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16. Abstract

Because of the huge costs involved, most freeways are commonly constructed in lateral and/or longitudinal stages. In the case of the former, service roads are constructed and opened to traffic before the main lanes. In the case of the latter, the service roads and/or main lanes are constructed on a freeway section by section basis. No other studies are available which indicate the economic impact of freeway stage construction on non-users and users. Adjacent area land use and development impacts are of concern to non-users. Travel time costs, vehicle running and speed change costs, and accident costs are of concern to vehicle users.

The report contains the findings of a study of two freeways located in Houston, Texas: (1) the NW Freeway which was completely stage constructed and (2) the SW Freeway which was only partially stage constructed. Authorization to purchase right of way was given in 1958 for the SW Freeway and in 1960 for the NW Freeway. Construction of the study portion of the NW Freeway is not complete, but construction of the SW Freeway has been complete since 1974. Both freeways have 6-8 main lanes with 4-6 lane service roads, and the alternate old routes are undivided 4 lane facilities.

During the before construction period, the socio-economic characteristics (population, number of housing units, housing prices and rental rates, and family income) of the areas adjacent to the two freeways are shown to be generally similar. In the construction and/or after periods these characteristics are shown to be dissimilar, partly due to differences in the construction schedules of the two freeways. A regression analysis of land use changes (continued on back side)

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ECONOMIC EFFECTS OF STAGE CONSTRUCTION OF THE NORTHWEST AND SOUTHWEST FREEWAYS IN HOUSTON, TEXAS

by

Margaret K. Chui
Research Associate

Jeffery L. Memmott
Research Associate

and

Jesse L. Buffington
Research Economist

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Economic of Highway Design Alternatives

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College Station, Texas

PREFACE

The authors wish to express their appreciation to those who have assisted or facilitated this study. Special acknowledgement is due Mr. James W. Barr and Mr. James R. Farrar, Jr. of the Texas State Department of Highways and Public Transportation. Thanks are due Mr. Roscoe H. Jones and Mr. Joseph C. Chow of the Houston City Planning Department for furnishing the detailed land use data. The planners, real estate brokers, and investors are to be commended for taking time to be interviewed for this study. Last, thanks are due to Miss Patti McClurg for the excellent job done in typing the manuscript.

The contents of this report reflects the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

Because of the huge costs involved, most freeways are commonly constructed in lateral and/or longitudinal stages. In the case of the former, service roads are constructed and opened to traffic before the main lanes. In the case of the latter, the service roads and/or main lanes are constructed on a freeway section by section basis. No other studies are available which indicate the economic impact of freeway stage construction on non-users and users. Adjacent area land use and development impacts are of concern to non-users. Travel time costs, vehicle running and speed change costs, and accident costs are of concern to vehicle users.

The report contains the findings of a study of two freeways located in Houston, Texas: (1) the NW Freeway which was completely stage constructed and (2) the SW Freeway which was only partially stage constructed. Authorization to purchase right of way was given in 1958 for the SW Freeway and in 1960 for the NW Freeway. Construction of the study portion of the NW Freeway is not complete, but construction of the SW Freeway has been complete since 1974. Both freeways have 6-8 main lanes with 4-6 lane service roads, and the alternate old routes are undivided 4 lane facilities.

During the before construction period, the socio-economic characteristics (population, number of housing units, housing prices and rental rates, and family income) of the areas adjacent to the two freeways are shown to be generally similar. In the construction and/or after periods these characteristics are shown to be dissimilar, partly due to differences in the construction schedules of the two freeways. A regression analysis of land use changes reveals that certain land uses are sensitive to nonstaged freeway construction. Planners,

real estate brokers and investors in Houston indicate that staging a freeway's construction does affect land use and development. A user analysis reveals that staging a freeway costs more in vehicle user costs than benefits gained from delaying construction expenditures.

SUMMARY OF FINDINGS

This report contains the findings of a study of the economic effects of stage construction on non-users and users of freeways in Houston, Texas. Two freeways are studied: (1) the NW Freeway which was completely stage constructed and (2) the SW Freeway which was only partially stage constructed. The latter freeway serves as a control to the former freeway. Authorization to purchase right of way was given in 1958 for the SW Freeway and in 1960 for the NW Freeway. Construction of the study portion of the NW Freeway is not complete, but construction of the SW Freeway has been complete since 1974.

Both freeways were constructed in lateral and longitudinal stages. Lateral stage construction occurs when the service roads are constructed first and the main lanes are constructed last. Longitudinal stage construction occurs when service roads and/or main lanes are constructed on a freeway section by section basis. In this study, the emphasis is on lateral stage construction.

The non-user impact of stage construction is measured by historical changes in abutting and non-abutting land use and interpreted by the opinions of highway planners, real estate brokers and investors living and operating in Houston. The user impact is measured by travel time costs, vehicle running costs, speedchange cycling costs and accident costs. The findings of this study are summarized below.

Characteristics of Study Freeways and Areas

1. The design and capacity of the study freeways and the alternate routes that they replaced are similar. The freeways have 6-8 main lanes with 4-6 lane service roads, and the alternate routes are undivided 4 lane facilities.

2. Right of way costs (in constant 1962 dollars) for the SW Freeway are about 28% lower than that of the NW Freeway. The difference in right of way costs is due to the delay in purchasing right of way for the NW Freeway and landowner donations of significant amounts of right of way for the SW Freeway.
3. Construction costs per mile (in constant 1962 dollars) for the NW Freeway are 2.2 times higher than that for the SW Freeway. The difference in construction costs is mainly due to the differences in construction schedules of the two freeways.
4. The ADT on the NW Freeway and its alternate route is higher than on the SW Freeway and its alternate route at the same stage of freeway service road and main lane construction.
5. During the before construction period, the socio-economic characteristics (population, number of housing units, housing prices and rental rates, and family income) of the areas adjacent to the two freeways are generally similar. During the construction period, these characteristics of the two areas are dissimilar, partly due to differences in the construction schedules of the two freeways.

