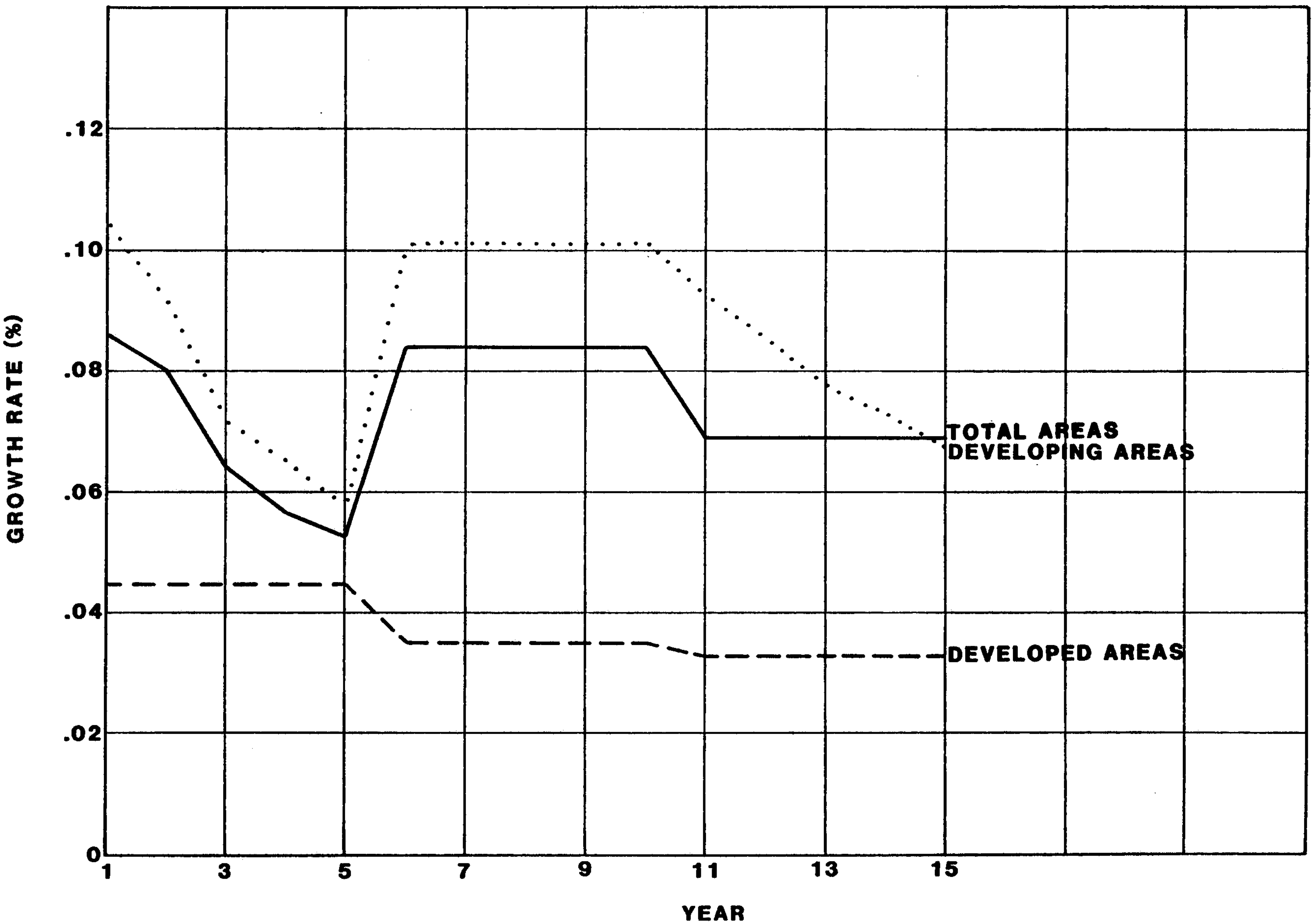
ADT_t = Average Daily Traffic in Year t

The overall growth rates were estimated using ordinary least-squares on the functional form most closely fitting the data for the entire 15 year period. It is interesting to note all three aggregated categories have an overall estimated growth rate which is constant. Even though the growth rate for the developed areas is much lower than for the developing areas (3.23% compared to 8.39%), it would tend to suggest that rather than using a declining growth rate for developed areas, a small, but constant growth rate may be more approriate.

This sample is too small to generalize the results to other areas in Texas outside these study areas, but it does cast some doubt on the HEEM's use of a declining growth rate without additional justification and study.

The segmented growth rates presented in Table 4 were estimated in the same manner as the overall growth rates except the growth rates for each segment were estimated separately. Figure 3 presents those segmented growth rates graphically. The developing areas show a declining growth rate for the first five years, then a high, constant growth rate of 10.1% during the initial impact period, then a declining

FIGURE 3 COMPARISON OF PRIMARY ROUTE SEGMENTED GROWTH RATES



growth rate during the last period.

The developed areas, on the other hand, show a far different pattern. The growth rate is constant during each segment, with a slight downward trend between segments. The growth rate goes from 4.44% in the first segment to 3.27% in the last segment. In this sample, the averaged ADT in the developed areas did not go up as a result of improvements along the study route, in sharp contrast to the large increase experienced in the developing areas. This result would suggest that some adjustment to the assumed growth rates should be made for improvements only in developing areas.

Effects of Capacity Change

A comparison of the 18 case study areas was also made for capacity changes. Table 5 presents the three capacity change categories and the study areas in each category are listed at the bottom of the table. The ADT figures for study areas in each category were averaged and are presented in Table 5. Unfortunately only one area fell into the no capacity change category which limits any generalizations or comparisons to other aggregated categories.

Figure 4 presents graphically the ADT figures for different capacity change categories. As expected, the 4-lane capacity change category has a much faster growth rate after the capacity change than the other categories. That observation is confirmed in Table 6 which presents the actual growth rates for each category along with the overall estimated growth rates and the estimated growth rates for each segment.

Table 5 Primary Route Averaged ADT, Classified by Capacity Change

Year	2 Lane Change [a]	4 Lane Change [b]	No Change [c]
1	6,640	11,100	14,770
2	6,480	12,100	15,560
3	7,030	13,980	16,340
4	7,680	14,720	16,530
5	7,900	15,130	18,560
6	7,890	15,570	20,980
7	8,760	15,250	23,140
8	8,770	17,030	22,690
9	9,760	19,760	23,100
10	10,530	23,120	24,510
11	12,030	24,690	22,980
12	13,420	26,230	25,600
13	14,120	29,100	24,660
14	15,470	29,980	27,170
15	17,670	30,660	30,280

a Areas 1,2,3,4,5,7,8,16,17,18

b Areas 6,9,10,11,13,14,15

c Area 12

FIGURE 4 PRIMARY ROUTE AVERAGED ADT, CLASSIFIED BY CAPACITY CHANGE

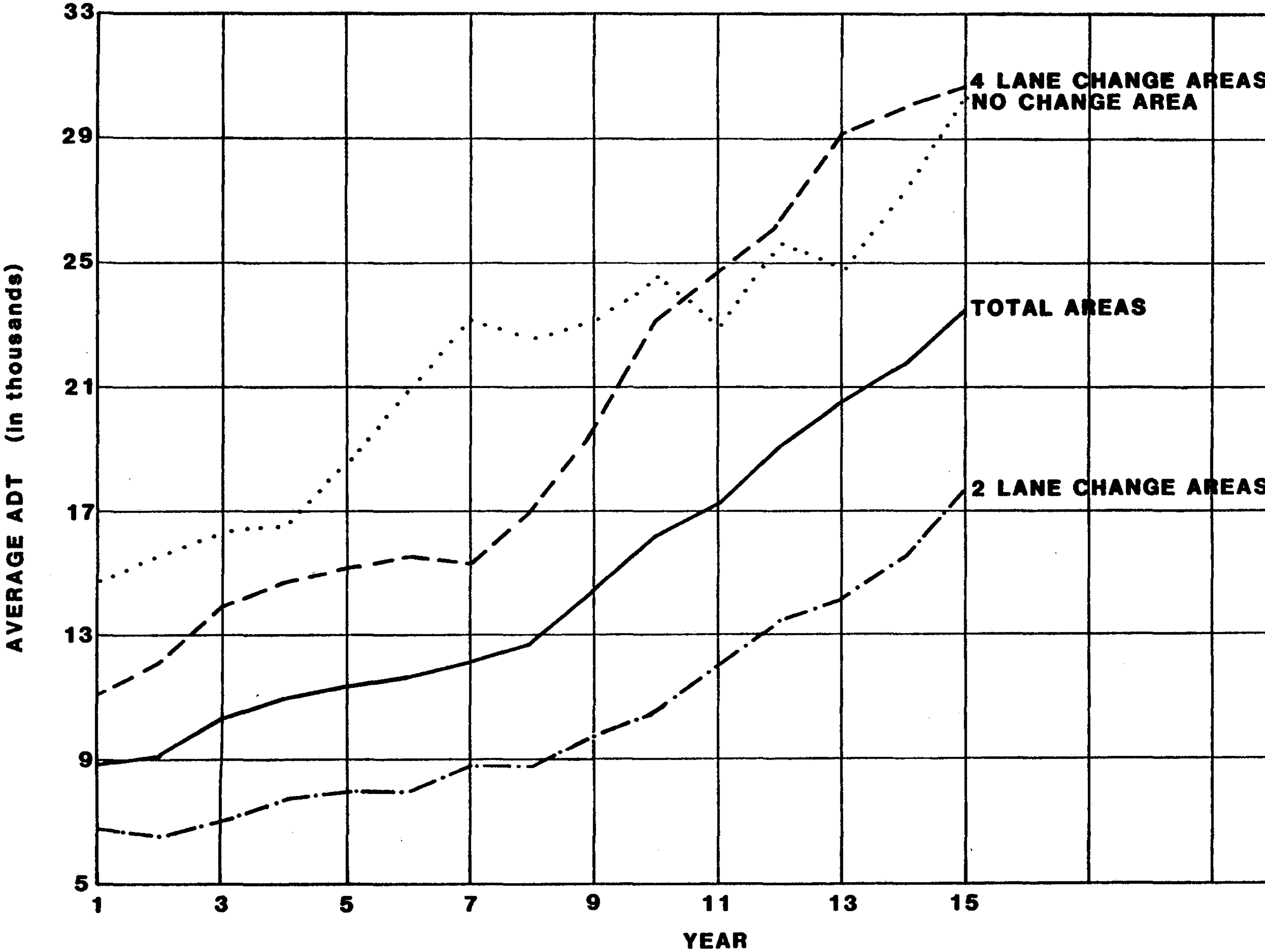


Table 6 Primary Route Growth Rates (%) for Capacity Changes

Year	Actual Growth Rates				Overall Calculated Growth Rates				Divided Segments Growth Rate			
	2 Lane Change	4 Lane Change	No Change	Total	2 Lane Change	4 Lane Change	No Change	Total	2 Lane Change	4 Lane Change	No Change	Total
1	-.0241	.0900	.0535	.0385	.0705	.0752	.0668	.0711	.0608	.1143	.0517	.0862
2	.0849	.1554	.0501	.1178	.0705	.0752	.0634	.0711	.0639	.0962	.0517	.0799
3.	.0925	.0530	.0117	.0644	.0705	.0752	.0604	.0711	.0543	.0721	.0517	.0640
4.	.0286	.0279	.1228	.0357	.0705	.0752	.0597	.0711	.0455	.0650	.0517	.0564
5.	-.0013	.0291	.1304	.0274	.0705	.0752	.0532	.0711	.0430	.0615	.0517	.0526
6.	.1103	-.0206	.1030	.0405	.0705	.0752	.0470	.0711	.0685	.1050	.0440	.0841
7.	.0011	.1167	-.0194	.0555	.0705	.0752	.0427	.0711	.0685	.1050	.0342	.0841
8.	.1129	.1603	.0181	.1286	.0705	.0752	.0435	.0711	.0685	.1050	.0305	.0841
9.	.0789	.1700	.0610	.1258	.0705	.0752	.0427	.0711	.0685	.1050	.0266	.0841
10.	.1426	.0679	-.0624	.0938	.0705	.0752	.0403	.0711	.0685	.1050	.0226	.0841
11.	.1155	.0624	.1140	.0767	.0705	.0752	.0430	.0711	.0911	.0751	.0611	.0689
12.	.0522	.1094	-.0367	.0760	.0705	.0752	.0386	.0711	.0911	.0664	.0611	.0689
13.	.0956	.0302	.1018	.0599	.0705	.0752	.0400	.0711	.0911	.0636	.0611	.0689
14.	.1422	.0227	.1145	.0763	.0705	.0752	.0363	.0711	.0911	.0536	.0611	.0689
15.	-	-	-	-	.0705	.0752	.0326	.0711	.0911	.0449	.0611	.0689

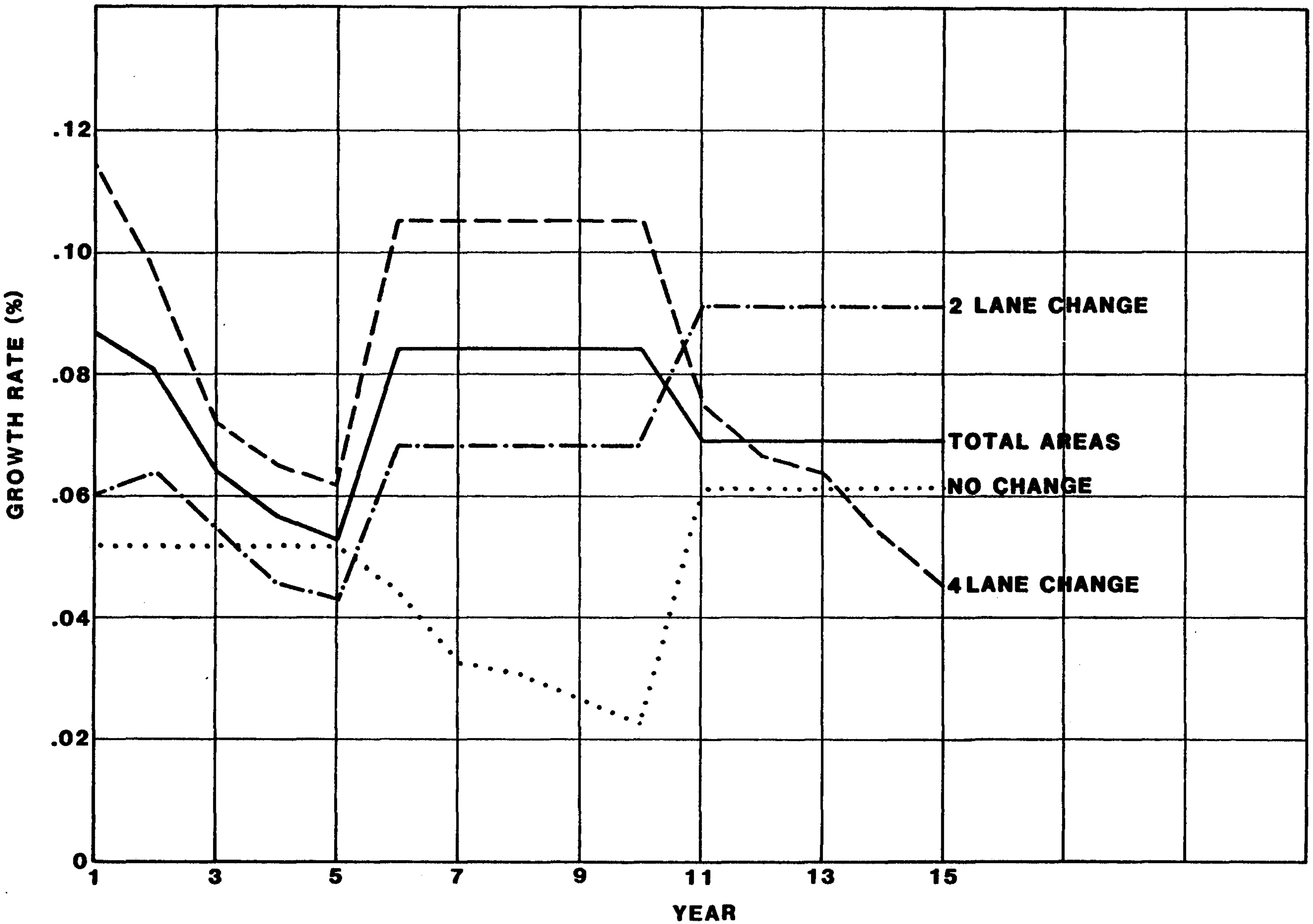
Overall the estimated growth rates are constant for both the 2-land and 4-lane capacity change categories, with the 4-lane category having a slightly higher growth rate, 7.52% to 7.05%. The no change category exhibits an overall declining growth rate pattern going from 6.68% in year 1 to 3.26% in year 15.

The estimated growth rate pattern changes somewhat when the study period is broken down into segments. Those segmented growth rates are presented graphically in Figure 5. The 4-lane change areas exhibit a declining growth rate in both the initial and last segments, with a high constant growth rate (10.5%) during the initial impact segment.

The 2-lane change areas also have a declining growth rate during the initial segment and a higher constant growth rate (6.85%) during the middle segment, but then the growth rate is even higher to 9.11% during the last period. This is mainly due to the impact of case study areas 1 and 2, which are located in rapidly growing areas of College Station, Texas. This area has been characterized by a high constant, or even slightly increasing growth rate, during the last five to ten years.

In general, the results seem to support the conclusion that the greater the capacity change the larger is the initial impact on ADT, but that effect on the growth rate diminishes over time.

FIGURE 5 COMPARISON OF PRIMARY ROUTE SEGMENTED GROWTH RATES BY CAPACITY CHANGE



Analysis of ADT on Parallel Routes

It has been assumed in the past that all routes in a specific corridor exhibit similtar types of growth patterns, in particular the same growth rate could be applied to both the primary route and secondary route(s). The HEEM, for example, calculates either a constant growth rate or a declining growth rate for the corridor traffic volume being examined. However the allocation procedure in the HEEM for distributing the projected traffic volume along the routes within the corridor is not affected by that assumed growth rate, so in effect, the same growth rate is applied to all routes within the corridor. The 18 case study areas were examined to provide some evidence as to the validity of the above assumption.

Aggregating parallel route ADT followed the same procedure outlined in the previous section for the primary routes. The historical ADT was normalized using the year before final planning and construction began (year 5) as the common reference point. The averaged ADT for the 18 case study parallel routes is presented in Table 7. Again, they were divided up into developed and developing categories in order to make them comparable to the primary routes.

The actual growth rates, along with the estimated overall growth rates and the segmented growth rates are presented in Table 8. The overall growth rates show a similar relationship already noted between the primary routes. Both the developed and developing areas have an estimated constant growth rate, with the developing areas having a much higher growth rate, 7.32% compared to the 2.59% growth rate for the developed areas.

Table 7 Parallel Routes Averaged ADT

Year	Developing	Developed	Total Areas
1	7,460	12,590	9,170
2	8,260	12,760	9,760
3.	8,700	13,130	10,180
4	9,150	13,480	10,590
5	10,340	13,780	11,490
6	11,320	14,340	12,330
7	12,130	14,330	12,860
8	12,900	14,410	13,400
9	13,520	14,660	13,900
10	14,230	15,120	14,530
11	15,570	15,870	15,670
12	16,370	16,380	16,370
13	17,780	17,030	17,530
14	19,780	17,730	19,100
15	21,930	18,370	20,740

FIGURE 6

PARALLEL ROUTES AVERAGED ADT

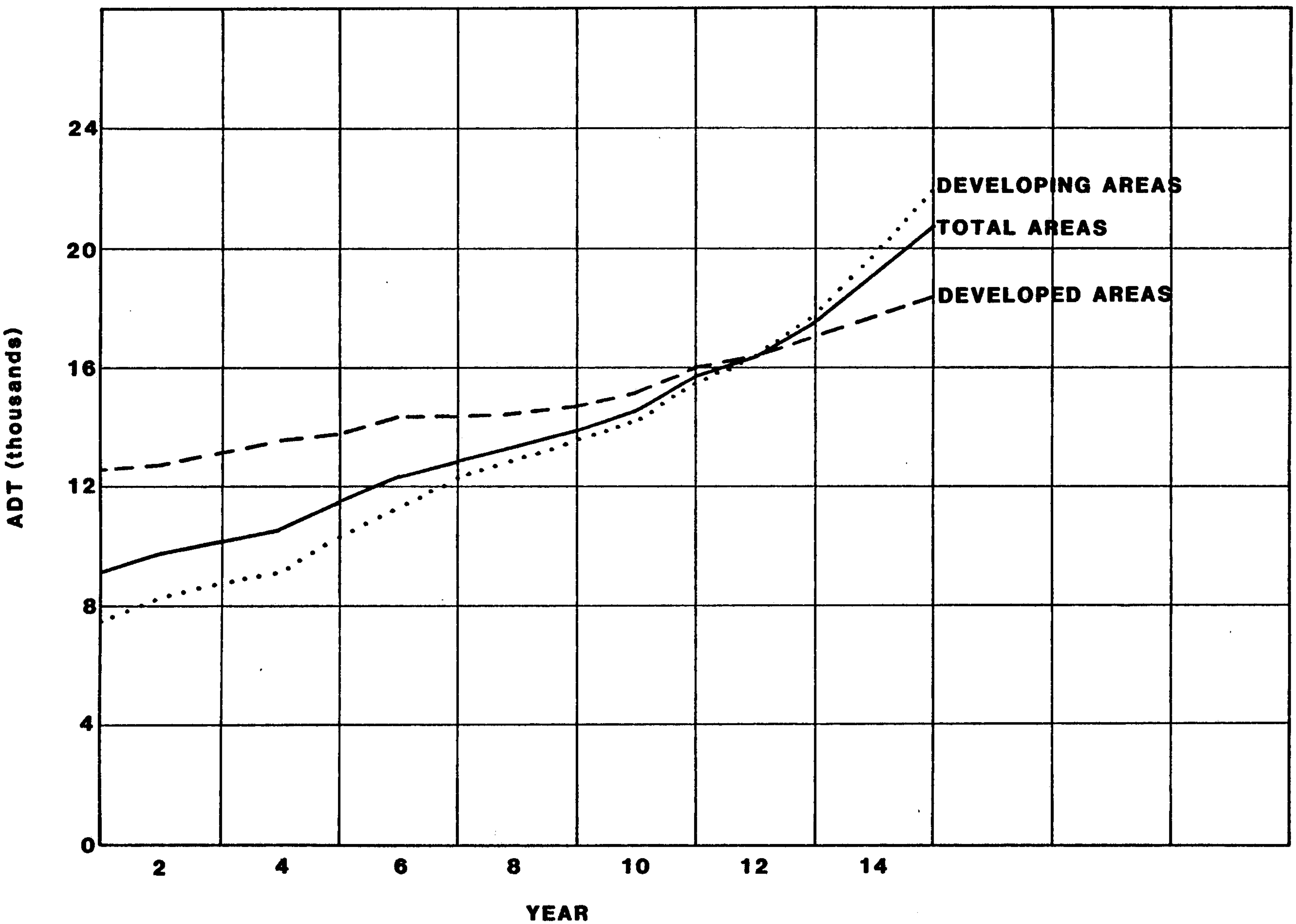


Table 8

Parallel Routes Growth Rates (%)

Year	Actual Growth Rates			Overall Calculated Growth Rates			Divided Segments Growth Rate		
	Developing	Developed	Total	Developing	Developed	Total	Developing	Developed	Total
1	.1072	.0135	.0643	.0732	.0259	.0555	.0755	.0236	.0533
2	.0533	.0290	.0430	.0732	.0259	.0555	.0755	.0236	.0533
3	.0517	.0267	.0403	.0732	.0259	.0555	.0755	.0236	.0533
4	.1301	.0223	.0850	.0732	.0259	.0555	.0755	.0236	.0533
5	.0948	.0406	.0731	.0732	.0259	.0555	.0755	.0236	.0533
6	.0716	-.0007	.0430	.0732	.0259	.0555	.0741	.0129	.0406
7	.0635	.0056	.0420	.0732	.0259	.0555	.0635	.0129	.0406
8	.0481	.0173	.0373	.0732	.0259	.0555	.0556	.0129	.0406
9	.0525	.0314	.0453	.0732	.0259	.0555	.0494	.0129	.0406
10	.0942	.0496	.0785	.0732	.0259	.0555	.0447	.0129	.0406
11	.0514	.0321	.0447	.0732	.0259	.0555	.0874	.0372	.0715
12	.0862	.0397	.0709	.0732	.0259	.0555	.0874	.0372	.0715
13	.1125	.0411	.0896	.0732	.0259	.0555	.0874	.0372	.0715
14	.1087	.0361	.0859	.0732	.0259	.0555	.0874	.0372	.0715
15	-	-	-	.0732	.0259	.0555	.0874	.0372	.0715

The segmented growth rates offer an interesting contrast to the primary routes. Looking at the middle segment in Table 8, when the initial impact from the primary route improvement is felt, a decline in the growth rates for both categories can be observed, though the decline is not as large in the developed areas. As expected, the positive initial impact on growth rates along the primary routes seems to be matched, at least to a certain extent, by a corresponding drop in the growth rates for parallel routes.

Comparison to Primary Routes

The difference in the growth rates between the primary routes and parallel routes for each of the several categories is presented in Table 9. The overall estimated growth rates show relatively little difference. The developing areas have a difference of 1.07% and developed areas .73%. The most significant differences appear in the segmented growth rate categories, where a large increase in the difference during the middle segment is evident for the developing areas.

Figure 7 depicts graphically the actual differences in growth rates between the primary routes and the parallel routes. Both the developing areas trendline and the developed areas trendline generally follow each other very closely, except for the initial impact segment from year 6 to year 10, where the difference is much larger for the developing areas than the developed areas.

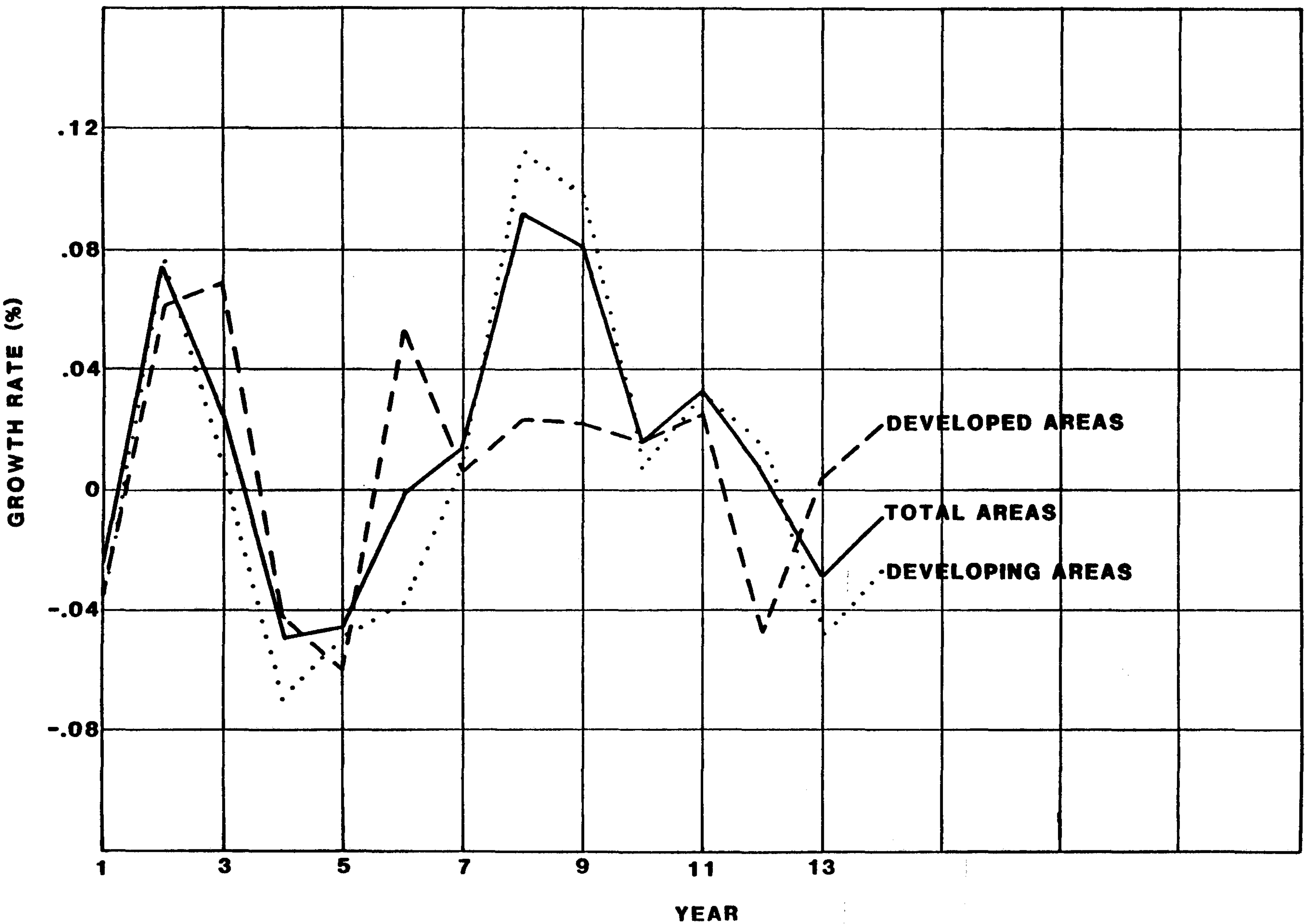
Figure 8, showing the difference in segmented growth rates gives a

Table 9 Difference in Growth Rates (%) between Primary Routes and Parallel Routes

Year	Actual Difference			Overall Diff. in Calc. Growth Rates			Difference in Segmented Growth Rates		
	Developing	Developed	Total	Developing	Developed	Total	Developing	Developed	Total
1	-.0392	-.0369	-.0258	.0107	.0073	.0156	.0290	.0208	.0329
2	.0761	.0608	.0748	.0107	.0073	.0156	.0161	.0208	.0266
3	.0054	.0689	.0241	.0107	.0073	.0156	-.0037	.0208	.0107
4	-.0695	-.0424	-.0493	.0107	.0073	.0156	-.0106	.0208	.0031
5	-.0492	-.0600	-.0457	.0107	.0073	.0156	-.0178	.0208	-.0007
6	-.0328	.0540	-.0025	.0107	.0073	.0156	.0269	.0218	.0435
7	.0090	.0054	.0135	.0107	.0073	.0156	.0375	.0218	.0435
8	.1119	.0231	.0913	.0107	.0073	.0156	.0454	.0218	.0435
9	.0971	.0217	.0805	.0107	.0073	.0156	.0516	.0218	.0435
10	.0077	.0152	.0153	.0107	.0073	.0156	.0563	.0218	.0435
11	.0309	.0254	.0320	.0107	.0073	.0156	.0049	-.0045	-.0026
12	.0140	-.0485	.0051	.0107	.0073	.0156	.0049	-.0045	-.0026
13	-.0487	.0033	-.0297	.0107	.0073	.0156	.0049	-.0045	-.0026
14	-.0277	.0210	-.0096	.0107	.0073	.0156	.0049	-.0045	-.0026
15	-	-	-	.0107	.0073	.0156	.0049	-.0045	-.0026

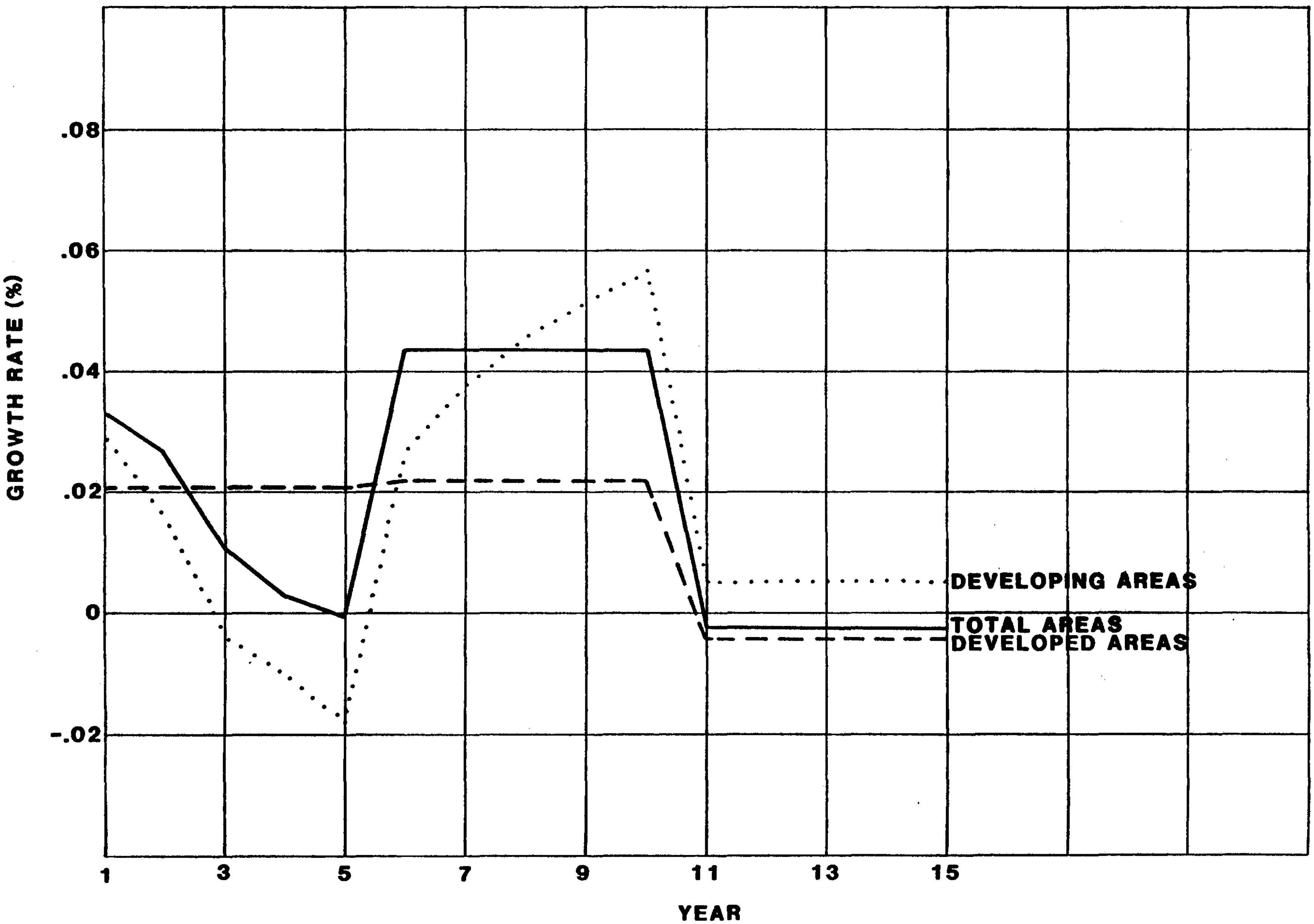
FIGURE 7

COMPARISON OF THE DIFFERENCE OF ACTUAL GROWTH RATES BETWEEN PRIMARY ROUTES AND PARALLEL ROUTES



COMPARISON OF ALL THE DIFFERENCE IN SEGMENTED GROWTH RATES BETWEEN PRIMARY ROUTES AND PARALLEL ROUTES

FIGURE 8



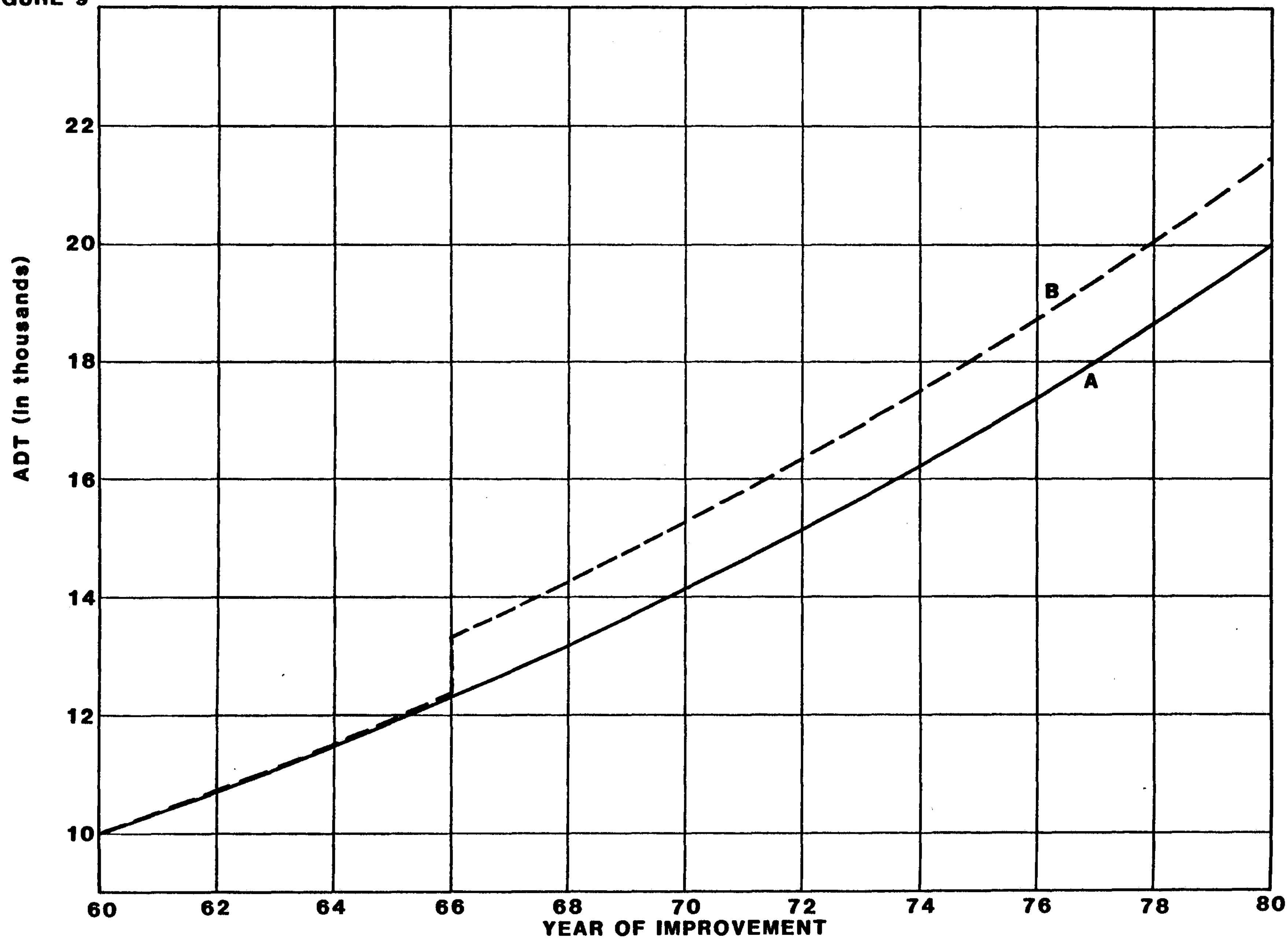
similar result. The developing areas show a decline in the difference which becomes negative by year 5, the parallel routes are growing faster than the primary routes, during the initial segment. Then during the middle segment, years 6 to 10, a big jump in the difference can be observed. The difference then drops close to zero during the last segment. The developed areas exhibit quite different results. The difference is virtually constant during the first 10 years at about 2%, then drops to slightly below zero during the last segment.

These results would indicate the impacts from improvements along the study routes are most evident in the developing areas, but the impact on the growth rate diminishes over time and tends to disappear in about 5 years after construction is begun. This would suggest that when an improvement is made in a developing area, the underlying ADT growth rate would not have to be adjusted, since the effect on the growth rate would not tend to be permanent. However, the ADT volumes themselves should be shifted upward in the year the improvement is made.

Figure 9 depicts how that might be accomplished. Curve A exhibits a constant growth rate and is the same one used earlier in Figure 1. Curve B has exactly the same growth rate but has been shifted upward by 1,000 in the sixth year. By the 20th year, that difference becomes about 1,500. A measure of the magnitude of that shift is presented in Table 20 later in this study, but generally the shift should depend on the stage of development, especially commercial development, of the study area.

FIGURE 9

EFFECT ON DEVELOPING AREA ADT FROM AN IMPROVEMENT ALONG PRIMARY ROUTE



Analysis of ADT on Intersecting Routes

The effects of primary route improvements on intersecting routes within each case study area are examined in a similar fashion to the analysis of the parallel routes presented in the previous section. Table 10 presents the averaged ADT figures for the case study area in each category after the ADT figures had been normalized using the year before final planning and construction began as the common reference point. Those ADT categories are presented graphically in Figure 10.

Growth rates were then calculated for the intersecting routes which are presented in Table 11. The developing areas have an overall calculated growth rate which is a constant 5.8%. The developed areas have an overall declining growth rate which reaches .54% in year 15.

Looking at segmented growth rates, the developing areas exhibit a slightly declining growth rate during the first and last segments, and a constant growth rate during the middle segment. The developed areas have a slightly positive growth rate during the first segment, which becomes positive again during the last segment.

Any inferences which can be made from these data are very limited due to the lack of ADT data available on most intersecting routes and the small sample size of the study. However, it does seem the growth rates for intersecting routes have been affected by improvements along the primary routes.