Impact of Stage Construction of Freeways

1. Land Use Impact:
   a. The analysis of actual land use changes reveals that single and multiple residential uses as well as industrial uses are sensitive to non-staged freeway construction.
   b. The length of time of having a service road present proves to be important in inducing commercial development.

c. Interviews with planners, real estate brokers and investors in Houston indicate that staging a freeway's construction does affect land use and development.

2. User Impact:

   a. The staging of a freeway costs more in vehicle user costs than in benefits gained from delaying construction expenditures.

   b. The delay of main lane freeway construction has a greater impact on user costs than the benefits of delaying service road construction.

Recommendations

1. Freeway staging decisions should not be made exclusively on the basis of budget constraints. Other factors such as land use impacts and vehicle user impacts need to be considered.
2. Staging effects of other types of highways should be studied.

IMPLEMENTATION STATEMENT

The report represents findings of a study of the economic effects of freeway stage construction. Recommendations are given for studying the economic effects of stage construction of other types of highways.

The findings of the study can be used immediately in decisions regarding scheduling the construction of freeway service roads and main lanes. The results indicate that construction of the service roads first and the main lanes several years later impacts land use and development of adjacent property and impacts vehicle user costs. This knowledge can be useful in SDHPT policy formulation regarding the stage construction of a freeway and how to measure the impacts of stage construction.

TABLE OF CONTENTS

	Page
PREFACE	i
ABSTRACT	ii
SUMMARY OF FINDINGS	iv
IMPLEMENTATION STATEMENT	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	ix
LIST OF FIGURES	xi
INTRODUCTION	1
Background	1
Objective and Scope of Study	4
Contents of Report	4
CHARACTERISTICS OF STUDY FREEWAYS AND AREAS	6
Construction and Cost Characteristics of Study Freeways	6
Traffic Characteristics of Study Freeways and Alternate Routes	12
Socio-Economic Characteristics of Study Areas	17
IMPACT OF STAGE CONSTRUCTION OF STUDY FREEWAYS	24
Land Use Impact	24
Vehicle User Impact	39
CONCLUSIONS AND RECOMMENDATIONS	45
REFERENCES	49
APPENDIX TABLES	50

LIST OF TABLES

Table		Page
1.	The Opening Dates of Service Roads and Freeway Main Lanes of SW and NW Freeways, by Section	7
2.	Right of Way Construction Costs in Constant 1962 Dollars of the Study Portion of NW and SW Freeways	11
3.	Average Daily Traffic Volumes on Hempstead Rd and South Main St/US 90A, Alternate Routes for NW and SW Freeways, by Year and Freeway Status	13
4.	Average Daily Traffic Volumes on the NW and SW Freeways, by Year and Status	16
5.	Corresponding Census Tract Numbers from 1950 to 1970 for Study Areas	18
6.	Socio-Economic Characteristics of the SW and NW Study Areas in the Before Period (1950-1960) and the During and After Period (1960-1970)	20
7.	Estimated Coefficients, Using Two Stage Least Squares	29
8.	Estimated Coefficients, Using Third Stage Least Squares	30
9.	Additional Costs as a Result of Staging of NW and SW Freeways	43
Appendix		
A1.	Right of Way and Construction Costs of the NW Freeway by Year and Section	51
A2.	Right of Way and Construction Costs of the SW Freeway by Year and Section	52
A3.	Twenty-four Hour ADT Counts Used to Calculate User Costs for NW Freeway Study Sections	53
A4.	Twenty-four Hour ADT Counts Used to Calculate User Costs for SW Freeway Study Sections	54
A5.	Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 2 of NW Freeway from 34th to 43rd Streets	55
A6.	Discounted User Costs for Existing or Proposed Travel Alternatives Involving Sections 3 and 4 of NW Freeway from 43rd Street to Cole Creek	56

Page

A7. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 2 of SW Freeway from Hillcroft to Beechnut Streets. 57

A8. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 3 of SW Freeway from Beechnut to Bissonnet Streets 58

A9. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 4 of SW Freeway from Bissonnet Street to County Line. 59

LIST OF FIGURES

Figure		Page
1.	Location of the NW and SW Freeways and Study Sections in Houston, Texas.	3

INTRODUCTION

Background

It is recognized that a major thoroughfare, such as a freeway, attracts not only traffic but also affects nearby land uses. Accessibility resulting from the existence of the thoroughfare is a major contributing factor. People are more willing to live further out from the city or further from other currently well developed areas if they can count on a quicker way to get to and from work. Industries are less reluctant to rule out the possibility of locating their firms in rural areas if they are certain of good accessibility for their workers and for their goods and supplies.

With the in-migration of people, housing has to be constructed to accommodate them. Whether it is single residential or multiple residential or a mix of the two depends very much on the needs of the people in-migrating into the area. Commercial establishments are created to provide services and shopping opportunities to residents. Therefore, commercial land use follows where people are locating. As demonstrated later in this report, one land use can affect other land use(s), and the presence of a major thoroughfare can obviously set off a chain reaction among land uses.

Besides the mere presence of a freeway, it is also believed that the method of constructing a freeway can influence how land is used. Because of the huge costs involved, most freeways are commonly built in longitudinal and/or lateral stages. In longitudinal staging, one segment of the freeway is built and opened before the next segment is started. In lateral staging, the service roads, if any, or part of the main lanes are built first. Later, all or the remaining main lanes are constructed.

It is true that for financial reasons, most freeways are staged, but the effects of staging a freeway are not well studied. It is believed that staging of freeways also affects user costs. A freeway does not reach maximum efficiency in carrying traffic until all the main lanes and service roads are constructed and opened for use. Until this is accomplished, part of the traffic that would normally use the freeway will have to choose an alternate route in the corridor which may require more travel time, incur higher vehicle operating costs and be more hazardous from an accident standpoint. It is obvious that knowledge of the effects of stage construction of any freeway should prove to be helpful to highway and city planning officials.