Table 10 Intersecting Routes Averaged ADT

Year	Developing Areas	Developed Areas [a]	Total areas [a]
1	6,130	16,420	9,160
2	6,530	15,870	9,280
3	7,020	16,870	9,920
4	7,240	18,490	10,550
5	7,490	19,080	10,900
6	7,950	19,300	11,290
7	8,580	18,960	11,630
8	8,840	18,310	11,630
9	9,430	18,830	12,190
10	10,010	19,100	12,680
11	10,640	19,820	13,340
12	11,430	19,900	13,920
13	12,560	20,130	14,790
14	13,520	20,360	15,530
15	13,520	20,370	15,530

a Excluding Case Study Area #18

FIGURE 10 INTERSECTING ROUTES AVERAGED ADT

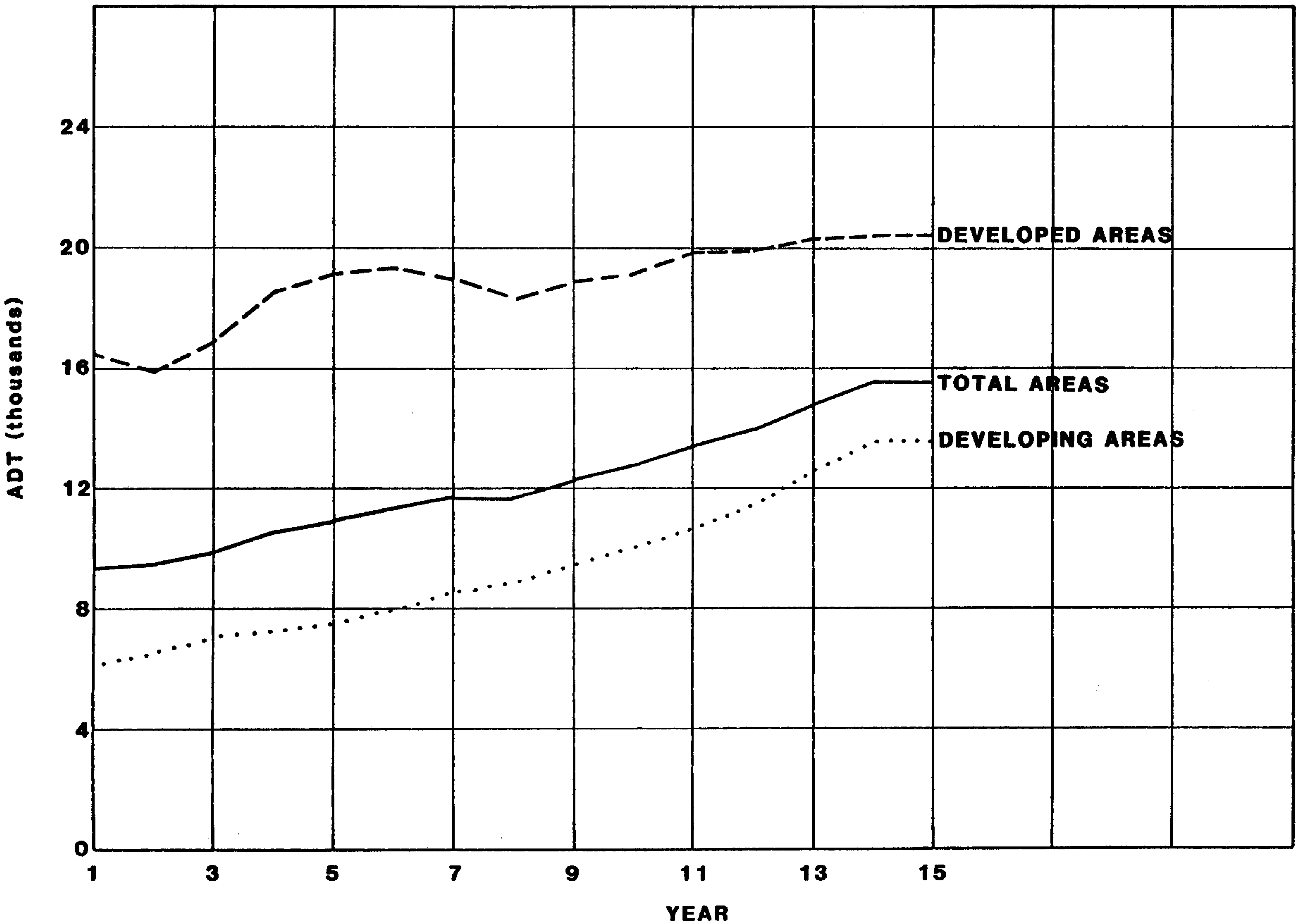


Table 11 Intersecting Routes Growth Rates (%)

Year	Actual Growth Rates			Overall Calculated Growth Rates			Divided Segments Growth Rate		
	Developing	Developed	Total	Developing	Developed	Total	Developing	Developed	Total
1	.0653	-.0335	.0131	.0580	.1005	.0385	.0623	.0052	.0476
2	.0750	.0630	.0690	.0580	.0520	.0385	.0549	.0055	.0476
3	.0313	.0960	.0635	.0580	.0326	.0385	.0475	.0049	.0476
4	.0345	.0319	.0332	.0580	.0223	.0385	.0447	.0041	.0476
5	.0614	.0115	.0358	.0580	.0173	.0385	.0417	.0038	.0476
6	.0792	-.0176	.0301	.0580	.0143	.0385	.0555	-.0046	.0279
7	.0303	-.0343	.0000	.0580	.0124	.0385	.0555	-.0040	.0279
8	.0667	.0284	.0482	.0580	.0113	.0385	.0555	-.0036	.0279
9	.0615	.0143	.0402	.0580	.0097	.0385	.0555	-.0031	.0279
10	.0629	.0377	.0521	.0580	.0086	.0385	.0555	-.0028	.0279
11	.0742	.0040	.0435	.0580	.0076	.0385	.0871	.0091	.0530
12	.0987	.0116	.0625	.0580	.0069	.0385	.0744	.0084	.0466
13	.0764	.0114	.0500	.0580	.0063	.0385	.0625	.0077	.0405
14	.0000	.0005	.0000	.0580	.0058	.0385	.0539	.0072	.0358
15	-	-	-	.0580	.0054	.0385	.0503	.0067	.0334

Comparison to Primary Routes

Table 12 gives a detailed look at the differences in growth rates between the primary routes and intersecting routes for the 18 case study areas.

The differences in actual growth rates are presented in Figure 11. The trendlines for the developed and developing areas seem to follow each other fairly closely in the first and last segments, but they seem to have a significant divergence during the middle segment.

That relationship becomes clearer by looking at the differences in the segmented growth rates presented in Figure 12. The difference for the developing areas category is declining during the first segment, then increases to a constant 4.55% during the middle segment, then drops close to zero during the last segment. In contrast, the developed areas show an almost constant difference of about 4% for the first 10 years, then declines to about 2.5% during the last segment.

Comparison to Parallel Routes

It is interesting to note the similarity in the above described difference between the primary and intersecting routes, Figure 12, and the previously presented differences between the primary and parallel routes, Figure 8. Both exhibit a similar pattern, there is a negative impact on the growth rates for both the parallel routes and intersecting routes resulting from an improvement along the primary route in developing areas. The impact in developed areas is much smaller for both parellel routes and intersecting routes.

Table 12 Difference in Growth Rates between Primary Routes and Intersecting Roads (%)

Year	Actual Growth Rates			Overall Calculated Growth Rates			Divided Segments Growth Rate		
	Developing	Developed	Total	Developing	Developed	Total	Developing	Developed	Total
1	.0027	.0101	.0254	.0259	-.0673	.0326	.0422	.0392	.0386
2	.0544	.0359	.0488	.0259	-.0188	.0326	.0367	.0389	.0323
3	.0204	-.0004	.0009	.0259	.0006	.0326	.0243	.0395	.0164
4	.0261	-.0520	.0025	.0259	.0109	.0326	.0202	.0403	.0088
5	-.0158	-.0309	-.0084	.0259	.0159	.0326	.0160	.0406	.0050
6	-.0404	.0646	.0104	.0259	.0189	.0326	.0455	.0393	.0562
7	.0422	.0453	.0555	.0259	.0208	.0326	.0455	.0387	.0562
8	.0933	.0120	.0804	.0259	.0219	.0326	.0455	.0383	.0562
9	.0881	.0388	.0856	.0259	.0235	.0326	.0455	.0378	.0562
10	.0390	.0271	.0417	.0259	.0246	.0326	.0455	.0375	.0562
11	.0081	.0535	.0332	.0259	.0256	.0326	.0052	.0236	.0159
12	.0015	-.0204	.0135	.0259	.0263	.0326	.0109	.0243	.0223
13	-.0126	.0330	.0099	.0259	.0269	.0326	.0150	.0250	.0284
14	.0810	.0566	.0763	.0259	.0274	.0326	.0190	.0255	.0331
15	-	-	-	.0259	.0278	.0326	.0171	.0260	.0355

FIGURE 11 COMPARISON OF THE DIFFERENCE IN ACTUAL GROWTH RATES BETWEEN PRIMARY ROUTES AND INTERSECTING ROUTES

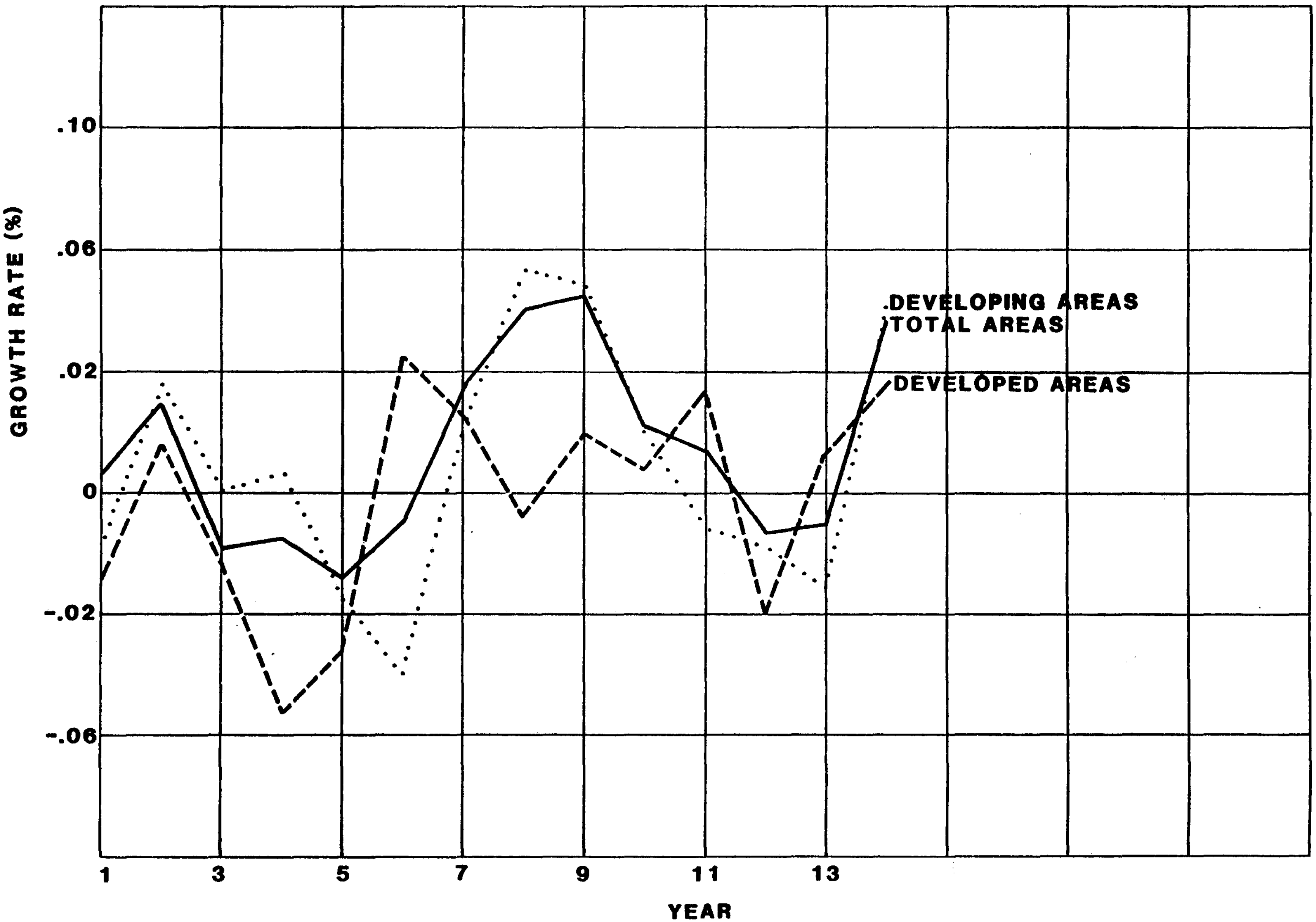


FIGURE 12 COMPARISON OF THE DIFFERENCE IN SEGMENTED GROWTH RATES BETWEEN PRIMARY ROUTES AND INTERSECTING ROUTES

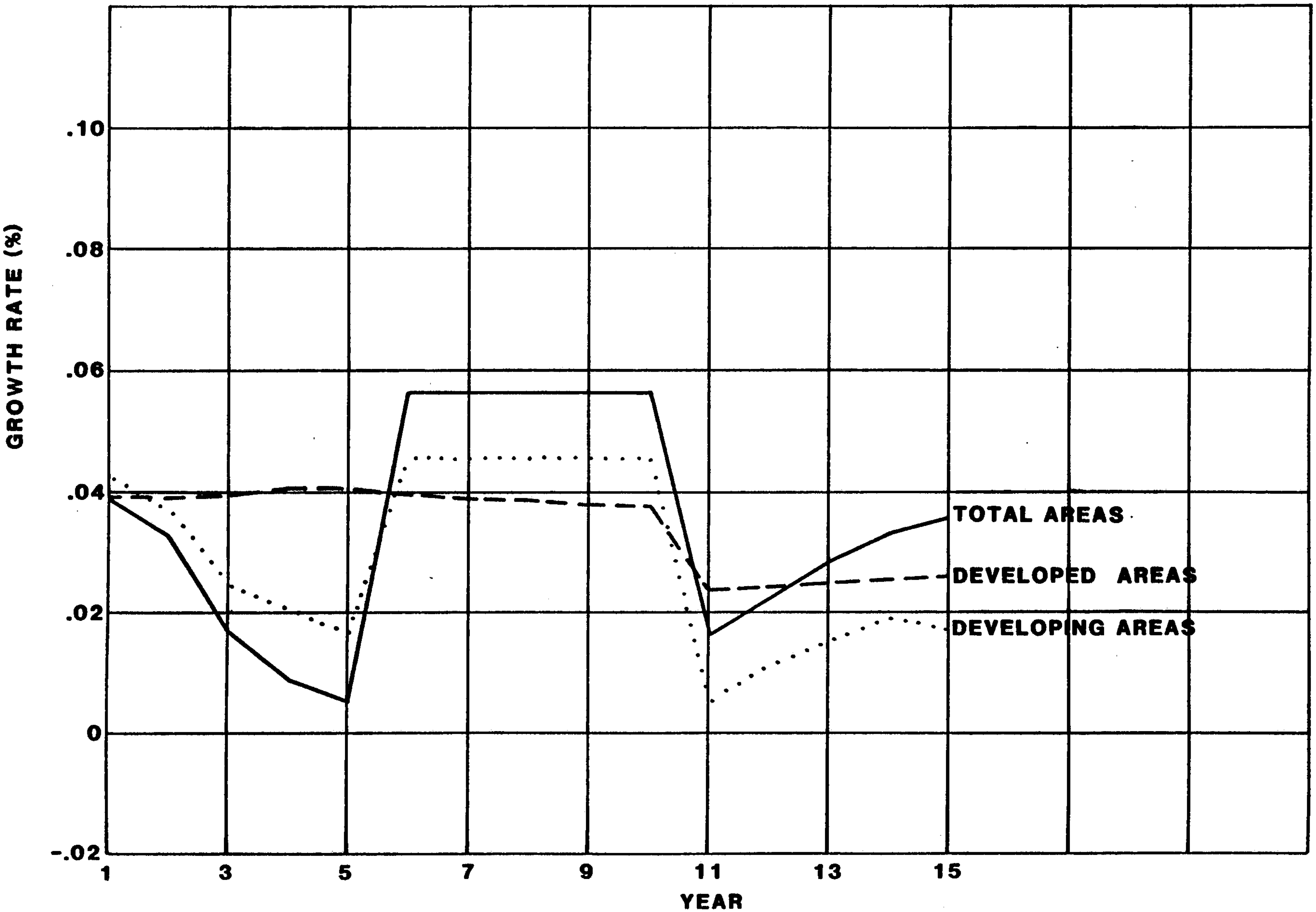
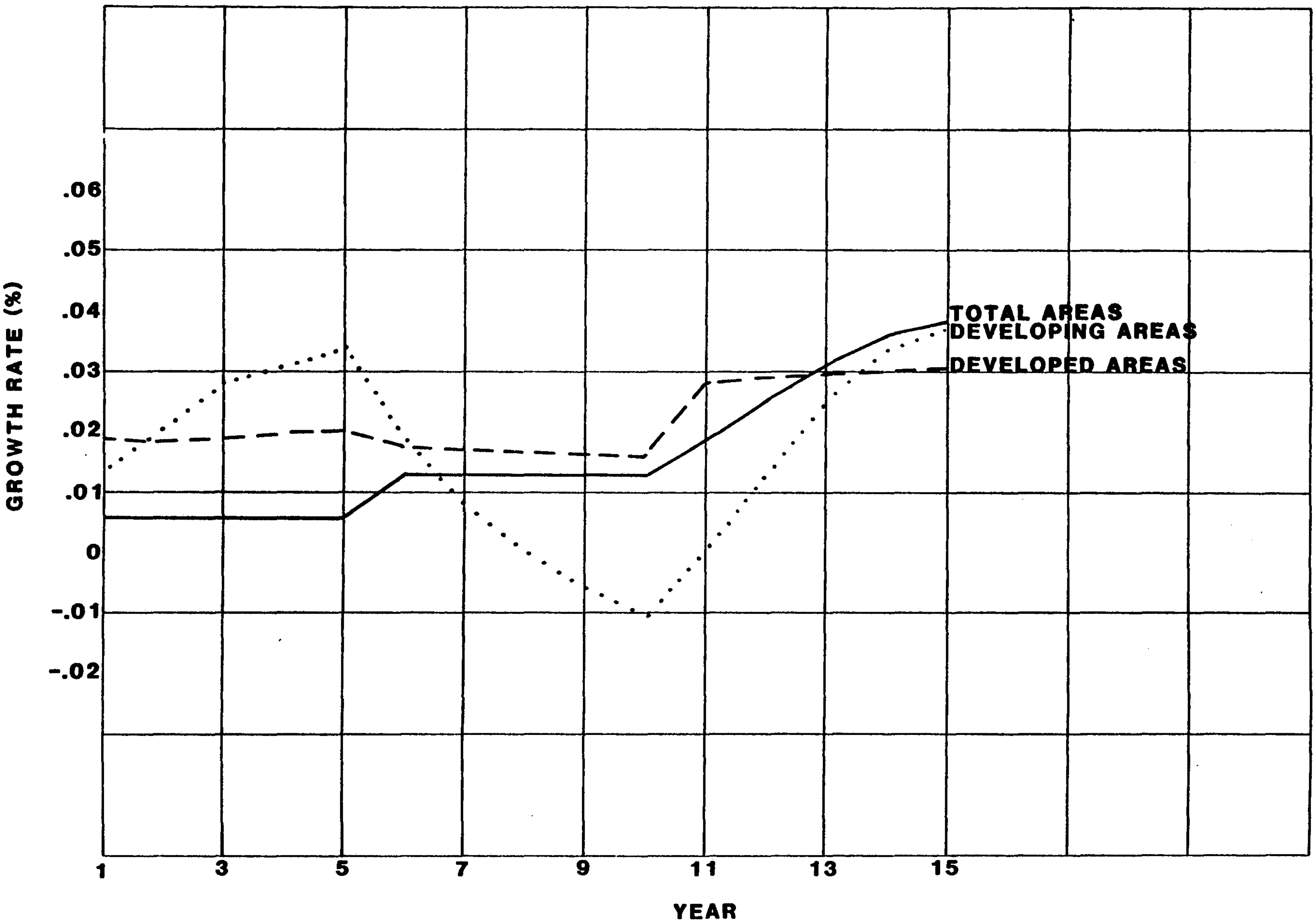


Figure 13 provides a comparison of the segmented growth rates for the parallel routes and intersecting routes in the 18 case study areas. The difference for developed areas stays fairly constant throughout the study period varying only between about 1.5% and 3%. The developing areas offer a greater contrast. The difference between the parallel and intersecting routes increases moderately during the first five years, then drops rapidly during the next five years from about 3.4% to -1.1%. This would indicate improvements on the primary routes have a greater negative impact on the parallel routes than intersecting routes. After that initial impact has passed, the difference gradually returns to the approximate size observed during the initial period.

These findings would indicate that in developing areas both parallel routes and intersecting routes receive a negative impact on their growth rates when the primary route is improved, and that effect is greater for the parallel routes. However, developed areas do not seem to be as sensitive to primary route improvements as developing areas. In this sample, very little impact was observed on the developed area growth rates for both parallel routes and intersecting routes. In addition, there did not seem to be any significant difference in the relative impact between parallel and intersecting routes.

FIGURE 13

COMPARISON IN DIFFERENCE IN SEGMENTED GROWTH RATES BETWEEN PARALLEL RATES AND INTERSECTING ROUTES



EXAMINATION OF ADT GROWTH RATES IN DALLAS COUNTY

A detailed examination of the factors affecting ADT growth rates was undertaken for Dallas County through a study of the accuracy of ADT, land use and population projections. In addition, an alternative model for projecting ADT is presented.

The HEEM currently uses only two growth rates, a constant growth rate designated for use in rapidly developing areas, and a declining growth rate, to be used when the constant growth rate is inappropriate. Due to the specification and particular method of calculating the declining growth rate, several iterations must be performed in order to calculate the growth rate and ADT for each year. In addition, a particular growth rate at the end of the projection period must be assumed. The calculated pattern of growth is quite sensitive to the assumed terminal growth rate.

The importance of the type of growth rate pattern used in the HEEM comes from the effect it has on the Economic Measure the HEEM calculates to access the desirability of a project. As the <u>Guide to the Highway Economic Evaluation Model</u> [20] points out:

> with a constant rate of traffic growth, the bulk of traffic growth, and therefore growth in benefits, occurs during the last half of the planning horizon. Conversely, with a declining rate of growth, most of the growth in traffic, and therefore benefits occurs early in the planning horizon . . . (p. 2-2)

Since future benefits are discounted, the same benefits are worth "less" in present value terms the farther in the future they are received.

Therefore for any given ADT projection, use of the declining growth rate formula would result in a higher Economic Measure than using the constant growth rate formula. In addition, the HEEM provides very little guidance as to which growth rate formula is appropriate in any particular application. To a great extent, the model relies upon the discretion and judgement of the user.

This section attempts to identify the factors which influence the growth rate and suggest methods to improve the actual growth rates used in the HEEM.

Analysis of ADT Projections

Capacity changes on the Federal and State Highway System in Dallas County were identified in order to examine the effects those changes had on growth rates and the accuracy of ADT projections for those projects, prepared by the State Department of Highway and Public Transportation (SDHPT).

Limitations and deficiencies in the data severely restricted the size of the sample used in the study. Only a relatively few traffic count stations with adequate historical ADT data are available from District Highway Traffic Maps and the RI-2-T-Log.

Table 13 lists all highway segments used in this study. They are listed by an assigned segment number and include all segments for which ADT projections have been made and have historical ADT figures at least back to the year before the projection was made. Even with the above limitations on sample size, the sample includes 47 highway segments, with

Table 13 Dallas County Highway Segments Used in Study

Segment Number	Mileposts		Highway Number	Control Section Number	Project			Capacity and Design	
	Begin	End			Number	Date of Letting	Date Completion	Before Project	After Project
5999	8.148	8.964	US 80	8-8	43	1/71	4/72	4 ln, raised median	6 ln, raised median
6088	10.321	10.984	IH 30	9-11	4	4/49*	11/50	0	6 ln, control access
6306	3.321	3.701	IH 45	92-2	29	10/53*	9/54	2 ln, no raised median	4 ln, control access
6313	6.446	7.250	IH 45	92-2	29	10/53*	9/54	2 ln, no raised median	4 ln, control access
6366	8.913	8.997	IH 45	92-2	57	12/69*	11/73	0	6 ln, control access
6370	10.151	12.215	IH 45	92-14	16	1/73	10/75	0	6 ln, control access
6372	12.276	13.891	IH 45	92-14	16	1/73	10/75	0	6 ln, control access
6381	1.000	1.700	SH 183	94-3	36	6/70*	7/73	4 ln, raised median	6 ln, control access
6387	4.338	4.880	SH 183	94-3	36	6/70*	7/73	4 ln, control access	6 ln, control access
6393	7.048	7.928	SH 183	94-3	36	6/70*	7/73	4 ln, control access	6 ln, control access
6461	0.000	0.630	US 80	95-10	6	8/58*	7/59	4 ln, control access	6 ln, control access
6509	28.899	30.213	IH 35E	196-3	80	12/72	9/76	4 ln, control access	6 ln, control access
6566	0.000	0.463	US 175	197-2	28	7/61*	1/64	0	6 ln, control access
6568	2.078	2.807	US 175	197-2	28	7/61*	1/64	0	6 ln, control access
6574	4.526	5.232	US 175	197-2	33	10/66	11/68	4 ln, raised median	6 ln, control access
6575	5.232	5.534	US 175	197-2	36	10/68*	3/71	4 ln, raised median	6 ln, control access
6578	7.491	7.747	US 175	197-2	36	10/68*	3/71	4 ln, raised median	6 ln, control access
6586	9.793	10.214	US 175	197-2	38	11/69*	1/72	2 ln, no raised median	4 ln, control access
6596	13.945	14.651	US 175	197-2	31	2/63*	6/64	2 ln, no raised median	4 ln, control access
6618	13.547	14.027	US 67	261-2	24	10/73*	4/75	2 ln, no raised median	4 ln, raised median
6621	14.830	15.173	US 67	261-2	23	2/74*	7/75	2 ln, no raised median	4 ln, raised median
6631	18.409	18.807	US 67	261-2	23	2/74*	7/75	2 ln, no raised median	4 ln, raised median
6684	23.514	24.154	Loop 12	353-5	49	1/68*	11/70	0	6 ln, raised median
6686	24.581	25.591	Loop 12	353-5	47	11/63*	9/64	4 ln, no raised median	6 ln, raised median

* Date Project Started

Table 13 (continued) Dallas County Highway Segments Used in Study

Segment Number	Mileposts		Highway Number	Control Section Number	Project			Capacity and Design	
	Begin	End			Number	Date of Letting	Date Completion	Before Project	After Project
6741	0.000	0.943	IH 35E	442-2	28	10/61*	11/63	2 ln, no raised median	4 ln, control access
6744	2.991	3.788	IH 35E	442-2	28	10/61*	11/63	2 ln, no raised median	4 ln, control access
6749	5.936	6.553	IH 35E	442-2	28	10/61*	11/63	2 ln, no raised median	4 ln, control access
6755	9.648	10.984	IH 35E	442-2	36	12/63*	10/65	2 ln, no raised median	6 ln, control access
6758	11.339	11.534	IH 35E	442-2	38	10/63*	7/65	0	8 ln, control access
6790	7.167	7.396	Loop 12	581-1	38	7/64	9/65	4 ln, no raised median	6 ln, raised median
6830	8.825	9.157	Loop 12	581-2	30	9/66*	6/68	2 ln, no raised median	6 ln, raised median
6841	12.961	13.209	Loop 12	581-2	41	12/71	8/75	2 ln, no raised median	6 ln, control access
6850	15.207	15.659	Loop 12	581-2	43	1/73	6/76	2 ln, no raised median	4 ln, control access
6856	16.248	16.998	Loop 12	581-2	43	1/73	6/76	2 ln, no raised median	6 ln, control access
6864	19.054	19.515	Loop 12	581-2	32	5/67*	10/69	2 ln, no raised median	6 ln, control access
6868	20.836	21.643	Loop 12	581-2	36	8/68*	10/70	0	6 ln, control access
6975	14.356	14.525	IH 635	2374-1	2	6/64*	3/67	0	8 ln, control access
6978	0.000	0.332	IH 635	2374-2	4	5/66*	10/69	0	8 ln, control access
7000	7.682	8.436	IH 635	2374-2	5	11/66*	8/70	0	8 ln, control access
7002	8.849	9.051	IH 635	2374-2	2	4/66*	11/68	0	8 ln, control access
7015	13.341	13.811	IH 20	2374-3	12	9/67*	3/74	0	8 ln, control access
7016	13.811	14.833	IH 20	2374-3	12	9/67*	3/74	0	8 ln, control access
7029	19.955	22.891	IH 20	2374-3	13	4/69*	10/71	0	8 ln, control access
7042	2.145	3.965	IH 20	2374-4	3	12/71*	8/74	0	8 ln, control access
7043	3.965	4.079	IH 20	2374-4	3	12/71*	8/74	0	8 ln, control access
7045	6.209	7.468	IH 20	2374-4	5	9/73	12/75	0	8 ln, control access
7047	9.731	10.476	IH 20	2374-4	2	3/71	7/74	0	8 ln, control access

* Date Project Started

34 different projects on 10 different highways within Dallas County. Historical ADT for these highway segments are presented in Appendix B, Table B1. Figure 14 shows the location of each highway segment in Dallas County.

Table 14 presents the projections on the above mentioned highway segments which are used in this study. There are 62 projections in all, since more than one projection has been made on some highway segments.

The wide variety of projections, including the date when the projection was made, the projection period, and the number of projections within that period, presented some difficulties in determining the accuracy of those projections.

For some projections, which were projected to 1975, the error is calculated directly by using the following formula:

$$E = \left| \frac{ADT_p - ADT_h}{ADT_p} \right|$$

where E = percentage error (in decimal form)

ADT_p = projected ADT, and

ADT_h = historical ADT.

The projected ADT is used in the denominator to give a smaller calculated error for overprojections than for the same absolute amount of underprojection.

One of the uses of ADT projections is to determine the required future capacity and presumably it is more desirable to have some amount of excess capacity than the same amount of under capacity. Therefore the formulas used for calculating projection errors will consistently favor over-

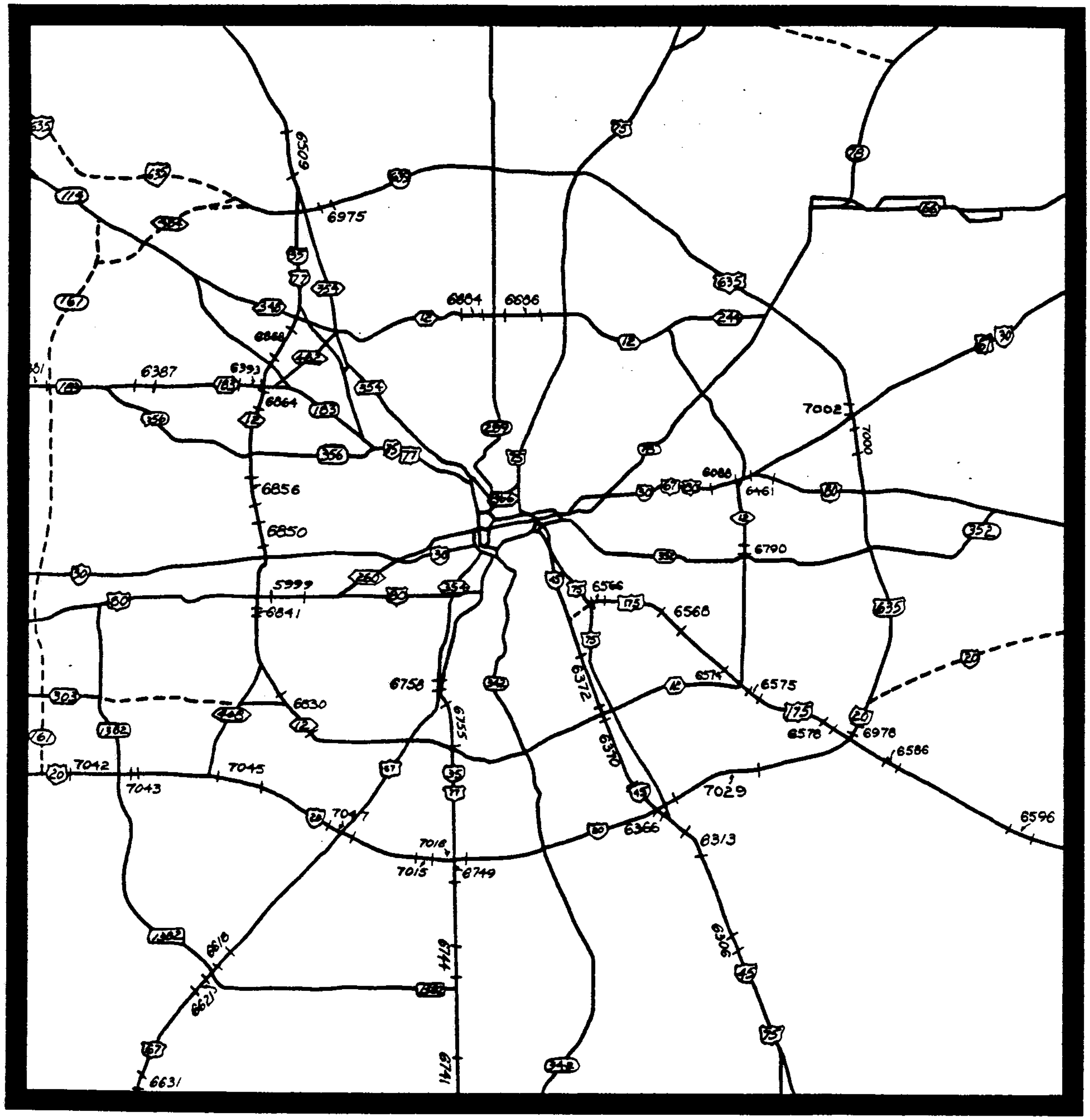


Figure 14

HIGHWAY STUDY SEGMENTS OF DALLAS COUNTY

NOTE: THE NUMBER OF EACH HIGHWAY SEGMENT IS SHOWN AND THE BOUNDARIES ARE DENOTED BY / /.

Table 14 Calculated Errors in SDHPT Projections

Study Point	Serial Number	Date of Projection	Projected ADT						Percentage Error (Decimal Form)
			First		Second		Third		
			Year	ADT	Year	ADT	Year	ADT	
1	5999	4/59	80	35,000					0.4412
2	6088	8/62	75	100,000					0.2585
3	6088	2/64	85	120,000					0.1587
4	6088	6/65	85	101,900					0.0433
5	6088	6/67	75	96,000					0.2276
6	6306	7/64	87	31,600					0.0863
7	6313	7/64	87	32,000					0.1117
8	6366	7/64	87	69,100					0.5076
9	6370	7/64	87	80,800					0.2376
10	6372	7/64	87	87,800					0.1793
11	6381	7/68	78	34,000	88	45,400			0.7379
12	6381	5/73	95	78,750					0.2940
13	6387	7/68	78	54,910	88	69,765			0.3648
14	6393	9/59	80	42,000					1.1827
15	6393	7/68	78	67,200	88	77,150			0.2468
16	6461	6/65	85	39,375					0.3980
17	6461	6/67	75	43,000					0.0826
18	6509	3/68	75	42,200	90	71,350			0.3661
19	6566	2/57	75	32,000					0.1600
20	6568	2/57	75	42,000					0.0307
21	6574	2/57	75	37,000					0.3586
22	6575	2/57	75	39,000					0.3051

Table 14 (continued) Calculated Errors in SDHPT Projections

Study Point	Serial Number	Date of Projection	Projected ADT: First Year	First ADT	Second Year	Second ADT	Third Year	Third ADT	Percentage Error (Decimal Form)
23	6578	2/57	75	34,000					0.2659
24	6578	5/65	65	18,200	75	34,000	85	40,700	0.2278
25	6586	2/57	75	29,000					0.1683
26	6586	10/68	89	53,000	94	58,800			0.0836
27	6586	4/69	89	53,000	94	57,900			0.0706
28	6596	2/57	75	31,000					0.5068
29	6618	4/69	82	11,250	92	13,925			0.2550
30	6621	4/69	82	13,350	92	16,625			0.1758
31	6631	4/69	82	6,900	92	8,875			0.2962
32	6684	2/65	80	42,100					1.4410
33	6686	2/65	80	43,900					0.0992
34	6741	1/57	75	18,580					0.0237
35	6744	1/57	75	21,430					0.2044
36	6749	1/57	75	29,900					0.2020
37	6749	8/65	88	47,100					0.2858
38	6755	2/57	75	40,000					0.5102
39	6755	9/59	75	43,300					0.3952
40	6758	2/57	75	69,000					0.3681
41	6758	9/59	75	76,000					0.2421
42	6790	7/74	75	21,100	85	30,100	95	38,000	0.1350
43	6830	9/66	86	12,550					0.3115
44	6841	3/71	90	73,250	95	79,850			0.1236

Table 14 (continued) Calculated Errors in SDHPT Projections

Study Point	Serial Number	Date of Projection	Projected ADT						Percentage Error (Decimal Form)
			First		Second		Third		
			Year	ADT	Year	ADT	Year	ADT	
45	6850	3/71	90	111,700	95	121,650			0.2221
46	6856	3/71	90	101,600	95	110,600			0.1836
47	6864	9/59	80	70,000					0.2157
48	6864	4/63	80	70,000	83	75,400			0.2591
49	6868	9/59	80	66,000					0.5115
50	6868	9/70	70	48,300	75	59,800			0.1692
51	6975	4/68	75	102,350	90	167,400			0.0581
52	6978	5/65	65	42,000	75	79,000	85	94,800	0.6718
53	7000	2/73	75	55,200	85	110,600	95	170,000	0.0466
54	7002	2/73	75	62,500	85	111,500	95	161,700	0.1298
55	7015	8/65	88	74,600					0.3517
56	7015	7/67	88	63,300					0.2594
57	7016	8/65	88	93,200					0.1657
58	7029	4/64	87	41,000					0.7271
59	7042	8/65	88	48,200					0.1455
60	7043	8/65	88	52,200					0.1818
61	7045	8/65	88	47,000					0.2161
62	7047	8/65	88	62,800					0.1114

projections.

In most cases, the projected year or years are still sometime in the future. To handle these cases, the ADT trend which the projection implies is compared to the historical ADT, since the projection was made, to estimate the error in the projection. When multiple projections were made, that trend is calculated using the following equation:

$$\ln ADT_t = a + b \ln + ct$$

where ADT_t = ADT in year t

By using the historical ADT for the year before the projection was made, along with the multiple projections, the ADT trend is established by calculating or estimating the coefficients in the above equation. The projection error is then calculated by taking an average of the errors for each year since the projection was made. The formula is given as follows:

$$E = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{ADT_{pt} - ADT_{ht}}{ADT_{pt}} \right|$$

where E = percentage error,

ADT_{pt} = projected ADT in year t,

ADT_{ht} = historical ADT in year t, and

n = number of years

Single projections with the projected year still in the future posed a problem. Only two data points were available, the historical

ADT for the year before the projection was made and the projected ADT. Of course, an infinite number of trendlines can pass between those two data points. Since if would be difficult, if not impossible, to determine what sort of trend was assumed when the projection was made, the actual historical ADT trend is used.

The same 5 functional forms for ADT, presented in Table 2, are used to find the one which most closely fit the historical data. That particular functional form is then used to estimate the trend of projected ADT and the projection error is calculated using the same procedure and formula described above for the multiple projection case.

Using the actual historical ADT trend rather than some unknown projected trend will tend to lower the calculated error, so some of the percentage errors presented in Table 14 probably have some downward bias. The size of the bias is unknown, but in most cases it shouldn't be very great.

Factors Affecting Errors in ADT Projections

In analyzing the variables which might affect the size of the errors, the highway segments and projections were divided up into the following categories: (1) time of projection, (2) stage of development, (3) stage of commercial/industrial development, and (4) size of capacity change. The average error for each category is presented in Table 15.

Overall, the ADT projections are very good, with an average error of .2870. Considering the difficulties in making any longrange forecasts, and in particular projecting 20 year traffic volumes for a small highway segment in a growing metropolitan area, the errors are very

Table 15 Average Percentage Errors (Decimal Form) in ADT Projections

Category	Projection Made Before Project Completed	Projection Made After Project Completed[a]	Total
Time Projection was Made			
before 1960	.3385	-	.3385
1960 - 1965	.3874	.1748	.3101
1966 - 1969	.2881	.1372	.2557
after 1969	.1983	.1038	.1629
Stage of Development			
Developed[b]	.2987	.1171	.2468
Developing	.3297	.1573	.2921
Stage of Commercial and Industrial Development			
Developed[c]	.5226	.1702	.3213
Developing	.2985	.1266	.2770
Size of Capacity Change			
2 lane	.3671	.1712	.3214
4 lane	.2856	-	.2856
6 lane	.2565	.1720	.2258
8 lane	.3128	.0782	.2625
Total	.3266	.1515	.2870

a Study Points 2, 3, 4, 5, 6, 7, 16, 17, 33, 37, 42, 51, 53, 54

b Segment Numbers 6387, 6566, 6574, 6684, 6686, 6758, 6790

c Segment Numbers 6088, 6366, 6393, 6461, 6566, 6790, 6830, 6850, 6975, 7029 small. In addition, the basic population, land use and other data used to make these forecasts were provided by local governments and other agencies in the area which may have introduced errors outside the control of the SDHPT.

It is interesting to note the significant change in the average percentage error if the projection was made after completion of the project and additional capacity had been added to the highway segment. The average error drops from .3266 to .1515 going from projections made before the project was completed to projections after the capacity had been added. This would tend to indicate capacity change does have a significant impact on the accuracy of ADT projections even though the size of the capacity change does not seem to exert a systematic effect in this sample.

The time period in which the projection was made also seems to have a signifiscent impact on the average errors, going from .3385 in the 1950's to .1629 in the 1970's. Certainly a portion of that difference is due to the greater length of time the historical ADT has had to deviate from the projected trend, however some of the observed decline may be due to improvements in forecasting techniques and additional forecasting experience over time.

The stage of commercial and industrial land development also seems to be exerting an influence on the size of the errors. Developed commercial and industrial areas are defined as segments where 10% or more of the acreage abutting the highway segment is classified as commercial or industrial land use. The average error of .3213 is larger for developed areas than the average error of .2770 for developing commercial and industrial areas. The difference is especially pronounced among projections made before completion of the project, where the average error for developing areas is .2985, compared to .5226 in the developed areas.

It would appear the level of economic activity in the area has an impact on the accuracy of ADT projections and is something which may not be adequately accounted for in current ADT forecasting procedures.

The stage of overall development in the area seems to be exerting some influence on the size of the average projection errors. However, that influence does not seem as strong as the effects observed from commercial and industrial development, and the effect goes in the opposite direction. In this sample, developing areas have a slightly higher average error, .2921, compared to .2468 average error for the developed areas.

A Model for Examining ADT Projection Errors

A multiple regression model was used to estimate which factors seem to be the most significant in influencing ADT projection errors and what proportion of the error can be explained by such factors. The model is given as:

$$E = \underset{(2.27)}{0.78034^*} - \underset{(-2.14)}{0.01091^*}T + \underset{(2.33)}{0.13694^*}F + \underset{(2.37)}{1.48371^*}D + e$$

$$R^2 = .2450$$

where E = percentage error,

T = year projection made,

F = 1 if projection was made before end of project, 0 otherwise, and

D = percentage of commercial and industrial land in 1970.

* indicates coefficients significant at 5% level, and ( ) includes the T-statistic for each estimated coefficient.

This model explains almost a fourth of the variation in ADT projection errors and each of the coefficients are statistically significant.

Figure 15 depicts graphically how the expected error, estimated in the above multiple regression model, changes as some of the factors affecting the error change. The estimated error declines as the year the projection was made approaches the present, and when the projection year passes the year the project is completed, the expected error drops by more than 13 percentage points. In addition, the stage of commercial and industrial development affects the error by increasing the error for any given projection year as the area becomes more developed.