Therefore, the current study was authorized to select two freeways, one constructed by staging and the other by nonstaging, with the latter to be considered as a control, for the purpose of studying the staging effects of a freeway. However, a survey of the construction histories of freeways over the State revealed the absence of an ideal pair of freeways for study. Efforts were then diverted into searching for two staged freeways which had different amounts of lateral stage construction. For example, one of the freeways had to have at least one section nonstaged laterally and the other sections staged over a longer period of time than the other freeway. Using these guidelines, two freeways in Houston, Texas were chosen for study. The Northwest (NW) Freeway was selected to be the study facility and the Southwest (SW) Freeway to be the control facility. All of the study sections of the NW Freeway were constructed in lateral and longitudinal stages. All but Section 1 of the SW Freeway were constructed in lateral stages. Figure 1 shows the location of the two freeways and the study sections. The first section of the SW Freeway (SW1) had both its service roads and its main lanes opened at the same time, and the other three sections were staged over a much shorter period of time than those

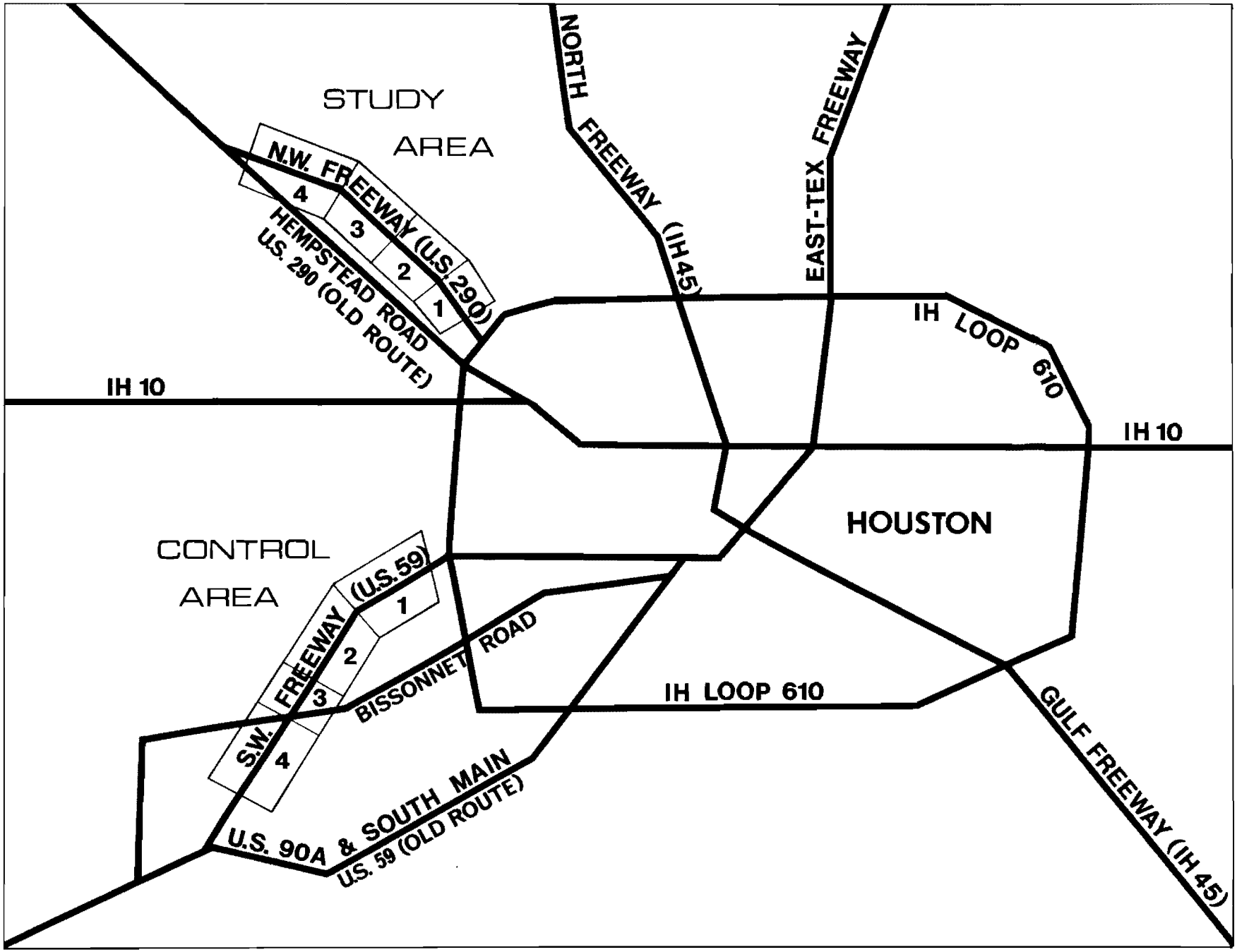

Figure 1. Location of the NW and SW Freeways and Study Sections in Houston, Texas.

of the NW Freeway. Even the longitudinal staging of the SW Freeway was different from that of the NW Freeway. The service roads were not staged longitudinally on the SW Freeway, whereas both the service roads and the main lanes were staged longitudinally on the NW Freeway. It is hoped that by studying these two freeways, the effects of stage construction can be revealed.

Objective and Scope of Study

The objective of this study is to determine the economic effects of stage construction of radial highways on users and non-users. The user effects are limited to travel time costs, vehicle operating costs, and accident costs incurred on the study and control freeways compared to the original alternate routes during the construction period. The non-user effects are limited to a comparison of land use changes on property adjacent to or near the study and control freeways.