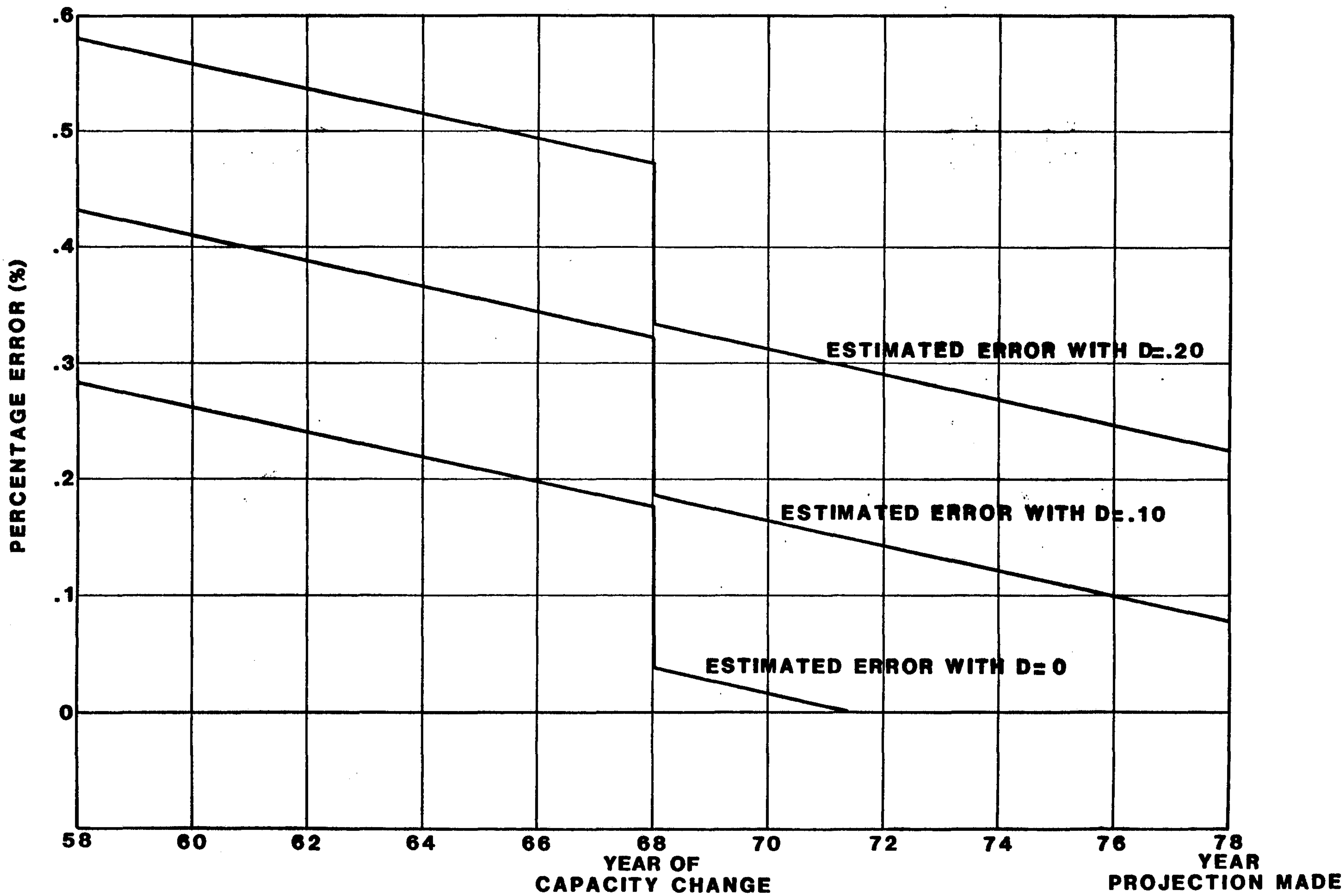
In general the SDHPT projections were fairly good with an average error of .2870 in this sample. However, there are some factors which seem to be affecting the size of the errors which, if taken into account, could potentially increase the accuracy of those projections. Later in the report, a simple alternative model for projecting ADT is presented which takes into account some of the factors shown to be significant from this analysis of ADT projection errors and the analysis of the 18 case study areas presented previously in this report.

Analysis of Land Use and Population Projections

ADT projection methods have involved projecting the number and location of vehicle trips by origin and destination. A key component of this process is developing trip generation factors. Using these trip generation factors, and the trips assigned to a particular zone, the future trips produced by an area, and therefore the traffic volume, can be estimated. Among other things, two of the factors assumed to affect trip generation factors are land use and population.

FIGURE 15

COMPARISONS OF ESTIMATED ERRORS IN ADT PROJECTIONS



In order to project ADT, projections of both land use and population are required. It is therefore of interest to look at the accuracy of land use and population projections and examine if the errors in those projections are related to each other and to the previously presented ADT projection errors.

In 1964, population and land use projections for 1985 were prepared in Dallas County. Those projections were made by survey zone and included various categories of land use. In order to compare these projections with the ADT projections, the abutting survey zones were aggregated for each highway segment. Each area contains as closely as possible the survey zones within about a half of a mile of the highway segment, and an average of about two square miles in total area. (The survey zones for each area are listed in Appendix B, Table B2.)

Errors in population and land use projections are calculated in the same manner as those used in analyzing the ADT projections in order to make them as comparable as possible. Since total developed land for each survey zone was not projected, the land use projections errors represent commercial and industrial development rather than total development.

Table 16 lists the errors in population and land use projections by highway segment number. Some areas which are in the analysis of ADT projections are not included because reliable historical data could not be obtained for some survey zones, and the errors for those areas were not estimated.

Table 16 also contains the overall errors in Dallas County population and land use projections. The population projections show an

Table 16 Percentage Errors in Population and Land Use Projections

Serial Number	Population Error	Land Use Error
5999	.2032	.1668
6088	.7135	.4518
6306	.2966	2.2685
6313	.7391	1.3982
6366	.5173	2.9225
6370	.0377	.5988
6372	.0710	.3108
6387	.1552	.2591
6393	.9681	1.1363
6461	.4323	.3165
6509	.0667	.6281
6566	.2696	.1607
6568	.4553	.0282
6574	.0384	.1616
6578	.2469	.1618
6586	.2217	.2675
6596	.4131	.2935
6618	.3906	.7783
6621	.2011	.8354
6686	.1230	.1796
6744	.2096	1.7608
6749	.4822	.5913
6755	.1532	1.0234
6758	.1161	.3547
6790	.4460	.4179
6830	.5388	.1544
6841	.0844	.1621
6850	.1285	1.0926
6856	.1458	.0630
6864	.5960	.1692
6868	4.6198	.6929
6975	.0799	.4250
6978	.2770	.6681
7002	.4542	.9339
7015	.6150	1.4077
7042	.4111	.7497
7043	.4885	2.3357
7045	.9518	5.4342
7047	.8076	.8864
Dallas County	.2642	.0559

average error of .2642, and the land use projections show an error of only .0559. Projections for individual areas around the sample highway segments are, on average, not as accurate as the overall projections.

Table 17 gives a summary of the average error for each set of projections broken down into various categories. The average error for population projections in this sample is .4658 and .8371 for land use projections. This result would suggest a distributional effect on the accuracy of land use projections and, to a lesser extent on population projections. Overall, fairly accurate forecasts have been made for a large aggregated area of Dallas County. Much less success is observed for much smaller subunits, and errors would have been much larger if errors for individual survey zone projections had been calculated. Such a finding would cast some doubt on their reliability and use in origin and destination studies, even though the accuracy would improve as these zones are aggregated into larger areas.

Table 17 also depicts some of the same effects on population and land use projections previously observed in ADT projections. The average error for both sets of projections declines somewhat if the projection was made after completion of the highway project, even though, as expected, that influence does not seem to be as strong as previously described for ADT projections.

Stage of overall development in the area also seems to be exerting an influence. The average error for both sets of projections is much lower for developed areas compared to developing areas. However, contrary to the ADT results, the stage of commercial and industrial

Table 17 Average Percentage Errors in Population and Land Use Projections by Stage of Development

Category	Projection Made Before Project Completed	Projection Made After Project Completed	Total
Population Projections			
Stage of Development			
Developed	0.2867	0.3687	0.3113
Developing	0.5466	0.4326	0.5191
Stage of Commercial and Industrial Development			
Developed	0.4464	0.4718	0.4549
Developing	0.4936	0.3884	0.4691
Total	0.4838	0.4134	0.4658
Land Use Projections			
Stage of Development			
Developed	0.4173	0.2640	0.3714
Developing	1.0126	0.9510	0.9977
Stage of Commercial and Industrial Development			
Developed	1.0248	0.3097	0.7864
Developing	0.8282	0.9314	0.8523
Total	0.8689	0.7449	0.8371

development in this sample does not seem to be exerting much influence on the average errors, although there is a slightly higher average error in developing commercial and industrial areas compared to the developed areas.

Relationship of Errors in ADT, Population and Land Use Projections

Comparison of errors in the various projections of ADT, population, and land use presents some difficulties. Population and land use projections can be compared directly since both were made about the same time and covered the same projection period. However, that is not the case for the ADT projections in this sample. These projections cover a wide variety of time periods, especially with respect to the time period when the projection was made. For that reason, only those ADT projections made between 1962 and 1965 are used in comparisons with population and land use projection errors.

Table 18 presents the correlation coefficients between the projection errors in various categories. Overall the projection errors show very little relationship, with the highest correlation coefficient of only .1411 between errors in land use and population projections. However, some correlation coefficients for specific categories are much higher and three are statistically significant.

There is a strong positive correlation in this sample between the errors in land use and population projections in developed areas, even though that relationship almost disappears when the developing areas are

Table 18 Correlation Coefficients of Errors in ADT, Population, and Land Use Projections

Category	Projection Made Before Project Completed	Projection Made After Project Completed	Total
Relation of Errors in Land Use Projections to Population Projections			
Developed Areas	.9147* (25.61)[a]	.9557 (10.54)	.8289* (17.57)
Developing Areas	.1049 (0.22)	-.2909 (0.46)	-.0430 (0.01)
Total	.1539 (0.66)	-.0430 (0.01)	.1411 (0.75)
Relation of Errors in ADT Projections to Population Projections			
Developed Areas	—	—	.6249 (0.64)
Developing Areas	-.1298 (0.15)	-.1449 (0.04)	-.1411 (0.26)
Total	-.1351 (0.19)	.0858 (0.03)	-.0800 (0.10)
Relation of Errors in ADT Projections to Land Use Projections			
Developed Areas	—	—	-.2139 (0.05)
Developing Areas	.0194 (0.003)	-.9267* (12.16)	-.0800 (0.08)
Total	.0298 (0.01)	-.4927 (1.28)	.0006 (0.00)

*Significant at 10% level

[a]F Statistic is listed below each coefficient in parenthesis

included. This could be the result of the previously described distributional effects on projection errors. Presumably the distribution of future economic activity, as well as population, can more accurately be anticipated in areas which are already developed compared to areas where the structure and distribution of economic ativity can only be predicted.

For example, a decision to locate a shopping center on a slightly different highway segment than had originally been anticipated could result in very large projection errors for each area, even though the overall effect on economic activity has been the same.

The only other significant correlation coefficient is for developing areas projection errors between ADT and land use projections made after completion of the highway project. The high, negative correlation between the errors is principally due to the small sample size and the large land use errors calculated in some of the survey zones.

Alternative Declining Growth Rate Formulas

The declining growth rate model used in the HEEM, as previously mentioned, assumes a given terminal growth rate at the end of the projection period, and the model goes through several iterations before the constants in the model are accurately estimated.

In addition, the model cannot be used to incorporate multiple projections. The ADT projections presented in this study include 20 multiple projections out of 62 total projections and 7 out of 8 since 1970. Disregarding the information provided by additional projections could significantly affect the final calculated economic measure in the HEEM for a proposed project alternative.

The HEEM declining growth rate model calculates the expected ADT and growth rate for any future year (t) up to the projected year, using the following formulas:

$$ADT_t = ADT_1 + \frac{g_1 ADT_1}{A} (1 - e^{-A(t-1)})$$

and

$$g_t = \frac{g_1 \; ADT_1 \; e^{-A(t-1)}}{ADT_t}$$

where g_t = growth rate in year t, and

A = constant.

Different values of g are tried, and each time A is iterated and the resulting calculated terminal growth rate, g_{n+1}, is checked against the assumed terminal growth rate. That process continues until the calculated terminal growth rate is less than the assumed terminal growth rate.

The program can go through a maximum of 1,000 different iterations of A before the loop is terminated and an error message is printed out.

However it can be shown that the numerous, time-consuming iterations are not necessary, and A can be iterated directly using the following formula:

$$A = \left(\frac{g_{n+1} \cdot ADT_{n+1}}{ADT_{n+1} - ADT_1}\right)(e^{An} - 1)$$

where n = number of years in projection period

The above formulation for A can be iterated very quickly using the same iteration technique used in the HEEM, known as Newton's Method, and offers the additional advantage that A must be iterated only once. Table B4 in Appendix B contains the program changes necessary to implement this alternative iterated formula in the HEEM.

Table 19 provides a comparison of the two iteration techniques, where ADT is assumed to increase from 10,000 to 20,000 in 20 years. With a terminal growth rate of 1%, both iteration methods give approximately the same results, the difference coming from the error introduced in the HEEM iteration by taking discreet values for g_1. The HEEM increases the value of g_1 by .0025 each loop, causing the error during the projection period.

The two methods deviate sharply as the terminal growth rate is increased for the same projected ADT. In this example, for any terminal growth rate greater than 2.38%, the HEEM will go through its iteration process only once, giving the results in Table 19. Any assumed terminal growth greater than 2.38% will not change the iteration and the resulting traffic distribution within the projection period will always be the

Table 19. Comparison of HEEM Declining Growth Iteration and Proposed Iteration[a]

Year(t)	HEEM Declining Growth Rate Iteration				Proposed Declining Growth Rate Iteration							
	Terminal Growth Rate				Terminal Growth Rate							
	1.00%		≥2.38%		1.00%		3.00%		3.50%		4.00%	
	ADT_t	g_t	ADT_t	g_t	ADT_t	g_t	ADT_t	g_t	ADT_t	g_t	ADT_t	g_t
1	10,000	.1025	10,000	.0525	10,000	.1009	10,000	.0417	10,000	.0342	10,000	.0286
6	14,194	.0477	12,594	.0407	14,150	.0476	12,169	.0375	11,874	.0345	11,633	.0318
11	16,964	.0263	15,124	.0330	16,920	.0266	14,545	.0344	14,115	.0347	13,743	.0376
16	18,792	.0157	17,593	.0277	18,767	.0160	17,149	.0319	16,795	.0349	16,472	.0376
21	19,999	.0097	20,002	.0238	20,000	.0100	20,000	.0300	20,000	.0350	20,000	.0400

[a]Assumes ADT goes from 10,000 to 20,000 in 20 years.

same, an approximate linear distribution.

The problem comes from the initial value assigned to the current growth rate, g_1. The initial value equals the average annual change in ADT plus the initial loop increment of .0025. After A is iterated, the terminal growth rate is calculated and checked against the assumed terminal growth rate. If the calculated value is less than or equal to the assumed value, then the looping stops and the ADT for each year during the projection period are calculated. In this example, any assumed terminal growth rate greater than 2.38% will cause the program to loop only once and produce identical results.

The proposed iteration technique offers the advantage that the information provided by an assumed terminal growth rate is not disregarded even if it is outside the range of the HEEM iteration. Table 19 provides some examples of the results which would be produced. With a terminal growth rate of 3.5%, the ADT distribution closely approximates a constant growth rate pattern, and with a rate of 4%, the distribution exhibits an increasing growth rate pattern. The proposed program will print out an error message if an increasing growth rate distribution does occur, indicating the assumed terminal growth rate is too high. This proposed program also offers the advantage of a lower error in the estimated values for ADT, since no error is introduced into the calculation for the value of the initial growth rate.

The above alternative iteration can result in a savings in computer time running the HEEM program, increased accuracy, and a greater range for the assumed terminal growth rate, but it still cannot incorporate multiple projections. Two alternative declining growth rate formulations which incorporate a given terminal growth rate are given as:

(1) Gamma Function

$$\ln ADT_t - g_{n+1}t = a + b\left(\ln t - \frac{t}{n+1}\right)$$

$$g_t = b\left(\frac{n+1-t}{t(n+1)}\right) + g_{n+1}$$

(2) Beta Function

$$ADT_t - g_{n+1}ADT_{n+1}t = a + b\left[2(n+1)t - t^2\right]$$

$$g_t = \frac{2b(n+1-t) + g_{n+1}ADT_{n+1}}{ADT_t}$$

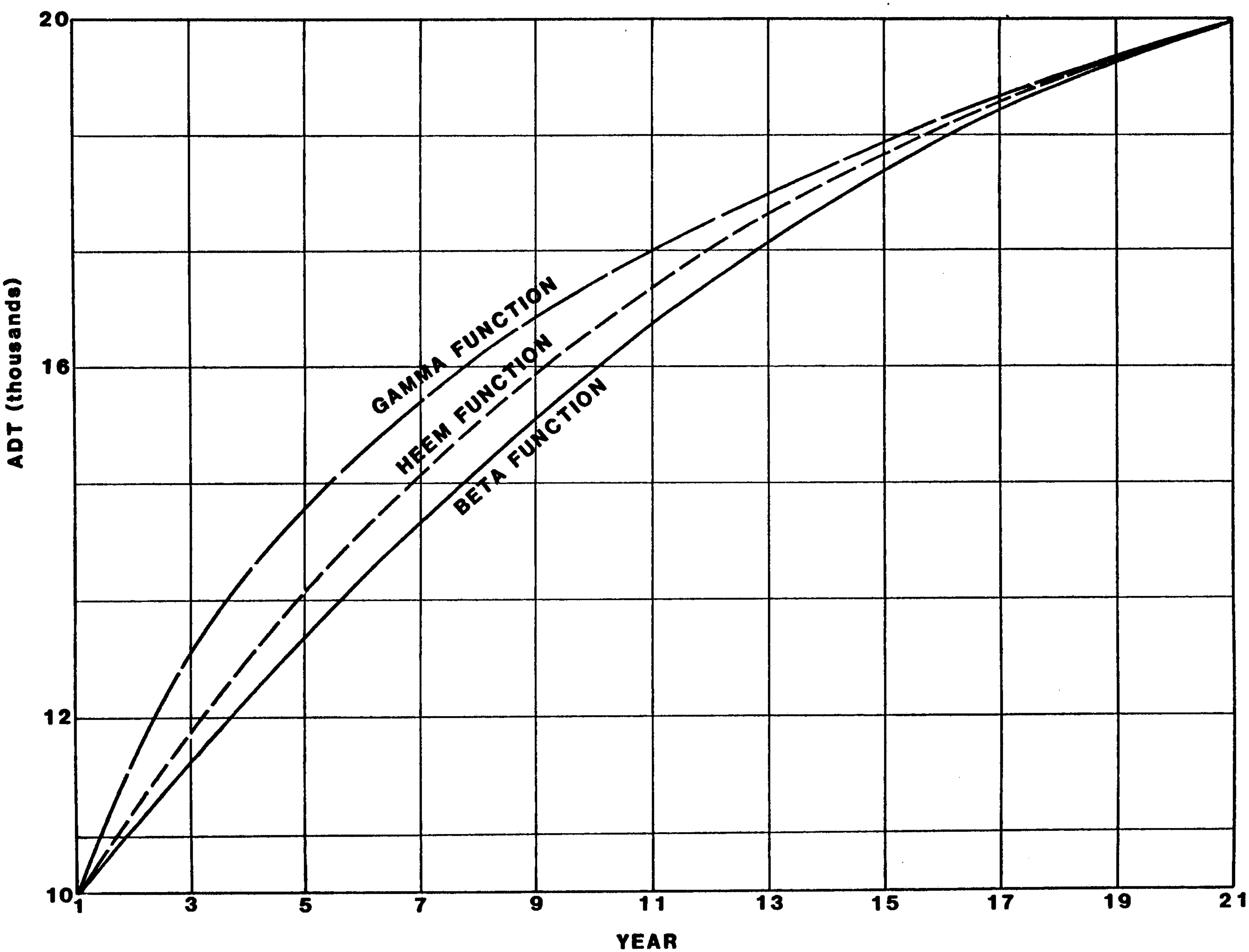
The coefficients a and b in either formula can very easily incorporate any number of projections, using simple linear regression or some other estimation technique.

Of course, each alternative will give, in general, a slightly different ADT trendline. As an example, suppose ADT is projected to double from 10,000 to 20,000 in 20 years, with a .01 terminal growth rate. Figure 16 depicts the ADT trendlines for both functions given above, along with the HEEM declining growth rate model. Both alternative functional forms give a slightly different ADT trendline from the HEEM declining growth rate function. The appropriate function to use, including the constant growth rate function, could be determined by the functional form which most closely fits the historical ADT for that particular corridor being examined.

However making such a determination does not eliminate the problem these declining growth rate functions have in being very sensitive to the arbitrarily assumed terminal growth rate. For example, in Figure 16, if .03 were assumed as the terminal growth rate, instead of .01, all functions

FIGURE 16

COMPARISON OF DECLINING GROWTH RATES



would become almost straight lines, and a terminal growth rate of .035 would make them almost identical to the constant growth rate function.

There is no distinct advantage to projecting a terminal growth rate in addition to the ADT. This conclusion is especially true for a single projected terminal growth rate representing a large geographical area. This study shows that a great variety of growth patterns can exist, and a single growth pattern for a large area is clearly inappropriate for all smaller units within that area.

In addition, this study suggests some factors which seem to have a significant influence on growth rates and ADT projections. The sample is too small in this study to make any definitive conclusions, but some patterns do seem to have emerged. The stage of overall development, along with commercial and industrial development seem to affect the growth rate pattern, but it does not seem appropriate to arbitrarily assign a particular declining growth rate to developed areas and a constant growth rate to developing areas.

The five simple functional forms presented in Table 2, and used throughout this study, give a far greater variety of declining growth rates, in addition to a constant growth rate, and could easily be expanded to include a greater variety of ADT growth patterns. Table 20 presents some of these alternative functional forms which could be used. In addition to the added variety, the arbitrary selection process could be eliminated by allowing the HEEM itself to pick the appropriate growth pattern by selecting the functional form most closely fitting the available historical ADT data for the highway corridor being examined.

This study indicates a significant ADT growth rate impact resulting from capacity changes along a particular highway corridor. The effect on

Table 20 Additional Functional Forms for ADT Models

Functional Form	Functional Form
1. $ADT_t = a + b t^2$	10. $\left(\frac{ADT_t}{10,000}\right)^2 = a + b t^2$
2. $ADT_t = a - \frac{b}{t}$	11. $\left(\frac{ADT_t}{10,000}\right)^2 = a - \frac{b}{t}$
3. $ADT_t = a - b e^{\frac{-t}{10}}$	12. $\left(\frac{ADT_t}{10,000}\right)^2 = a - b e^{\frac{-t}{10}}$
4. $ADT_t = a + b e^{\frac{t}{100}}$	13. $\left(\frac{ADT_t}{10,000}\right)^2 = a + \frac{b}{t}$
5. $\ln ADT_t = a + b t^2$	14. $\frac{1}{ADT_t} = a + \frac{b}{t}$
6. $\ln ADT_t = a - \frac{b}{t}$	15. $\frac{1}{ADT_t} = a + b e^{\frac{-t}{10}}$
7. $\ln ADT_t = a - b e^{\frac{-t}{10}}$	
8. $\ln ADT_t = a + b e^{\frac{t}{100}}$	
9. $\left(\frac{ADT_t}{10,000}\right)^2 = a + b \ln t$	

the growth rate seems to be temporary, and after a few years the growth rate returns to its previous pattern. However, a capacity change could obviously affect the projected ADT, even if the underlying growth pattern were unaffected. This would suggest an improvement in the accuracy of ADT projections could potentially be achieved if those effects could accurately be accounted for in the projection process. The following section presents a simple ADT projection model and tests it against the same Dallas County data used in calculating SDHPT projection errors.

A Simple Model for Projecting ADT

Current methods of projecting ADT involve a relatively large amount of data, and are somewhat time consuming since a separate set of projections must be prepared for each project being studied. In addition, many projections are not very accurate. It would be of some benefit, therefore, if a simple model for projecting ADT could be developed which could be used with a minimum of time and data and which would improve the accuracy of these projections.

As a first approximation, the five functional forms for ADT, presented in Table 2, were used to project ADT for each highway segment with adequate historical ADT before the SDHPT projections were made. The lack of historical ADT data eliminated all new location construction projects and some improvement projections, but left 19 highway segments in this sample which could be used to project ADT.

In order to compare the accuracy of these projections to the SDHPT projections, the functional form which most closely fit the historical ADT data was used to make projections to the same years as the comparable SDHPT projections. In addition, the projections used only the ADT data to the year before the SDHPT projections were made. The ADT data since that time were not used in any form to make the projections in order to compare the accuracy of these projections to the SDHPT projections. Projection errors were calculated in exactly the same manner as those previously presented for the SDHPT projections.

This simple regression model does not take into account the effect that a capacity change may have on ADT. Three different functional forms were used to measure the size of that effect.

The equations are given as:

(1) $\ln ADT_t = a_1 + a_2 t + a_3 C$,

(2) $\ln ADT_t = a_1 + a_2 \ln t + a_3 C$, and

(3) $\ln ADT_t = a_1 + a_2 e^{\frac{-t}{10}} + a_3 C$;

where $C = 1$ if capacity has increased and

$= 0$ otherwise.

These three were chosen because each one can be estimated using multiple regression and each one estimates the effect that a capacity change has as a constant percentage of ADT. The estimated percentage change (PC) in ADT is a function of the estimated coefficient a_3, and is given by:

$$PC = e^{a_3}$$

The particular functional form which most closely fit the historical ADT was used for each highway segment with adequate historical ADT. Table 21 provides an average of the estimated effects that capacity changes have, reflected by the sample ADT data.

Table 21 Capacity Change Effects on ADT

	Average Percentage Change
Developed Areas	.0613
Developing Areas	.1695
Total:	.1362

A much larger sample would be needed to determine, with greater precision, the effects of capacity changes on ADT. For example, the number of lanes added to capacity should affect the percentages presented in Table 21, but this sample is too small to measure those effects.

Multiple regression projections were then prepared for each highway segment used in the simple regression projections. When the capacity change occurred before the SDHPT projection, a projection was made using one of the three multiple regression equations listed above. When the SDHPT projection was made before the capacity change, the simple regression projections were adjusted by the average percentages presented in Table 21. In each case, percentage errors in the projections were again calculated in the same manner as the previously presented SDHPT projection errors.

The results of each projection method are presented in Table 22. The multiple regression method lowered the average percentage error from .2222 using SDHPT projections, to .1857 using this sample. Of course this multiple regression model cannot be relied upon to lower the projection error in every case, but it does offer an approach for further study and testing to improve the accuracy of ADT projections at a lower time and data gathering cost.

Table 22 Analysis of ADT Projections

Serial Number	Percentage Errors in ADT Projections		
	SDHPT	Simple Regression	Multiple Regression
6381	.2940	.2712	.2404
6387	.3648	.1783	.2085
6393	.2468	.0905	.0627
6461	.3980	.5744	.0379
6461	.0826	.3655	.0500
6509	.3661	.1226	.0829
6578	.2278	.2198	.0873
6586	.0836	.3513	.2584
6586	.0706	.4075	.3134
6618	.2550	.5619	.4292
6621	.1758	.3957	.2902
6631	.2962	.4028	.2847
6686	.0992	.0663	.0868
6749	.2858	.7449	.2090
6790	.1350	.1948	.1399
6830	.3115	.4297	.3549
6841	.1236	.2980	.2185
6850	.2221	.0800	.0896
6856	.1836	.1018	.0844
Average	.2222	.3083	.1857

A larger sample would be required to construct a reliable multiple regression model to project ADT. The present model could be expanded to account for the effects of different types of improvements, along with the size of the capacity change. In addition, the type, as well as the level of economic activity should be incorporated. Projections involving new location construction could be made potentially with a corridor approach to ADT projections, possibly as a supplement to current ADT projection methods.

If a reliable multiple regression model is developed, it is possible it could be adapted for use in the HEEM. The model itself could make its own corridor ADT projections and in the process determine the appropriate growth pattern for ADT up to the projected year. Instead of having an externally assumed projected ADT and trying to determine the appropriate growth pattern to conform to that projection, this alternative method would estimate the two together, improving both the consistency and potentially the accuracy of the model.

This, of course would not mean that current ADT projections and projection methods are unncessary. Many times historical information provides poor or inaccurate guidance for future events. This could certainly be the case for ADT projections. The procedure described above could be incorporated into the HEEM as a supplemental analysis and the results compared as part of a sensitivity analysis for various values of the projected ADT.

CONCLUSION AND RECOMMENDATIONS

Conclusions

This study has revealed that there are a number of factors which seem to be influencing ADT growth patterns. The sample size is too small to measure the magnitude of those effects, but some conclusions can be made from this sample.

The aggregative analysis of the 18 case study areas has revealed that the stage of area development and the size of capacity change may have significant impacts on ADT growth rates, even though that influence may diminish over time. There also may be a significant impact on parallel and intersecting routes resulting from a capacity change on the primary route. A logical conclusion would be that it is not appropriate to use the same growth rates for all routes within a corridor without some additional study and justification.

The analysis of ADT growth rates on highway segments within Dallas County has provided additional information on the factors affecting ADT growth patterns and the accuracy of ADT, land use, and population projections. The analysis revealed that about one fourth of the variation in the size of the ADT projection errors could be explained by the year the projection was made, the percentage commercial/industrial land use, and a binary variable to measure the effects of a capacity change after the projection was made.

It might be further concluded that implementing improved formulations of the HEEM declining growth rate model, presented in this study, could significantly reduce the time costs of running the model and could incorporate more that one ADT projection for a given highway corridor. Ultimately it seems that determination of the appropriate growth rate formula in the HEEM should be combined with an ADT projection model rather than trying to fit an appropriate growth rate pattern to a given ADT projection. For this reason, a simple multiple regression model to project ADT is presented that would also estimate the appropriate growth rate pattern. The model was tested against the SDHPT projections in this sample, reducing the average error by about 16%.

Recommendations

Based upon the findings presented in this report, the following recommendations are made:

1. A larger sample of highway improvement segments should be obtained to determine the proper ADT growth rate patterns to use and the factors which affect those growth rates.

2. The HEEM model should be adjusted so that it would take account of major improvements in developing areas. A simple method to accomplish this would be to shift the ADT curve upward when construction is completed, but retain the same growth rate pattern.

3. The HEEM should be adjusted to allow for different growth rate patterns for each route within the corridor. Alternative recommendations for growth rates in the HEEM are:

    a. Use the declining growth rate formula presented in this report which requires only one iteration, thereby reducing the running cost of the model,

or

    b. Use one or both alternative growth rate formulas proposed in this study which incorporate an assumed terminal growth rate, requiring no iterations even when multiple projections are made.

c. Incorporate into the HEEM the ability to choose the appropriate growth pattern which is not sensitive to an assumed terminal growth rate. A number of functional forms for varying traffic growth patterns could be programmed into the HEEM, including those suggested in this report, and the functional form most closely fitting the available historical ADT would be used.

or

d. Incorporate into the HEEM the ability to estimate the projected ADT, along with the growth rate pattern, from historical ADT, proposed capacity changes, and stage of development. Additional study will be required to determine the exact procedure and model which could significantly improve the accuracy of ADT projections.

4. Reduce errors in ADT projections by using formulas that account for capacity changes and stages of land use development, especially commercial land use.

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APPENDIX A

Table A1 ADT for Various Functional Forms [a]

Year	Functional Form [b]				
	(1)	(2)	(3)	(4)	(5)
60	10,000	10,000	10,000	10,000	10,000
61	10,353	10,406	10,500	10,575	10,724
62	10,718	10,822	11,000	11,140	11,402
63	11,096	11,247	11,500	11,696	12,042
64	11,487	11,682	12,000	12,243	12,649
65	11,892	12,127	12,500	12,782	13,229
66	12,311	12,581	13,000	13,313	13,784
67	12,746	13,046	13,500	13,836	14,318
68	13,195	13,520	14,000	14,351	14,832
69	13,660	14,004	14,500	14,858	15,330
70	14,142	14,498	15,000	15,358	15,811
71	14,641	15,002	15,500	15,851	16,279
72	15,157	15,516	16,000	16,338	16,733
73	15,692	16,040	16,500	16,817	17,176
74	16,245	16,575	17,000	17,290	17,607
75	16,818	17,120	17,500	17,757	18,028
76	17,411	17,675	18,000	18,217	18,439
77	18,025	18,240	18,500	18,671	18,841
78	18,661	18,816	19,000	19,120	19,235
79	19,319	19,403	19,500	19,563	19,621
80	20,000	20,000	20,000	20,000	20,000

[a] assuming ADT goes from 10,000 to 20,000 in 20 years

[b] Functional forms presented in Table 2

Table A2 Primary Route Historical ADT

Case Study Number	Year																							
	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956
1			13,720		8,780	8,400	4,180	2,050		1,510	610	590												
2			23,900		11,980	9,550				6,140														
3			8,350							5,560													1,580	
4			5,150				3,750			4,840	4,340												4,330	
5				9,260		11,650	10,780		3,880		8,300		10,430		10,100		16,360		11,130		10,910			
6		34,940	33,530	32,170	30,870		28,700		20,950	16,460	12,990		9,520		7,940		6,160	4,500	2,850	2,990	3,130			
7		13,720	11,810	9,900	12,010	11,590	10,980	7,530	4,070			3,520		3,150		4,300	4,880							
8		18,420	20,320	22,220				14,200	13,890	13,220	13,470	12,300	12,100	12,300		12,500								
9		41,070		41,190	41,250	39,540	40,460	42,230	33,980	32,600	31,720	24,700	16,490	15,450	19,540	20,880	20,500	20,460	14,090	14,190				
10		14,860	15,530	16,200	14,850	14,190	13,530				12,900					12,100								
11		42,510		43,800		45,090	41,440					23,650	19,430	15,000	22,050	22,110	24,320	16,210	15,310					
12		30,280	27,170	24,660	25,600	22,980	24,510	23,100	22,690	23,140	20,980	18,560	16,530	16,340		14,770	13,200							
13		47,370	43,520		35,830	34,870	34,480	26,230			16,080		13,490	14,780	11,250		8,090	6,510						
14		13,410	14,650	14,120	14,140	13,440	13,110	12,750	11,510	10,220	9,480	9,190	9,590	10,600	10,440	10,200	9,780	11,900		8,010		7,870		
15		21,720	19,670	20,730	20,870	17,680	17,760	18,300	17,560	21,440	22,890	21,380	19,980	15,690	14,820	14,340	13,560	13,040	12,470	11,890		12,940		13,990
16	19,030	18,320	17,600		19,500		15,500		16,100		16,100	16,000	15,900		13,400	15,300		13,720	12,430	12,900	16,480	15,990	15,320	
17	16,360	14,490	12,600		10,500		10,500		10,900	15,450	10,000		8,100	7,600	7,100	8,000		7,890	7,040	6,530	6,590	6,360	6,340	
18	16,000		14,460		14,000											6,260								

Table A3 Estimated Fuctional Form of Primary Route Historical ADT

Case Study Number	Estimated Functional Form	R^2	Estimated Growth Rate
1	$\ln ADT_t = -111.06238 + 27.81453 \ln t$	.9601	$\frac{27.8145}{t}$
2	$\ln ADT_t = -4.16676 + .18252\ t$	.8979	.18252
3	$ADT_t = -17577.05 + 334.4175\ t$	.9951	$\frac{334.4175}{ADT_t}$
4	$\left(\frac{ADT_t}{10,000}\right)^2 = .059896 + .002071\ t$	.1048	$\frac{103536}{ADT_t^2}$
5	$\ln ADT_t = 12.90270 - .862498 \ln t$	.1576	$-\frac{.862498}{t}$
6	$\ln ADT_t = -32.01425 + 9.7998 \ln t$	.9748	$\frac{9.7998}{t}$
7	$ADT_t = -40165.52 + 676.13334\ t$	.7608	$\frac{676.1334}{ADT_t}$
8	$\ln ADT_t = 6.56644 + .04278\ t$	.8214	.04278
9	$\left(\frac{ADT_t}{10,000}\right)^2 = -63.51423 + 1.05966\ t$	.8546	$\frac{52982846}{ADT_t^2}$
10	$\ln ADT_t = 8.16343 + .01909\ t$	.8289	.01909
11	$\left(\frac{ADT_t}{10,000}\right)^2 = -71.11331 + 1.17549\ t$	.8488	$\frac{58774432}{ADT_t^2}$
12	$ADT_t = -278158.72 + 70394.72 \ln t$	.9386	$\frac{70394.72}{t(ADT_t)}$
13	$\ln ADT_t = 26.37402 + 8.54375 \ln t$	.9798	$\frac{8.54375}{t}$
14.	$ADT_t = -9920.1815 + 308.0225\ t$	.7317	$\frac{308.0225}{ADT_t}$
15	$\ln ADT_t = 2.14026 + 1.80285 \ln t$	.6671	$\frac{1.80285}{t}$
16	$\left(\frac{ADT_t}{10,000}\right)^2 = -1.77673 + .064396\ t$	.5348	$\frac{3219804}{ADT_t^2}$
17	$\ln ADT_t = 6.38691 + .04058\ t$	.8285	.04058
18	$ADT_t = -184776.28 + 45947.78 \ln t$	.9950	$\frac{45948}{t(ADT_t)}$

Table A4 Primary Route Normalized Historical ADT

Year	Case Study Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	300[b]	3,140[b]	2,800[a]	4,340[a]	11,020[a]	7,050[a]	4,300	12,400[a]	14,190	13,060[a]	12,240[b]	14,770	9,670[a]	8,010	13,470[a]	15,300	8,000	4,790[b]
2	420[b]	3,710[b]	3,100[a]	4,340[a]	11,130	7,940	3,730[a]	12,300	14,090	13,220[a]	15,310	15,560[a]	11,250	9,960[a]	12,940	13,400	7,100	5,530[b]
3	590	4,390[b]	3,420[a]	4,340[a]	13,750	8,730[a]	3,150	12,100	20,460	13,370[a]	16,210	16,340	14,780	11,900	12,420[a]	14,650[a]	7,600	6,260
4	610	5,190[b]	3,720[a]	4,340[a]	16,360	9,520	3,340[a]	12,300	20,500	13,530	24,320	16,530	13,490	9,780	11,890	15,900	8,100	6,960[a]
5*	1,510 [70]	6,140 [70]	4,030[a] [65]	4,340[a] [64]	13,230[a] [64]	11,260[a] [68]	3,520 [68]	13,470 [69]	20,880 [64]	14,190 [74]	22,110 [64]	18,560 [68]	14,790[a] [68]	10,200 [64]	12,470 [61]	16,000 [68]	9,050[a] [68]	7,670[a] [66]
6	1,780[a]	6,990[a]	4,340[a]	4,340[a]	10,100	12,990	3,700[a]	13,220	19,540	14,850	22,050	20,980	16,080	10,440	13,040	16,100	10,000	8,370[a]
7	2,050	7,850[a]	4,640[a]	4,340[a]	10,270[a]	16,460	3,890[a]	13,890	15,450	16,200	15,000	23,140	19,480[a]	10,600	13,560	16,100[a]	15,450	9,070[a]
8	4,180	8,700[a]	4,950[a]	4,340[a]	10,430	20,950	4,070	14,200	16,490	15,530	19,430	22,690	22,880[a]	9,590	14,340	16,100	10,900	9,780[a]
9	8,400	9,550	5,250[a]	4,340[a]	9,370[a]	24,830[a]	7,530	16,210[a]	24,700	14,860	23,650	23,100	26,280	9,190	14,820	15,800[a]	10,700[a]	10,480[a]
10	8,780	11,980	5,560	4,340	8,300	28,700	10,980	18,210[a]	31,120	15,140[b]	27,210[a]	24,510	34,480	9,480	15,690	15,500	10,500	11,190[a]
11	11,250	17,940[a]	5,960[a]	4,840	8,590[a]	29,790[a]	11,590	20,220[a]	32,600	15,430[b]	30,770[a]	22,980	34,870	10,220	19,180	17,500[a]	10,500[a]	11,890
12	13,720	23,900	6,360[a]	4,430[a]	8,880	30,870	12,010	22,220	33,980	15,730[b]	34,320[a]	25,600	35,830	11,510	21,380	19,500	10,500	12,590[a]
13	18,610[b]	28,260[b]	6,760[a]	4,110[a]	9,830[a]	32,170	9,900	20,370	42,280	16,030[b]	37,880[a]	24,660	39,680[a]	12,750	22,890	18,550[a]	11,550[a]	13,300[a]
14	25,160[b]	33,420[b]	7,150[a]	3,750	10,780	33,530	11,810	18,420	40,460	16,330[b]	41,440	27,170	43,520	13,110	21,440	17,600	12,600	14,000
15	33,910	39,520[b]	7,550[a]	4,100[a]	11,650	34,940	13,720	19,210[b]	39,540	16,650[b]	45,090	30,280	47,370	13,440	17,560	18,320	14,490	14,230[a]

* last year before construction

a estimated using linear interpolation

b estimated using growth rate calculated in Table A3

Table A5 Primary Route Estimated Growth Rates

Years Measured	Area	Functional Form	R^2	Growth Rate
Overall	Developing	$\ln ADT = 8.98149 + .08393\ t$	.9849	.0839
years 1 - 15	Developed	$\ln ADT = 9.00182 + .03321\ t$	.9541	.0332
	Total	$\ln ADT = 8.97584 + .07112\ t$	.9825	.0711
Segmented				
years 1 - 5	Developing	$\left(\frac{ADT}{10,000}\right)^2 = 0.62447 + .16818\ t$	.9866	$\frac{8,408,800}{ADT^2}$
	Developed	$\ln ADT = 8.98560 + .04441\ t$	.8007	.0444
	Total	$\left(\frac{ADT}{10,000}\right)^2 = 0.62453 + .13438\ t$	.9736	$\frac{6,719,070}{ADT^2}$
6 - 10	Developing	$\ln ADT = 8.79457 + .10102\ t$	.9438	.1010
	Developed	$\ln ADT = 8.95939 + .03469\ t$	.9655	.0347
	Total	$\ln ADT = 8.2284 + .08413\ t$	.9479	.0841
11 - 15	Developing	$ADT = -375.0 + 1907.0\ t$	.9976	$\frac{1907}{ADT}$
	Developed	$\ln ADT = 9.02167 + .03266\ t$	.9507	.0327
	Total	$\ln ADT = 9.0275 + .06892\ t$	.9984	.0689

Table A6 Primary Route Estimated Growth Rates for Capacity Changes

Years Measured	Area	Functional Form	R^2	Growth Rate
Overall	No change	$ADT = 13{,}894.4762 + 987.10714\ t$	.9295	$\frac{987.107}{ADT}$
years 1 - 15	2 ln.change	$\ln ADT = 8.62376 + .070496\ t$	.9624	.0705
	4 ln.change	$\ln ADT = 9.24232 + .075183\ t$	.9686	.0752
Segmented	No change	$\ln ADT = 9.54399 + .05173\ t$	.9249	.0517
years 1 - 5	2 ln.change	$\left(\frac{ADT}{10{,}000}\right)^2 = 0.35288 + .05363\ t$	.8860	$\frac{2{,}681{,}640}{ADT^2}$
	4 ln.change	$\left(\frac{ADT}{10{,}000}\right)^2 = 0.97626 + .28168\ t$	.9551	$\frac{14{,}084{,}110}{ADT^2}$
6 - 10	No change	$ADT = 11{,}465.629 + 5{,}533.8074\ \ln t$	.7774	$\frac{5{,}533.81}{t(ADT)}$
	2 ln.change	$\ln ADT = 8.56740 + .06854\ t$	.9514	.0685
	4 ln.change	$\ln ADT = 8.95378 + .10498\ t$	.8970	.1050
11 - 15	No change	$\ln ADT = 9.37213 + .061125\ t$	.8601	.0611
	2 ln.change	$\ln ADT = 8.39185 + .091109\ t$	.9801	.0911
	4 ln.change	$ADT = -24{,}062.853 + 20{,}396.807\ \ln t$	.9541	$\frac{20{,}396.81}{t(ADT)}$