Other socio-economic variables are used to determine the comparability of the areas served by the study and control freeways before construction began.

Contents of Report

This report contains a comparison of staging as opposed to nonstaging of freeway construction by studying various sections of the NW and SW freeways. The various historical characteristics of the two freeways and the surrounding areas are compared to determine major differences. Among the characteristics analyzed are the following: (1) cost and construction characteristics of the study freeways, (2) traffic characteristics of the study freeways and alternate routes, and (3) socio-economic characteristics of the study areas.

The impact of stage construction of the study freeways is determined by measuring changes in abutting or nearby land use and vehicle user costs. The land use impact of stage construction is determined by (1) the results of a regression analysis and (2) the opinions of highway planners, real estate brokers and real estate investors. In the case of the regression analysis, the regression model used is described in the report. The vehicle user costs are determined by using the Texas Highway Economic Evaluation Model (HEEM).

Finally, this report contains conclusions and recommendations that are based on the findings of the user and non-user analyses. Also, certain supporting data are presented in the Appendix.

CHARACTERISTICS OF THE STUDY FREEWAYS AND AREAS

In order to investigate the effects of staging as opposed to nonstaging a freeway construction on land use and vehicle user costs, two of the freeways in Houston which have these types of construction were chosen for the study. They are the Southwest (SW) Freeway and the Northwest (NW) Freeway. Based on definitions given earlier on staging and nonstaging freeway construction, Section 1 of the SW Freeway from Rice Street to Hillcroft Street (Figure 1) is nonstaged because both the service road and the main lanes were built simultaneously and opened for use in 1962, whereas the other sections of the SW Freeway and all sections of the NW Freeway are staged. In this section, various characteristics of these two freeways and the areas along these two freeways are discussed separately.

Construction and Cost Characteristics of Study Freeways

The construction and cost characteristics of the study freeways are discussed below under separate headings.

Freeway Design and Construction Schedules

Table 1 shows the division of each of the SW and NW Freeways in four study sections. Location and length of each section and opening dates of the service roads and of the freeway main lanes of each section are also given. Figure 1 illustrates the location of the two study freeways in relation to the Houston metropolitan area. To reflect the historic backgrounds of the two freeways, two important dates are discussed below.

Table 1. The Opening Dates of Service Roads and Freeway Main Lanes of SW and NW Freeways, by Section

Freeway	Section	Location of Section	Length of Section (Miles)	Opening Date of Service Roads	Opening Date of Freeway Main Lanes
SW	1	Rice to Hillcroft	2.1	1962	1962
SW	2	Hillcroft to Beechnut	2.5	1962	1965
SW	3	Beechnut to Bissonnet	1.4	1962	1969
SW	4	Bissonnet to County Line	2.5	1962	1974
NW	1	Mangnum to 34th St.	0.8	1970	1975
NW	2	34th St. to 43rd St.	1.4	1970	1979
NW	3	43rd St. to Tidwell	1.4	1975	1981
NW	4	Tidwell to Cole Creek	2.5	1975	Not Open

Fund Authorization Date. Both the SW and NW Freeways had 50-50 ROW (right of way) contractual agreements before they were built. A 50-50 contractual agreement means that the ROW is purchased jointly by the district and the county on a 50-50 basis. Procedure for this type of agreement involves the following important dates:

* Contractual Agreement Date - An agreement is reached between the district and the county.
* Reimbursement After Date - Funds for the purchase of right of way are reimbursed.
* Fund Authorization Date - Funds for the purchase of ROW are authorized, and the actual purchasing of ROW begins.
* Letting Date - Construction of the freeway begins.

Among all the above mentioned dates, the fund authorization date is the most important, since it signifies the firm commitment from SDHPT for construction. An examination of the records on the SW and NW Freeways indicate the two freeways were conceived fairly close in time from each other, but the construction schedules of each were definitely different. Fund authorization dates for the SW and NW Freeways were 1958 and 1960, respectively. All four study sections of the SW Freeway were completed by 1974. In the case of the NW Freeway, the first three sections were completed by 1981, and the fourth is still not opened.

Opening Date. For freeways which have both service roads and freeway main lanes, the opening date for public use depends on the completion of the separate facilities. The opening date for service roads may not necessarily coincide with that for the freeway main lanes if construction of the two facilities is not completed at the same time even though construction may have started at

the same time. According to the definitions set forth previously, a freeway section is staged laterally if the opening dates for the service road(s) and the main lanes are different, and it is nonstaged if they are the same.

Therefore, the first section of the SW Freeway, SW1, is nonstaged since both the service roads and the main lanes were opened in 1962 while all other sections of the SW Freeway (SW2, SW3 and SW4) and all four sections of the NW Freeway (NW1, NW1, NW3 and NW4) were staged because of the differences in opening dates for service roads and main lanes. Actually, service roads for all sections of the SW Freeway were built at one time in 1962. The main lanes, except for SW1, were built later, section by section. For the NW Freeway, the service roads were built in two stages. NW1 and NW2 had their service roads completed in 1970, while NW3 and NW4 had theirs' completed in 1975. The main lanes were completed in 1975, 1979 and 1981 for NW1, NW2 and NW3, respectively, and the main lanes for NW4 are still not opened at this time.

Of all sections, SW4 has the longest interval between opening dates of its service roads in 1962 and of its main lanes in 1974, totaling a span of twelve years. SW2 has the shortest interval of three years between openings of the two types of facilities. In this respect, the NW Freeway resembles the SW Freeway, with the exception of SW1. The longest interval between the opening of its service roads and its main lanes is nine years, with NW2 opening its service roads in 1970 and its main lanes in 1979. NW1 had a five year interval between the opening of the service roads and the main lanes.

The design of the two freeways and the alternate routes that they replaced are similar. When completed, the NW Freeway will have six to eight main lanes serving all four of the study sections. Its service roads will have four to six lanes.