Table A7 Parallel Routes Historical ADT

Case Study Number	Estimated Growth Rate	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
1	.0235			5,440		5,190							
2	.0486			3,950							2,810		
3	.0791			4,910							1,500		
4	.0739			2,150									
5	.0378			12,220	13,630	12,190	11,100		9,700		9,120		6,960
6	.0384		7,290	7,110	6,940	6,770		6,380				5,400	
7	.0455		20,130		18,090	17,080	16,960		16,200		15,100		13,160
8	.0997		41,200	32,140	23,080		21,380	22,660	20,250	18,450	18,100	15,490	13,260
9	.1252		39,900	35,500	31,000	27,230	23,860		20,750				11,050
10	.0677		16,170	15,930	15,690	17,680	15,600	15,880	15,290	13,950	13,200	11,750	
11	.1871		34,810	29,540		19,830	16,760	13,730					
12	.1027		46,690	36,460	26,290	26,500	25,220	25,840	26,300	26,950	27,000	21,270	18,290
13	.1026		20,100	18,920	17,820	16,780	17,100	11,820		9,970		9,910	10,000
14	-.0191				6,510			4,370		7,450	5,700		
15	.0926		79,910	72,960	69,560	68,440	63,790	58,390	57,370	53,750	46,750	46,620	43,840
16	.0329	18,100	18,480	18,850		18,500		17,100		16,400		17,800	16,750
17	.0087	33,430	34,020	34,600		33,180		32,610		33,350	33,500	33,650	
18	.0133									30,220	30,400		

Table A7 (Continued) Parallel Routes Historical ADT

Case Study Number	Estimated Growth Rate	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956
1	.0235												
2	.0486												
3	.0791											900	
4	.0739											490	
5	.0378		7,210		7,250		8,190			6,690			
6	.0384		5,040		4,690	4,200	4,000			3,400			
7	.0455		11,220	11,800	12,390	8,570							
8	.0997	10,140	9,790		9,440								
9	.1252												
10	.0677				5,590								
11	.1871												
12	.1027	13,280	13,180		7,820	7,470							
13	.1026	10,010		8,140		4,470	2,630						
14	-.0191		5,060		6,770			7,650			8,240		
15	.0926	42,320	36,200	31,120	28,890	23,910	21,510	18,780	15,640		9,970		
16	.0329	15,700		14,600	14,600		13,530	11,670	10,830	10,580	8,260	8,920	
17	.0087	28,650	31,350	34,050	31,060		29,080	28,340	28,860				
18	.0133				27,740								

Table A8 Parallel Routes Normalized Historical ADT

Year	Case Study Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	4,200[b]	2,320[b]	1,080[a]	740[a]	7,190[a]	4,690	12,390	9,620[a]	4,300[b]	13,200	1,480[b]	7,820	6,310[a]	7,850[a]	9,130[b]	14,600	31,060	27,050[b]
2	4,300[b]	2,440[b]	1,130[a]	820[a]	7,690[a]	4,870[a]	11,800	9,790	4,840[b]	13,950	1,750[b]	10,500[a]	8,140	7,650	9,970	14,600	34,050	27,410[b]
3	4,400[b]	2,560[b]	1,180[a]	910[a]	8,190	5,040	11,220	10,140	5,440[b]	15,290	2,080[b]	13,180	9,080[a]	7,360[a]	12,810[a]	15,150[a]	31,350	27,740
4	4,510[b]	2,680[b]	1,220[a]	990[a]	7,720[a]	5,160[a]	12,190[a]	13,260	6,130[b]	15,880	2,470[b]	13,280	10,010	7,060[a]	15,640	15,700	28,650	28,180[a]
5*	4,610[70][b]	2,810[70]	1,270[65][a]	1,070[64][a]	7,250[64]	5,280[68][a]	13,160[68]	15,490[69]	6,890[64][b]	15,600[74]	2,930[64][b]	18,290[68]	10,000[68]	6,770[64]	18,780[6]	16,750[68]	31,150[68][a]	28,630[66][a]
6	4,720[b]	2,970	1,320[a]	1,150[a]	7,230[a]	5,400	14,130[a]	18,100	7,760[b]	17,680	3,480[b]	21,270	9,910	5,920[a]	21,510	17,800	33,650	29,070[a]
7	4.840[b]	3,140[a]	1,360[a]	1,240[a]	7,210	5,650[a]	15,100	18,450	8,730[b]	15,690	4,730[b]	27,000	9,940[a]	5,060	23,910	17,100[a]	33,500	29,510[a]
8	4,950[b]	3,300[a]	1,410[a]	1,320[a]	7,090[a]	5,890[a]	15,650[a]	20,250	9,820[b]	15,930	4,910[b]	26,950	9,970	5,220[a]	28,890	16,400	33,350	29,960[a]
9	5,070[b]	3,460[a]	1,450[a]	1,400[a]	6,960	6,140[a]	16,200	22,660	11,050	16,170	5,820[b]	26,300	10,900[a]	5,380[a]	31,120	16,750[a]	32,980[a]	30,400
10	5,440[b]	3,620[a]	1,500	1,490[a]	8,040[a]	6,380	16,580[a]	21,380	13,480[a]	17,260[b]	6,910[b]	25,840	11,820	5,540[a]	36,200	17,100	32,610	30,220
11	5,320[a]	3,790[a]	1,990[a]	1,570[a]	9,120	6,580[a]	16,960	22,230[a]	15,900[a]	18,430[b]	8,210[b]	25,220	17,100	5,700	42,320	17,800[a]	32,900[a]	30,900[b]
12	5,190	3,950	2,470[a]	1,650[a]	9,410[a]	6,770	17,080	23,080	18,330[a]	19,680[b]	9,740[b]	26,500	16,780	7,450	43,840	18,500	33,180	31,310[b]
13	5,570[b]	4,140[b]	2,960[a]	1,740[a]	9,700	6,940	18,090	32,140	20,750	21,010[b]	11,570[b]	26,290	17,820	5,910[a]	46,620	18,680[a]	33,890[a]	31.730[b]
14	5,700[b]	4,340[b]	3,450[a]	1,820[a]	10,400[a]	7,110	19,110	41,200	22,310[a]	22,440[b]	13,730	36,460	18,920	4,370	46,750	18,850	34,600	32,150[b]
15	5,830[b]	4,550[b]	3,940[a]	1,900[a]	11,100	7,290	20,130	45,310[b]	23,860	23,960[b]	16,760	46,690	20,100	5,080[a]	53,750	18,480	32,020	32,580[b]

* last year before construction

a estimated using linear interpolation

b estimated using growth rate in Table A7

Table A9 Parallel Routes Estimated Growth Rates

Years Measured	Area	Functional Form	R^2	Growth Rate
Overall years 1-15	Developing	$\ln ADT = 8.86018 + .073151\ t$	.9942	.0732
	Developed	$\ln ADT = 9.39756 + .025895\ t$	.9692	.0259
	Total	$\ln ADT = 9.06234 + .05549\ t$	.9928	.0555
Segmented years 1 - 5	Developing	$\ln ADT = 8.84799 + .075526\ t$	.9726	.0755
	Developed	$\ln ADT = 9.41281 + .023552\ t$	.9898	.0236
	Total	$\ln ADT = 9.07115 + .053270\ t$	.9831	.0533
6 - 10	Developing	$\ln ADT = 8.53794 + .44471 \ln t$	.9994	$\frac{4477}{t}$
	Developed	$\ln ADT = 9.48369 + .012870\ t$	.8034	.0129
	Total	$\ln ADT = 9.17676 + .040613\ t$	.9994	.0406
11 - 15	Developing	$\ln ADT = 8.66952 + .087424\ t$	.9827	.0874
	Developed	$\ln ADT = 9.26074 + .037178\ t$	.9986	.0372
	Total	$\ln ADT = 8.85700 + .071487\ t$	.9860	.0715

Table A10 Intersection Routes Historical ADT

Case Study Number	Estimated Growth Rate	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
1	.0599			7,200		5,460	5,450	5,680	5,080				
2	.2716			4,460		2,710	2,400	1,880	1,110		640	630	390
3	.0398			6,010							5,210		
4	.0273			9,000		8,040							
5	.0292			26,530		24,940		26,730		22,850		22,180	
6	.1155					13,340		13,890			6,930		
7	.0487			26,620		27,880	26,850	22,630		21,640		20,290	
8	.1198			12,290		10,100		7,610					
9	.1016				20,890	20,690	21,370	26,220		19,750		11,590	
10	-.0119			23,340	22,370	27,830	31,740	31,990	30,350	27,650	24,880	26,150	
11	.0369				20,670		18,340		20,920		17,520		14,060
12	.0279			25,230	24,330	23,640	23,030	23,360	23,520	22,370	21,350	20,380	18,870
13	.0153			11,850		10,640	9,550		9,910				10,730
14	.0050			2,180	2,280					2,860			
15	.0342		14,980			14,930		16,080			14,550		
16	.0165	20,410		20,810		20,800		22,400		19,800		20,100	
17	.0154	6,030		8,660		4,600		7,540		7,660		5,620	
18	-.0868						11,110					17,130	

Table A10 (Continued) Intersection Routes Historical ADT

Case Study Number	Estimated Growth Rate	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956
1	.0599												
2	.2716												
3	.0398											2,780	
4	.0273											5,090	
5	.0292	22,880		19,890		17,250	17,040			16,590			
6	.1155	5,740		4,640		3,640							
7	.0487	19,360	15,580	14,890		15,250							
8	.1198												
9	.1016	10,080	11,950	10,040		7,520		4,760	4,710				
10	-.0119												
11	.0369	13,060	15,400		13,000		13,580		11,420				
12	.0279	18,050	18,000		18,850								
13	.0153		11,550		7,500								
14	.0050	3,140		1,930	1,930								
15	.0342				9,340								
16	.0165	21,400		19,000	20,600		18,870	18,410	19,190	21,500	22,080	20,330	
17	.0154	5,770		5,700	5,160		5,410	5,370	5,100	5,040			
18	-.0868												

Table A11 Intersecting Routes Normalized Historical ADT

Year	Case Study Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	3,580[b]	240[b]	3,530[a]	5,580[a]	16,740[a]	4,140[a]	15,070[a]	3,080	4,710	26,150	11,420	18,850	7,500	1,890[b]	7,380[b]	20,600	5,160	31,450[b]
2	3,800[b]	310[b]	3,710[a]	5,750[a]	16,890[a]	4,640	14,890	3,450	4,760	24,880	12,500[a]	18,430[a]	9,530[a]	1,900[b]	7,630[b]	19,000	5,700	28,830[b]
3	4,030[b]	390	3,900[a]	5,910[a]	17,040	5,190[a]	15,580	3,860	6,140[a]	27,650	13,580	18,000	11,550	1,910[b]	7,890[b]	20,200[a]	5,740[a]	26,440[b]
4	4,270[b]	630	4,090[a]	6,070[a]	17,250	5,740	19,360	4,320[b]	7,520	30,350	13,290[a]	18,050	11,140[a]	1,920[b]	8,160[b]	21,400	5,770	24,240[b]
5*	70 4,520[b]	70 640	65 4,280[a]	64 6,240[a]	64 18,570[a]	68 6,140[a]	68 19,830[a]	69 4,840[b]	64 8,780[a]	74 31,990	64 13,000	68 18,870	68 10,730	64 1,930	61 8,440[b]	68 20,750[a]	68 5,700[a]	66 22,220[b]
6	4,790[b]	880[a]	4,460[a]	6,400[a]	19,890	6,530[a]	20,290	5,420[b]	10,040	31,740	14,200[a]	20,380	10,530[a]	1,930	8,730[b]	20,100	5,620	20,380[b]
7	5,080	1,110	4,650[a]	6,570[a]	21,390[a]	6,930	20,970[a]	6,070[b]	11,950	27,830	15,400	21,350	10,320[a]	2,540[a]	9,030[b]	19,950[a]	6,640[a]	18,650[b]
8	5,680	1,880	4,840[a]	6,730[a]	22,880	9,250[a]	21,640	6,800[b]	10,080	22,370	13,060	22,370	10,120[a]	3,140	9,340	19,800	7,660	17,130
9	5,450	2,400	5,020[a]	6,890[a]	22,530[a]	11,570[a]	22,140[a]	7,610	10,840[a]	23,340	14,060	23,520	9,910	3,080[a]	10,210[a]	21,100[a]	7,600[a]	15,710[b]
10	5,460	2,710	5,210	7,060[a]	22,180	13,890	22,630	8,860[a]	11,590	23,060[b]	15,790[a]	23,360	9,730[a]	3,030[a]	11,080[a]	22,400	7,540	14,400[b]
11	6,330[a]	3,590[a]	5,320[a]	7,220[a]	22,520[a]	13,620	26,850	10,100	15,670[a]	22,790[b]	17,520	23,030	9,550	2,970[a]	11,950[a]	21,600[a]	6,070[a]	13,200[b]
12	7,200	4,460	5,440[a]	7,380[a]	22,850	13,340	27,880	11,200	19,750	22,520[b]	19,220[a]	23,640	10,640	2,920[a]	12,810[a]	20,800	4,600	12,110[b]
13	7,630[b]	5,670[b]	5,550[a]	7,550[a]	24,790[a]	14,880[b]	27,250[a]	12,290	22,990[a]	22,250[b]	20,920	24,330	11,250[a]	2,860	13,680[a]	20,810[a]	6,630[a]	11,110[b]
14	8,090[b]	7,210[b]	5,670[a]	7,710[a]	26,730	16,600[b]	26,620	13,760[b]	26,220	21,980[b]	19,630[a]	25,230	11,850	2,740[a]	14,550	20,810	8,660	10,180[b]
15	8,570[b]	9,170[b]	5,780[a]	7,880[a]	25,840[a]	18,250[b]	27,920[b]	15,410[b]	21,370	21,720[b]	18,340	25,930[b]	12,030[b]	2,630[a]	15,060[a]	20,610[a]	7,350[a]	9,330[b]

* last year before construction

a estimated using linear interpolation

b estimated using growth rate calculated in Table A10

Table A12 Intersecting Routes Estimated Growth Rates

Years Measured	Area	Functional Form	R^2	Growth Rate
Overall years 1 - 15	Developing	$\ln ADT = 8.65160 + .058025\ t$	.9920	.0580
	Developed	$ADT = 15{,}717.977 + 1{,}650.2346 \ln t$	.8425	$\frac{1650.23}{t(ADT)}$
	Total	$\ln ADT = 9.08370 + .038486\ t$	.9876	.0385
Segmented years 1 - 5	Developing	$\left(\frac{ADT}{10{,}000}\right)^2 = 0.33556 + .04682\ t$	.9817	$\frac{2{,}341{,}155}{ADT^2}$
	Developed	$\left(\frac{ADT}{10{,}000}\right)^2 = 2.18734 + .02789\ t$	.8358	$\frac{1{,}394.415}{ADT^2}$
	Total	$\ln ADT = 9.06136 + .047610\ t$	.9667	.0476
6 - 10	Developing	$\ln ADT = 8.65340 + 05553\ t$	.9878	.0555
	Developed	$ADT = 19{,}997.742 - 532.0103 \ln t$	.0829	$\frac{-532.01}{t(ADT)}$
	Total	$\ln ADT = 9.15871 + .027925\ t$	.9274	.0279
11 - 15	Developing	$ADT = -13{,}762.658 + 10{,}198.103 \ln t$	.9541	$\frac{10{,}198.1}{t(ADT)}$
	Developed	$\ln ADT = 9.65258 + .100286 \ln t$	.9452	$\frac{.10029}{t}$
	Total	$ADT = -5{,}285.1545 + 7{,}779.3569 \ln t$	.9537	$\frac{7{,}779.36}{t(ADT)}$

APPENDIX B

Table B1 Historical ADT

Segmented Number	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
5999	15,040	15,740	15,070	15,550	14,360	16,710	16,070	15,570	15,570	16,710	16,960	16,010
6088	86,720	82,630	81,940	74,150	74,280	76,500	70,310	65,320	62,070	58,430	55,080	53,170
6306	23,240	21,860	19,520	18,540	16,770	18,540	20,300	17,100	14,060	13,440	12,920	12,500
6313	26,060	23,230	21,890	20,000	18,520	19,420	21,320	17,580	14,500	13,920	13,400	12,770
6366	24,950	23,540	20,580	8,000	5,010	0						
6370	31,850	30,160	33,000	0								
6372	41,840	39,740	35,040	0								
6381	69,500	71,000	65,390	61,740	56,140	50,660	43,960	40,970	36,460[a]	35,220[a]	32,390[a]	34,280
6387	91,920	92,530	87,930	81,060	74,180	66,460	61,350	55,100	54,180	48,590	45,740	45,430
6393	99,230	100,690	96,570	87,280	80,080	75,520	71,650	63,400	62,300	58,310	55,120	54,450
6461	49,770	47,720	45,340	46,550	41,050	43,800	42,000	37,660	36,200	33,720	32,890	29,720
6509	66,350	71,740	65,290	57,510	56,120	59,940	55,910	47,410	42,680	40,500	36,500	32,020
6566	37,560	39,070	36,020	37,120	34,620	35,850	32,700	31,810	29,800	30,560	28,850	26,530
6568	41,510	42,930	39,510	40,710	35,730	38,050	36,820	34,250	30,970	32,260	29,770	27,290
6574	26,240	27,320	25,470	23,730	20,080	24,260	23,710	19,750	18,420	20,280	19,250	18,840
6575	29,000	31,250	29,730	27,100	25,490	29,610	29,990	26,030	24,790	27,500	25,180	24,300
6578	25,790	27,910	26,810	24,960	23,150	26,380	26,230	19,970[a]	15,540	19,870	20,700[a]	
6586	29,370	27,430	25,690	24,120	21,730	23,580	22,670	18,420	15,790	14,860	12,800	12,810
6596	18,670	18,090	16,600	15,290	13,910	14,930	16,570	13,890[a]	11,510[a]	10,370	9,150	9,100
6618	14,970	13,410	10,210	9,800	8,930	9,160	8,570	7,580	5,470	5,370	4,780	4,520
6621	15,770	13,460	11,180	10,730	9,640	9,370	9,380	8,310	5,620	5,600	5,610	5,250
6631	10,800	8,470	6,930	6,840	6,580	6,510	6,400	5,320	4,400	4,370	3,900	3,640
6684	33,070	36,090	34,200	30,430	28,620	28,600	27,630	30,480	0			
6686	37,610	39,020	38,070	31,030	32,300	32,590	31,970	33,680	33,680	33,720	35,430	35,730

a ADT Counts which could not be verified using traffic count maps. Those counts are not used in calculating errors in ADT projections

Table B1 (cont.)

Historical ADT

Segmented Number	1966	1965	1964	1963	1962	1960	1958	1957	1956	1955	1954	
9999	15,710	15,750	12,260	15,810	15,330	15,970	16,850	18,350				
6088	42,470	33,010	28,910	27,270	25,550	17,150						
6306	12,760	10,790	10,040	9,250	8,440	8,190						
6313	13,150	11,440	10,550	9,680	9,490							
6366												
6370												
6372												
6381								12,480		12,020		
6387	38,490	34,110	32,630	28,660	26,580	18,990		10,680	12,100	11,490	10,180	
6393	47,160	42,920	41,440	36,980	34,740	22,680	12,650	13,940	14,520	14,820	14,340	
6461	28,560	21,790	17,900	16,990	13,190	9,660	8,740	8,790		6,840		
6509	26,150	22,810	21,610	19,820	18,160	13,590		10,820	11,000	10,400		
6566	22,450	26,360	20,730	0								
6568		25,850	23,070	11,520	10,530		12,580	12,740	12,070			
6574	16,340	15,220	13,390	10,030	9,190	10,120	9,190	11,340	10,710			
6575	21,960	22,360	21,310	20,030	18,390	14,660	15,810	15,150	13,650			
6578		16,380	15,380	14,280	12,280	10,540	11,080	10,810	11,010	10,870		
6586	11,360	11,620	11,440	10,320		8,810		8,550	8,670	8,240	7,330	
6596	7,380	7,800	7,810	7,030	6,770				5,610			
6618	4,460	3,950	3,900	3,160	3,130							
6621	4,880	4,380	4,310	3,720	3,690	3,260	3,230	3,610	3,040	2,920	2,580	
6631	3,450	3,080	3,020	2,530	2,600	2,610	2,550	2,810	2,220	2,240	1,880	
6684												
6686	34,530	34,660	31,640	31,630	31,620	28,100	29,520	28,770	26,390	24,860	26,790	

a ADT Counts which could not be verified using traffic count maps. Those counts are not used in calculating errors in ADT projections

Table B1 (cont.) Historical ADT

Segmented Number	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
6741	22,780	22,490	21,570	18,140	16,870	18,550	18,190	17,210	15,360	14,380	13,130	11,010
6744	28,500	28,510	26,600	25,810	24,260	26,390	24,090	22,140	21,380	17,290	16,150	13,620
6749	38,040	38,770	35,260	35,940	33,980	36,850	36,460	32,260	33,000	26,970	25,000	20,720
6755	56,470	55,950	57,600	60,410	53,030	56,890	53,490	48,080	46,970	44,280	42,520	38,730
6758	101,110	99,250	95,900	94,400	87,150	90,690	85,590	80,060	0			
6790	18,420	19,450	18,430	19,430	18,790	19,240	19,950	24,430	24,960	23,750	21,550	20,480
6830	9,120	9,310	12,600	13,820	13,100	12,400	11,730	12,940	12,600	11,090	9,810	7,010
6841	38,920	29,540	30,000	25,010	22,690	21,780	19,820	18,960	17,810	16,740	14,970	12,790
6850	42,520	34,580	31,540	25,850	25,780	24,920	24,990	25,950	20,240	17,890	15,870	14,450
6856	43,680	40,520	33,630	22,910	28,610	26,500	25,190	26,610	21,370	18,150	16,130	15,080
6864	51,290	52,620	47,990	37,560	39,540	39,960	34,250	28,850	21,370	17,390	14,400	14,050
6868	65,170	62,210	51,640	49,680	46,220	41,910	35,920	26,220	210[a]	0		
6975	115,680	113,990	99,190	92,750	85,840	78,550	71,640	59,000	0			
6978	34,990	33,090	32,260	27,300	23,120	22,800	19,670	12,260	0			
7000	64,010	62,450	58,970	49,120	45,900	40,210	35,930	25,690	0			
7002	84,650	77,200	71,830	52,600	45,540	43,850	42,230	32,220	0			
7015	31,270	28,410	25,660	14,660	9,060	0						
7016	34,420	31,190	27,850	18,880	11,460	6,470	6,230	0				
7029	26,490	23,630	21,800	15,420	11,570	8,630	6,870	0				
7042	27,740	22,620	22,180	9,350	0							
7043	30,570	27,760	25,800	11,510	0							
7045	29,010	27,420	25,060	12,080	0							
7047	38,250	32,350	31,720	16,990	3,780[a]	0						

a ADT Counts which could not be verified using traffic count maps. Those counts are not used in calculating errors in ADT projections

Table B1 (cont.)