The SW Freeway has at least six main lanes serving all of the four study sections. About one-fourth of Section 1 has two additional main lanes, and another outbound lane was added for that portion of Section 1 in 1977. At the same time, two additional lanes were added to the other three-fourths of Section 2, bringing its main lane capacity up to eight lanes. The SW Freeway has six lane service roads serving all four of its study sections.

The alternate routes for each of the study freeways have four undivided lanes. Hempstead Road is the alternate route for the NW Freeway and US 90A and South Main are the alternate routes for the SW Freeway.

Right of Way and Construction Costs

As already indicated, funds were authorized to purchase right of way in 1958 for the SW Freeway and in 1960 for the NW Freeway. Table 2 shows the right of way costs for the two freeways, as measured in 1962 dollars using the U.S. Consumer Price Index (CPI). A comparison of the cost per mile reveals that the right of way cost for the SW Freeway is about 28 percent lower than that for the NW Freeway. Part of this difference can be explained by the fact that the right of way for the SW Freeway was purchased at least two years earlier than that for the NW Freeway. Also, part of the right of way for the SW Freeway was donated by one or more landowners. On the other hand, most of the right of way for the NW Freeway was purchased later over a period of five to 10 years. Stage construction allowed more time for purchasing the right of way, but this time delay resulted in higher right of way cost for the NW Freeway. Tables A1 and A2 in the Appendix show a more detailed breakdown of actual right of way costs by study section for each freeway.

Table 2. Right of Way and Construction Costs in Constant 1962 Dollars of the Study Portions of NW and SW Freeways

Freeway and Freeway Element	Cost per Mile[a]	Total Cost[a]
	- - - Dollars - - -	
NW Freeway		
Right of Way	110,469	673,860
Construction[b]	3,694,590	22,537,000
Total	3,805,059	23,210,860
SW Freeway		
Right of Way	79,983	679,854
Construction[b]	1,716,118	14,587,000
Total	1,796,101	15,266,854

[a] Cost of the four study sections of each freeway, covering a total distance of 6.1 miles for the NW Freeway and 8.5 miles for the SW Freeway. The U.S. Consumer Price Index is used to deflate these costs.

[b] Includes traffic signal and lighting costs.

Source: State Department of Highway and Public Transportation

Table 2 also lists the construction costs, measured in 1962 dollars, of the study portions of the two freeways. These costs include traffic signal and lighting costs. The construction cost per mile for the NW Freeway is 2.2 times those for the SW Freeway. As in the case of right of way costs, part of the difference in construction costs of the two freeways is due to the ten years lag from completing the construction of the NW Freeway compared to that of the SW Freeway. Most of the extra construction cost incurred on the NW Freeway is due to the delay in construction of the main lanes. Consequently, this delay represents an extra cost to stage construction.

Traffic Characteristics of Study Freeways and Alternate Routes

Traffic characteristics in the form of Average Daily Traffic (ADT) are presented separately below for the study freeways and their alternate routes.

Alternate Routes

The alternate route for the NW Freeway is Hempstead Road (old route for US 290). The new route for US 290 is the NW Freeway. The alternate route for the SW Freeway is South Main which is also US 90A and the old route for US 59 before the SW Freeway was built.

Table 3 shows the historical ADT for the alternate routes from 1958 to 1981, and it also shows the construction status of the study freeways through this period. Therefore, the effects of the construction status of the study freeways on ADT for the respective alternative routes can be observed.

The ADT on each alternate route was about the same when authorization was given to purchase the right of way for the study freeways, that is, 12,205 for

Table 3. Average Daily Traffic Volumes on Hempstead Rd. and South Main St/US 90A (Alternate Routes for NW and SW Freeways), by Year and Freeway Status

Year of Count	Status of Study Freeways	Average Daily Traffic Volume	
		Hempstead Rd (alt. for NW FRWY)[a]	South Main/US 90A (alt. for SW FRWY)[b]
1958	Row purchase auth for SWF	10,570	13,705
1959		10,650	13,845
1960	Row purchase auth for NWF	12,205	13,460
1961		13,315	15,125
1962	Service rds open for all SWF Main lanes open for Sect 1 of SWF	13,240	14,237
1963		15,430	14,330
1964		15,910	14,905
1965	Main lanes open for Sect 2 of SWF	17,425	12,467
1966		17,120	13,880
1967		18,930	14,375
1968		19,290	14,670
1969	Main lanes open for Sect 3 of SWF	21,325	15,650
1970	Service rds open for Sects 1 & 2 of NWF	21,410	16,420
1971		22,280	20,180
1972		22,320	19,915
1973		25,690	22,250
1974	Main lanes open for Sect 4 of SWF	26,080	20,425
1975	Service rds open for Sects 3 & 4 of NWF Main lanes open for Sect 1 of NWF	18,000	21,060
1976		17,526	23,460
1977		15,713	25,585
1978		19,944	28,265
1979	Main lanes open for Sect 2 of NWF	21,074	28,143
1980		20,714	21,200
1981	Main lanes open for Sect 3 of NWF	c	c

[a] Average of two count stations, one north of 34th St and one south of Cole Creek.

[b] Average two count stations, one north of Fondren Rd and one south of IH 610.

c Not obtained.

Hempstead Rd and 13,705 for South Main. During the four-year period between the right of way authorization date and the opening date of the service roads for all four sections of the SW Freeway, the ADT on South Main increased from 13,705 to 14,237 or less than four percent. On the other hand, 15 years lapsed between the right of way authorization date and the opening date of the service roads of all four sections of the NW Freeway. During that time, the ADT on its alternate route (Hempstead Rd.) increased from 12,205 to 18,000, being a 47 percent increase.

Table 3 shows a lapse of 12 years between the opening of the service roads and the main lanes for all four sections of the SW Freeway. During that period, the ADT on its alternate route (South Main) increased from 14,237 to 20,425 or 43%. For three out of four sections, the ADT on this alternate route declined when the main lanes were added, providing relief for the former. Since the main lanes for all the sections of the NW Freeway have not been opened, the effects of added main lane capacity on the ADT of the alternate route cannot be fully assessed.

It has been five years since the service roads were opened for all four sections of the NW Freeway. During that time, the ADT for the alternate route increased from 18,000 to 20,714 or 15 percent. The ADT on this route would have been greater if the main lanes for Sections 1 and 2 of the NW Freeway (NW1 and NW2) had not opened. In each of the cases, the ADT dropped temporarily.

In conclusion, the ADT on the NW Freeway's alternate route has been higher than the SW Freeway's alternate route at the same stage of service road and main lane construction. With both alternate routes having the same capacity and design, the results of the above ADT comparisons indicates that the NW Freeway should have been constructed at least as rapidly as the SW Freeway.

Appendix Tables A3 and A4 lists the historical ADT of the individual count stations on the alternative routes.

Study Freeways

After at least one section of a study freeway is open to traffic, the ADT history can be recorded. As shown in Table 4, the ADT history for the SW Freeway began in 1963 and for the NW Freeway in 1971.

One year after opening at least the first study section of the study freeways, the ADT's were not greatly different, being 12,400 for the NW Freeway and 9,700 for the SW Freeway. At that point in the construction schedule, the SW Freeway had service roads open for all four study sections and main lanes open for Section 1, and the NW Freeway had service roads open for only Section 1 and 2. It took another five years before the NW Freeway had all its service roads open and main lanes open for Section 1. By that time, the ADT on the NW Freeway had risen to 26,550.

After an additional four years lapsed, the NW Freeway had the main lanes open in Section 2. Then the ADT on the NW Freeway had almost doubled to 47,575. The comparable ADT for the SW Freeway at that construction stage was only 10,700. Two years later, the NW Freeway had the main lanes open for Section 3, and by then the ADT most likely had increased to about 50,000 (actual data not obtained). The comparable ADT for the SW Freeway at that construction stage was 58,700. Since Section 4 of the NW Freeway is still not open, the ADT's of the two freeways at this construction stage cannot be compared.

In conclusion, the ADT of the NW Freeway is higher than that of the SW Freeway at the same stage of service road and main lane construction, except for the third and fourth (probably) stages of main lane construction. Again,

Table 4. Average Daily Traffic Volumes on the NW and SW Freeways, by Year and Status

Year of Count	Status of Study Freeways	Average Daily Traffic Volume	
		NW Freeway[a]	SW Freeway[b]
1958	Row purchase auth for SWF		
1959			
1960	Row purchase auth for NWF		
1961			
1962	Service rds open for all SWF		
	Main lanes open for Sect 1 of SWF		
1963			9,700
1964			11,120
1965	Main lanes open for Sect 2 of SWF		10,700
1966			12,060
1967			48,085
1968			52,060
1969	Main lanes open for Sect 3 of SWF		58,700
1970	Service rds open for Sects 1 & 2 of NWF		66,450
1971		12,400	76,235
1972		13,450	81,580
1973		16,240	88,465
1974	Main lanes open for Sect 4 of SWF	16,195	92,560
1975	Service rds open for Sects 3 & 4 of NWF	26,550	111,495
	Main lanes open for Sect 1 of NWF		
1976		27,915	115,445
1977		36,420	131,655
1978		44,695	139,800
1979	Main lanes open for Sect 2 of NWF	47,575	151,765
1980		48,000	155,000
1981	Main lanes open for Sect 3 of NWF	c	c

[a] Average of two count stations, one located north of 34th St and one south of Cole Creek.

[b] Average two count stations, one north of Bissonnet Rd. and one south of IH 610.

c Not obtained.

the results indicate that the NW Freeway should have been constructed as rapidly as the SW Freeway.

The historical ADT for the individual count stations on the alternate routes are shown in Appendix Tables A3 and A4.

Socio-Economic Characteristics of Study Areas

The study areas defined in this study include a one-half mile strip of land on each side of the study freeways. It is thought that an investigation of the changes in population, housing units, housing costs and family income in the study areas should reveal some of the social and economic characteristics of the general areas where the freeway facilities lie. It is hoped that this information should prove to be helpful to officials in city or highway planning departments, enabling them to better understand the areas in general.

Census tracts should provide the best available data source for this kind of study. Over the years, census tract numbers change. In some cases, there is a complete changeover in the numbering of the tract, or the same tract is broken down into smaller tracts. Census tracts covering, at best, the study area are identified and the differences among the numbering of these tracts are resolved so that the same areas are kept unchanged. Table 5 shows the changes in census tracts in the study areas from 1950 to 1970.

These characteristics are examined in two different time periods of construction of the freeway. The before construction period is defined to be from 1950 to 1960, covering a few years before ROW purchases through the completion most of the of ROW purchases for both the NW and the SW Freeways. The during and after construction period is defined as the period from 1960 to 1970. Ideally, this period should begin from 1960 and end in 1980 since it would

Table 5. Corresponding Census Tract Numbers from 1950 to 1970 for Study Areas

Freeway Segment	Census Tract Numbers by Year		
	1950	1960	1970
NW2	65	65A, 65B	517, 518
NW3	92	92A	527
NW4	--	92B	529
NW5	--	92B	529
SW1	91	91F, 91G, 91H, 91I	423
SW2	91	91G, 91H	424, 425
SW3	--	91G, 91H, 91I	424, 425, 426
SW4	--	91G, 91H, 91I	425, 435, 426

capture more of the during and after construction effects of the NW Freeway than the period of 1960-1970 would. By 1970, even though most of the SW Freeway, except SW4, had been completed, the NW Freeway had only its service roads open for two of the four sections, NW1 and NW2, and none of its main lanes were open until 1975. However, because of the unavailability of the 1980 census at this time, it is thought the years of 1960-1970 would be best to represent the during and after construction period under the circumstances.