Historical ADT

Segmented Number	1966	1965	1964	1963	1962	1960	1958	1957	1956	1955	1954	
6741	10,290	8,620	7,870	7,680	7,430	5,620	5,350	5,810	6,070			
6744	13,980	10,950	9,410	9,130		7,560	6,410	6,460	6,950			
6749	18,190	12,960	11,410	11,440	12,100	10,150	8,720	9,870		8,670	8,330	
6755	35,920	19,990	18,720	18,890	19,750							
6758												
6790	22,850	24,000	22,770	20,180	19,690	18,010	17,190	17,360		15,630		
6830	7,040	6,880	6,400	5,680	5,270	4,390	5,360	4,950	4,900			
6841	12,420	12,210	11,610	10,750	10,710	9,000	9,760	10,700	8,930	5,920		
6850	14,140	13,870	12,060	10,990	10,740							
6856	13,830	12,790	10,980	8,980	10,830	10,390						
6864	12,170	10,740	9,660	9,190	8,960	8,600	9,270	9,580				
6868												
6975												
6978												
7000												
7002												
7015												
7016												
7029												
7042												
7043												
7045												
7047												

a ADT Counts which could not be verified using traffic count maps. Those counts are not used in calculating errors in ADT projections

Table B2 Land Development in 1970
Around Selected ADT Segment Numbers

Segment Number	Survey Zones	% Developed Land	% Commercial & Industrial Acreage
5999	3496, 3533, 3536, 3658, 3686, 3691	.5367	.0625
6088	2594, 2603, 2604, 2608	.5259	.1103
6306	4396, 4398, 4408, 4490, 4491	.1593	.0285
6313	4352, 4354, 4355, 4359, 4360	.2047	.0548
6366	4340, 4346, 4348, 4351, 4360, 4362	.4411	.1935
6370	4193, 4196, 4199, 4206, 4208, 4217, 4219, 4975	.1910	.0867
6372	4193, 4196, 4199, 4219, 4962, 4964, 4975	.3251	.0399
6387	1360, 1361, 1366, 1425, 1446	.7914	.0986
6393	1399, 1400, 1401, 1481, 1482, 1484, 1505	.6421	.1231
6461	2766, 2806, 2807, 2808, 2809, 2810, 2813, 2816	.3980	.1020
6509	0146, 0149, 0152, 0154, 0157, 0158, 0159, 0200, 0201, 0202, 0248, 0249, 0251, 0253	.3608	.0847
6566	3324, 3355, 3356, 3357, 3369, 3370	.6611	.1295
6568	3248, 3252, 3362, 3365, 3366, 3370	.1601	.0206
6574	3242, 3243, 3244, 3245, 3256, 3257, 3258, 3259	.7529	.0647
6578	3166, 3168, 3169, 3177, 3178, 3179, 3283, 3284	.4002	.0410
6586	3040, 3044, 3189, 3193, 3195, 3198	.2235	.0240
6596	3027, 3032, 3033, 3034, 3058, 3059	.2493	.0190
6618	3811, 3812, 3813, 4754, 4756, 4757	.2387	.0100
6621	3812, 3813, 3814, 3815, 3822, 4756, 4757, 4762, 4773	.2371	.0054

Table B2 (continued)

Land Development in 1970
Around Selected ADT Segment Numbers

Segment Number	Survey Zones	% Developed Land	% Commercial & Industrial Acreage
6686	0517, 0621, 0622, 0623, 0624, 1832, 1870, 1871	.9769	.0481
6744	4321, 4586, 4588, 4682, 4700, 4719	.1259	.0130
6749	4287, 4289, 4295, 4296, 4644, 4645, 4646, 4648, 4840	.3429	.0114
6755	3963, 3989, 4062, 4064, 4248	.5004	.0636
6758	3922, 3923, 3950, 3952, 3953, 3956, 4045, 4047	.9985	.0060
6790	2581, 2582, 2584, 2855, 2856, 2857, 2864	.6274	.1118
6830	3732, 3733, 3734, 3735, 3754, 3755, 3756, 3880	.3176	.1041
6841	3533, 3534, 3535, 3536, 3539, 3540, 3542	.3697	.0271
6850	3471, 3472, 3474, 3475, 3476, 3531, 3534	.4639	.1144
6856	1515, 1516, 1520, 1664, 1665, 1667, 1669, 1675	.3312	.0184
6864	1399, 1400, 1484, 1485, 1505, 1506	.4800	.0596
6868	0342, 0343, 1390, 1398, 1399, 1400	.2193	.0366
6975	0272, 0274, 0281, 0305, 0306, 0350, 0351, 0352, 0356	.6254	.1496
6978	3177, 3179, 3189, 3199, 3217, 3218, 3219	.2811	.0127
7002	1270, 1272, 2713, 2795, 2796, 2800	.2570	.0009
7015	4643, 4644, 4645, 4646, 4648, 4836	.3839	.0511
7042	4923, 4926, 4935, 4937	.2217	.0123
7043	3749, 3764, 4923, 4926, 4935, 4937	.1980	.0111
7045	3842, 3853, 3854	.0991	.0124
7047	3894, 3896, 3897, 3898, 3899, 3900	.0841	.0397

Table B3 Equations for Estimating ADT Using SDHPT Projections

Study Point	Serial Number	Functional Form
1	5999	$\left(\frac{ADT}{10{,}000}\right)^2 = -21.971 + .42776\ t$
3	6088	$\left(\frac{ADT}{10{,}000}\right)^2 = -383.63 + 6.2074\ t$
4	6088	$\left(\frac{ADT}{10{,}000}\right)^2 = -282.62 + 4.5466\ t$
6	6306	$\ln ADT = -6.6372 + 3.8062\ \ln t$
7	6313	$\ln ADT = -6.1699 + 3.7044\ \ln t$
8	6366	$\left(\frac{ADT}{10{,}000}\right)^2 = -248.97 + 3.4106\ \ln t$
9	6370	$\left(\frac{ADT}{10{,}000}\right)^2 = 408.04 + 5.4405\ t$
10	6372	$\left(\frac{ADT}{10{,}000}\right)^2 = -481.80 + 6.4240\ t$
11	6381	$\ln ADT = 65.847 - 16.883\ \ln t + .23257\ t$
12	6381	$\ln ADT = 8.8660 + .02535\ t$
13	6387	$\ln ADT = 22.100 - 3.8218\ \ln t + .07005\ t$
14	6393	$ADT = -64727 + 1334.1\ t$
15	6393	$\ln ADT = -.14010 + 2.9798\ \ln t - .02214\ t$
16	6461	$\left(\frac{ADT}{10{,}000}\right)^2 = -34.281 + .58571\ t$
18	6509	$\ln ADT = 89927 - .27958\ \ln t + .03816\ t$
24	6578	$\ln ADT = -87.058 + 28.455\ \ln t - .33817\ t$
26	6586	$\ln ADT = -68.907 + 22.168\ \ln t - .22156\ t$
27	6586	$\ln ADT = -83.954 + 26.526\ \ln t - .27229\ t$
29	6618	$\ln ADT = -66.325 + 21.340\ \ln t - .22423\ t$
30	6621	$\ln ADT = -66.540 + 21.437\ \ln t - .22474\ t$
31	6631	$\ln ADT = -22.153 + 83533\ \ln t - .07095\ t$
32	6684	$ADT = -294700 + 4210.0\ t$
33	6686	$ADT = -196858 + 54942\ \ln t$
37	6749	$ADT = -454.69 + 112073\ \ln t$

Table B3 (continued) Equations for Estimating ADT Using SDHPT Projections

Study Point	Serial Number	Functional Form
42	6790	$\ln ADT = -22.552 + 8.8295 \ln t - .07484\ t$
43	6830	$\ln ADT = -47.490 + 16.458 \ln t - .16796\ t$
44	6841	$\ln ADT = -97.927 + 30.504 \ln t - .31260\ t$
45	6850	$\ln ADT = -127.46 + 39.002 \ln t - .40467\ t$
46	6856	$\ln ADT = -112.72 + 34.799 \ln t - .35932\ t$
47	6864	$\ln ADT = 3.0846 + .09190\ t$
48	6864	$\ln ADT = -151.79 + 47.337 \ln t - .55612\ t$
49	6868	$ADT = -1889204 + 446187 \ln t$
51	6975	$\left(\frac{ADT}{10,000}\right)^{2.818} = -9831.3 + 140.45\ t$
52	6978	$\ln ADT = -74.750 + 25.057 \ln t - .29538\ t$
53	7000	$\ln ADT = -91.093 + 28.429 \ln t - .27719\ t$
54	7002	$\ln ADT = -78.325 + 24.929 \ln t - .24436\ t$
55	7015	$\left(\frac{ADT}{10,000}\right)^{2} = -270.84 + 3.7101\ t$
56	7015	$\left(\frac{ADT}{10,000}\right)^{2} = -207.52 + 2.8427\ t$
57	7016	$ADT = -389247 + 5482.4\ t$
58	7029	$ADT = -181938 + 2562.5\ t$
59	7042	$\left(\frac{ADT}{10,000}\right)^{2} = -122.80 + 1.6595\ t$
60	7043	$\left(\frac{ADT}{10,000}\right)^{2} = -144.03 + 1.9463\ t$
61	7045	$\left(\frac{ADT}{10,000}\right)^{2} = -116.76 + 1.5779\ t$
62	7047	$\left(\frac{ADT}{10,000}\right)^{2} = -191.93 + 2.6292\ t$

Table B4. Proposed Program Change for Declining Growth Rate Calculation in HEEM (Program lines 3620 through 3850)

```
674 X=((VOLUME(I+1)-VOLUME(1))/I)/VOLUME(1)
    X1=((VOLUME(I+1)-VOLUME(1))/I)/VOLUME(I+1)
    IF (X1.LT.ASSUMP(9)) GOTO 681
680 A = 0.1
    GOTO 682
681 A = -0.1
682 F = 1-EXP(A*I)+((VOLUME(I+1)-VOLUME(1))/(ASSUMP(9)*VOLUME(I+1))*A)
    FP= (VOLUME(I+1)-VOLUME(1))/(ASSUMP(9)*VOLUME(I+1))-I*EXP(A*I)
    FR= ABS(F/FP)
    IF (FR.LE.0.0001) GOTO 684
    A = A - F/FP
    GOTO 682
684 GO= (ASSUMP(9)*VOLUME(I+1)/VOLUME(I))*EXP(A*I)
    IF (GO-X.LE.2.5) GOTO 685
508 FORMAT (/82H *** PROJECTED VOLUME TOO HIGH - CHANGE PROJECTION OR
   1USE CONSTANT GROWTH RATE ***)
    WRITE(6,508)
    GOTO 640
685 IF (GO.GE.ASSUMP(9)) GOTO 687
509 FORMAT (/95H *** MAXIMUM DECLINING GROWTH RATE TOO HIGH - CHANGE A
   1SSUMPTION OR USE CONSTANT GROWTH RATE ***)
    WRITE (6,509)
    GOTO 640
687 K = (VOLUME(I+1)-VOLUME(1))/(1.-EXP(-A*I))
    DO 688 I2 = 1,40
    VOLUME(I2) = VOLUME(1)+K*(1.-EXP(-A*(I2-1)))
688 CONTINUE
510 FORMAT (24X,15HGROWTH RATE IN ,I4,3H = , F5.2,1H%)
    GR100 = GO*100.
    G2 = ((A*K*EXP(-I*A))/VOLUME(I+1)*100.
    WRITE (6,510) IYR,GR100
    WRITE (6,510) IPYR,G2
```

Table B5 Comparison of Declining Growth Rates

Year	HEEM Function		Gamma Function		Beta Function	
	ADT_t	g_t	ADT_t	g_t	ADT_t	g_t
1	10,000	.1009	10,000	.2452	10,000	.0600
2	10,970	.0849	11,571	.1217	10,785	.0538
3	11,864	.0724	12,767	.0806	11,540	.0485
4	12,688	.0624	13,683	.0560	12,265	.0440
5	13,449	.0543	14,433	.0476	12,960	.0401
6	14,150	.0476	15,071	.0394	13,625	.0367
7	14,798	.0420	15,628	.0335	14,260	.0337
8	15,394	.0372	16,124	.0291	14,865	.0309
9	15,944	.0331	16,570	.0257	15,440	.0285
10	16,452	.0296	16,977	.0229	15,985	.0263
11	16,920	.0266	17,351	.0207	16,500	.0242
12	17,351	.0239	17,696	.0188	16,985	.0224
13	17,750	.0215	18,018	.0172	17,440	.0202
14	18,117	.0195	18,319	.0159	17,865	.0190
15	18,455	.0176	18,601	.0147	18,260	.0175
16	18,767	.0160	18,867	.0137	18,625	.0161
17	19,055	.0145	19,117	.0128	18,960	.0148
18	19,321	.0132	19,355	.0120	19,265	.0135
19	19,566	.0120	19,581	.0112	19,540	.0123
20	19,792	.0110	19,795	.0106	18,785	.0111
21	20,000	.0100	20,000	.0100	20,000	.0100

Table B6 Equations for Estimating Simple Regression Projections

Study Point	Segment Number	Functional Form	R^2
12	6381	ADT = -96,440 + 1943.8 t	.9930
13	6387	ln ADT = -19.588 + 7.2000 lnt	.9730
15	6393	ADT = -168,762 + 3,267.9 t	.9303
16	6461	ln ADT = 2.9288 + .10664 t	.9450
17	6461	ln ADT = 1.9654 + .12317 t	.9492
18	6509	ln ADT = 4.4108 + .08678 t	.9780
24	6578	ln ADT = 7.2757 + .03554 t	.7040
26	6586	ln ADT = 6.9614 + .03666 t	.9415
27	6586	ln ADT = 6.9568 + .03674 t	.9515
29	6618	$\left(\frac{ADT}{10,000}\right)^2 = -1.3400 + .02312\ t$	.9551
30	6621	ln ADT = 5.3427 + .04735 t	.9122
31	6631	ln ADT = 5.4971 + .03963 t	.8244
33	6686	$\left(\frac{ADT}{10,000}\right)^2 = -12.753 + .35917\ t$	.8222
37	6749	ln ADT = 7.1150 + .03543 t	.8403
42	6790	ln ADT = 5.0389 + 1.1730 t	.5182
43	6830	$\left(\frac{ADT}{10,000}\right)^2 = -1.0056 + .02164\ t$	.6124
44	6841	ADT = -24,536 + 576.86 t	.8275
45	6850	ln ADT = 4.5144 + .07644 t	.9671
46	6856	ln ADT = 4.3458 + .07884 t	.8556

Table B7 Calculated Errors in Simple Regression Projections

Study Point	Serial Number	Date of Projection	Projected ADT: First Year	First ADT	Second Year	Second ADT	Third Year	Third ADT	Percentage Error
12	6381	1973	95	88,220					.2712
13	6387	1968	78	130,750	88	311,620			.1783
15	6393	1968	78	86,140	88	118,820			.0905
16	6461	1965	85	161,640					.5744
17	6461	1967	75	73,360					.3655
18	6509	1968	75	55,220	90	202,930			.1226
24	6578	1965	65	14,560	75	20,770	85	29,630	.2198
26	6586	1968	89	27,550	94	33,090			.3513
27	6586	1969	89	27,620	94	33,190			.4075
29	6618	1969	82	7,450	92	8,870			.5619
30	6621	1969	82	10,150	92	16,290			.3957
31	6631	1969	82	6,290	92	9,350			.4028
33	6686	1965	80	39,980					.0663
37	6749	1965	88	27,810					.7449
42	6790	1974	75	24,420	85	28,280	95	32,220	.1948
43	6830	1966	86	9,250					.4297
44	6841	1971	90	27,380	95	30,270			.2980
45	6850	1971	90	88,810	95	130,150			.0800
46	6856	1971	90	93,130	95	138,140			.1018

Table B8 Equations for Estimating Percentage Change in ADT Resulting from a Capacity Change

Segment Number	Functional Form	R^2	Percentage Change
5999	$\ln ADT = 9.6066 + 37.547\, e^{-\frac{t}{10}} + .02014\, c$	.1151	.0203
6381	$\ln ADT = 6.4799 + .05864\, t + .12730\, c$	.9819	.1358
6387	$\ln ADT = 17.370 + 6.6559 \ln t - .09840\, c$	.9878	-.0937
6393	$\ln ADT = -16.628 + 6.5219 \ln t - .17146\, c$	.9642	-.1576
6461	$\ln ADT = 11.599 - 746.65\, e^{-\frac{t}{10}} - .45875\, c$	.9711	-.3679
6509	$\ln ADT = 3.7548 + .09807\, t - .18274\, c$	.9836	-.1670
6574	$\ln ADT = 8.4661 + .01634\, t + .36473\, c$	.7856	.4401
6575	$\ln ADT = 10.362 - 238.85\, e^{-\frac{t}{10}} + .03686\, c$	.9327	.0375
6578	$\ln ADT = .24761 + 2.2423 \ln t + .23199\, c$	.9468	.2611
6586	$\ln ADT = 5.6559 + .05850\, t - .00022\, c$	.9395	-.0002
6596	$\ln ADT = 4.7502 + .06663\, t - .08813\, c$	.9423	-.0844
6618	$\ln ADT = 1.9952 + .09663\, t - .00224\, c$	.9734	-.0022
6621	$\ln ADT = 4.4016 + .06309\, t + .21616\, c$	.9524	.2413
6631	$\ln ADT = 4.3943 + .05814\, t + .15924\, c$	.9369	.1726
6686	$\ln ADT = 10.467 - 67.906\, e^{-\frac{t}{10}} + .03990\, c$	.7514	.0407
6741	$\ln ADT = 4.6658 + .06871\, t + .07127\, c$	.9581	.0739
6744	$\ln ADT = 4.5435 + .07383\, t + .08463\, c$	.9626	.0883
6749	$\ln ADT = 5.0382 + .07107\, t + .12872\, c$	.9206	.1374
6755	$\ln ADT = 1.5360 + 2.7477 \ln t + .59725\, c$	.9813	.8171
6790	$\ln ADT = 10.080 - 87.821\, e^{-\frac{t}{10}} - .06810\, c$	.2643	-.0658
6830	$\ln ADT = 8.9638 - 141.21\, e^{-\frac{t}{10}} + .49301\, c$	.8959	.6372
6841	$\ln ADT = 5.6999 + .05806\, t + .21999\, c$	.9497	.2461
6850	$\ln ADT = -13.038 + 5.3980 \ln t + .07967\, c$	.9687	.0829
6856	$\ln ADT = 4.2120 + .08111\, t + .11499\, c$	.9421	.1219
6864	$\ln ADT = 5.3071 + .06289\, t + .58210\, c$	.9592	.7898

Table B9 Equations for Estimating Multiple Regression Projections

Study Point	Segment Number	Functional Form	R^2
16	6461	$\ln ADT = -9.1041 + 4.4788 \ln t + .22159\ c$	.9632
17	6461	$\ln ADT = 3.8044 + .09107\ t + .16509\ c$	.9634
37	6749	$\ln ADT = -9.7688 + 4.6414 \ln t -.15435\ c$	.9536
42	6790	$\ln ADT = 10.1972 - 134.62\ e^{-\frac{t}{10}} - .06328\ c$	.6485

Table B10 Calculated Errors in Multiple Regression Projections

Study Point	Serial Number	Date of Projection	Projected ADT						Percentage Error
			First		Second		Third		
			Year	ADT	Year	ADT	Year	ADT	
12	6381	1973	95	103,170					.2404
13	6387	1968	78	138,760	88	330,720			.2085
15	6393	1968	78	91,420	88	126,100			.0627
16	6461	1965	85	60,790					.0379
17	6461	1967	75	49,000					.0500
18	6509	1968	75	64,580	90	237,330			.0829
24	6578	1965	65	17,030	75	24,290	85	34,650	.0873
26	6586	1968	89	32,220	94	38,700			.2584
27	6586	1969	89	32,300	94	38,820			.3134
29	6618	1969	82	8,710	92	10,370			.4292
30	6621	1969	82	11,870	92	19,050			.2902
31	6631	1969	82	7,360	92	10,930			.2847
33	6686	1965	80	42,430					.0868
37	6749	1965	88	51,960					.2090
42	6790	1974	75	23,380	85	24,500	95	24,930	.1399
43	6830	1966	86	10,820					.3549
44	6841	1971	90	32,020	95	35,400			.2185
45	6850	1971	90	103,860	95	152,210			.0896
46	6856	1971	90	108,920	95	161,550			.0844