Table 6 presents the socio-economic characteristics of the study areas in the before period (1950-1960) and in the partial during and after period (1960-1970). At the beginning of the before period (1950), the socio-economic characteristics of the two areas are shown to have been generally similar. At the end of the before period (1960), the socio-economic characteristics of the two areas are shown to have become even more similar. One reason why the two areas were more similar at this time due to the commitment to purchase right of way for a freeway at about the same time. By 1970, the socio-economic characteristics of the two areas are shown to have become more dissimilar. By this time, differences in the construction schedules of the two freeways had widened considerably, encouraging faster settlement and development of the SW Freeway than of the NW Freeway.

The absolute and relative changes in each socio-economic characteristic of the two areas are summarized below for each of the defined periods.

Population Changes

In the before construction period, population in the NW study area increased 16,841, or 151.8%, from 11,097 in 1950 to 27,938 in 1960 (Table 6). Meanwhile, the SW study area experienced a much more rapid growth during the

Table 6. Socio-Economic Characteristics of the Study Areas in the Before Period (1950-1960) and the During and After Period (1960-1970)

Year	Area	Population	Family Income ($)	No. Dwell. Unit	# Single Dwell. Unit	Med. House Price ($)	Med. Gross Rent ($)
1950	NW	11,097	3,308	3,438	2,954	6,432	29.00
	SW	5,463	3,054	1,830	1,736	8,971	29.20
1960	NW	27,938	6,377	8,787	7,403	12,200	59.00
	SW	21,665	7,822	6,213	6,191	15,333	79.00
1970	NW	41,203	10,585	13,249	10,953	17,000	110.00
	SW	58,783	13,100	20,493	12,409	23,640	167.00
Change in the Before Period (1950-1960)	NW	16,841 (151.8%)	3,069 (92.8%)	5,349 (155.6%)	4,449 (150.6%)	5,768 (89.7%)	30.00 (103.4%)
	SW	16,202 (296.6%)	4,756 (156.1%)	4,383 (239.5%)	4,455 (256.6%)	6,362 (70.9%)	50.00 (171.2%)
Change in the During and After Period (1960-1970)	NW	13,265 (47.5%)	4,208 (66.0%)	4,462 (50.8%)	3,550 (48.0%)	4,800 (39.4%)	51.00 (86.4%)
	SW	37,118 (171.3%)	5,278 (67.5%)	14,280 (229.8%)	6,218 (100.4%)	8,307 (54.2%)	88.00 (111.3%)

same period. Its population rose from 5,463 in 1950 to 21,665 in 1960, an increase of 16,202, or 296.6%. In comparison, the city of Houston grew from 596,163 in 1950 to 938,219 in 1960, a total increase of 342,056, or an equivalent of 57.4%. Obviously, both areas were growing at a much faster rate than the city as a whole, mainly due to concrete plans to construct a freeway to serve each area. Again, population growth excellerated more in the SW Freeway area than in the NW Freeway area partly because of differences in construction schedules.

In the during and after construction period, rapid population growth in both areas continued, but not at as a great a rate as occurred in the before period. While the NW study area had a growth of 47.5% in population during this period, the SW study area experienced an increase of 171.3%, or nearly four times that of the NW study area. The three-fourth completed SW Freeway apparently attracted a lot more residents to that area than the NW Freeway which had barely started construction.

Housing Units Changes

As expected, the number of housing units available in both periods followed very closely to the population trend described above (Table 6). In the before period, the number of dwelling units in the NW study area rose 155.6% from 3,438 in 1950 to 8,787 in 1960 while the SW study area had an increase of 239.5% from 1,830 to 6,213. For the same time period, single dwelling units experienced similar increases in both study areas, with increases of 150.6% and 256.6%, in the NW and the SW study areas, respectively.

In the during and after construction period, the SW study area had slightly more than four times the increase in dwelling units as the NW area. From

1960 to 1970, the number of dwelling units rose 50.8% in the NW area and 229.8% in the SW area. Meanwhile, the number of single dwelling units increased by 48% in the NW study area and 100.4% in the SW study area. Most probably the near completion of the SW Freeway during this period caused land values to increase so much that single dwelling units became uneconomical to build and instead, multiple dwelling units were constructed. Therefore, the major portion of the percentage change in dwelling units was due to the increase in multiple dwelling units and not due to the increase in single dwelling units. This influence of a freeway on housing was not prominent in the NW area largely because the NW Freeway during this period was nowhere near completion. Service roads for two of its four sections were completed only at the end of the period.

Housing Values and Rental Charges

Both house prices and rental fees increased significantly in the before construction period in both the NW and the SW study areas (Table 6). In the NW area, the median house price increase 89.7% from $6,432 in 1950 and $12,200 in 1960. During the same period when the status of both study freeways was similar, the median house price in the SW area increased 70.9% from $8,971 to $15,333. The median gross rental fees to renters in both study areas in 1950 was about the same, $29 in the NW area and $29.20 in the SW area. By 1960, rental fees increased to $59.00 and $79.00, representing increases of 103.4% and 171.2%, in the NW and the SW areas, respectively.

In the during and after period, there were smaller increases in this socio-economic characteristic in both study areas, yet the SW area still outranked the NW area in percentage increases. Again, the presence of a freeway apparently induced higher land values which are reflected in higher housing

prices and higher rental fees. In the NW area, the median house price rose to $17,000 in 1970, a total of 39.4% increase, while the median gross rent rose to $110, representing an increase of 86.4%. Meanwhile, in the SW study area, the median house price increased 54.2% to $23,640 by 1970 and the median gross rent increased 111.3% in the same period.

Family Income Changes

Economically, the SW and the NW study areas are comparable (Table 6). In the before construction period, the average family income in the NW area increased 92.8% from $3,308 in 1950 to $6,377 in 1960, whereas in the SW area, average family income increased 156.1% from $3,054 to $7,822.

In the during and after construction period, percentage increases in family income in both areas were just about the same, 66% in the NW area versus 67.5% in the SW area.

To summarize, Table 6 lists the changes of four discussed socio-economic characteristics of the SW and the NW study areas in both the before construction period and the during and after construction period. Even though family income levels in both areas were comparable, the SW study area definitely experienced a faster growth in population, and consequently in housing units and housing prices, than the NW study area. The especially rapid growth in the SW area in the during and after construction period strongly indicates that a freeway indeed tends to attract residents to its nearby areas because of increased accessibility, and as a result, it generally induces higher land and housing values.

IMPACT OF STAGE CONSTRUCTION OF STUDY FREEWAYS

As is indicated earlier, all sections of the NW Freeway were constructed in lateral stages, that is, the service roads were constructed first and the main lanes were put in later. Also, Sections 2, 3, and 4 of the SW Freeway were constructed in lateral stages. All sections of both freeways were constructed in longitudinal stages, that is, one section was completed before the next section. Since the service roads were constructed for all sections of the SW Freeway at one time, longitudinal staging occurred only for construction of the main lanes.

Even though lateral and longitudinal stage construction occurred on both of the study freeways, the primary emphasis of the analysis presented here is on determining the economic impact of lateral stage construction. The SW Freeway which has one section (Section 1) that was not constructed in lateral stages, is regarded as the control freeway in the land use analysis presented below. Since construction of the service roads and main lanes of the NW Freeway occurred over a much longer period of time than in the case of the SW Freeway, the effects of long term staging can be determined.

The extent of land use and vehicle cost impacts of freeway stage construction are presented under separate headings below.

Land Use Impact

The land use impact accessment of freeway stage construction is based on two data bases: (1) historical land use data and (2) current opinions of knowledgeable persons living in Houston. The land use data were obtained from the records of the Houston City Planning Department and aerial photographs of

the United States Department of Agriculture. The opinion data were obtained through in depth interviews with city planning officials, SDHPT planners, real estate brokers and investors operating in the Houston area.

The analyses and findings based on the above two data sources are presented below.

Analysis of Historical Land Use Data

Land use data for one-half mile strips on each side of the SW and the NW Freeways were obtained for the following six years: 1953, 1957, 1962, 1970, 1975 and 1980. The year which is closest to the opening date of a certain facility is used to represent the opening date of that facility since most of the actual opening dates do not fall exactly on any of these six years but rather fall in between.

The one-half mile study strip on either side of each freeway is divided into two parts: the abutting portion which is 100 feet wide next to the freeway and the nonabutting portion which encompasses the remainder of the study strip. Therefore, the four sections of each of the two study freeways are multiplied into eight subsections, yielding a total of sixteen subsections for both freeways. With six years' land use data on each of these subsections, a total of 96 observations or data points which can be used in the regression analysis presented below.

A regression model is formulated in order to relate each land use to the staging and nonstaging effects of freeway construction by use of a set of dummy variables. Besides the staging effects, other effects such as abutting and nonabutting, freeway location differences, capacity changes and average daily traffic volumes (ADT) are also investigated. Out of the many types of land

use, five of the more dominant ones are chosen for the study. They include single residential, multiple residential, commercial, industrial and undeveloped land uses. The dependent variables (DV) in the model are represented by these five land uses, and they are defined as follows:

(1) SHP = Percentage of single residential acreage to total acreage in each study subsection,

(2) MHP = Percentage of multiple residential acreage to total acreage in each study subsection,

(3) COMP = Percentage of commercial acreage to total acreage in each study subsection,

(4) INDP = Percentage of industrial acreage to total acreage in each study subsection,

(5) UDEVP = Percentage of undeveloped acreage to total acreage in each study subsection.

The effects tested are the explanatory variables (EV) which include six sets of dummy (qualitative) variables and one continuous variable. They are defined below:

(1) Dummy variable for abutting effect

DA = 1 if land is abutting study freeway section,

= 0 otherwise;

(2) Dummy variable for freeway location differences

LC = 1 if land is along the Southwest Freeway,

= 0 otherwise;

(3) Dummy variable for freeway construction type where only service roads are built

SR = 1 if freeway section is built with only service roads,

= 0 otherwise;

(4) Dummy variable for freeway construction type where freeway section is staged

SFS = 1 if freeway section is staged,

= 0 otherwise;

(5) Dummy variable for freeway construction type where freeway section is nonstaged

SFN = 1 if freeway section is nonstaged,

= 0 otherwise;

(6) Dummy variable for capacity change

CP = 1 if number of freeway main lanes changes,

0 otherwise; and

(7) Continuous variable for average daily traffic volume, ADT.

Since it is believed that interaction among land uses is highly probable, the model is, therefore, expressed in a set of simultaneous equations. Each of the dependent variables is expressed as a function of other dependent variable(s) and some combination of explanatory variables. In functional form, it is shown as follows:

$$DV_i = \alpha_i + \sum_{\substack{j \\ i \neq j}} B_{ij} DV_j + \sum_k \gamma_{ik} EV_k$$

where i = type of land use i = 1, ..., 5,

j = type of land use which is different from i, and

k = number of explanatory variables k = 1, ..., 7.

Since the staging effect is the most relevant effect investigated in this study, the three sets of dummy variables, SR, SFS and SFN, attempting to capture this effect are included in all the equations.

The simultaneous equation model is estimated first by two stage least squares (2SLS) to give consistent and unbiased estimates of the coefficients. Since it is likely that there is interactions among disturbances across equations, third stage least squares (3SLS) are also used to reestimate the model in order to improve the efficiency of the estimated coefficients.

It is felt that interpretation of the estimated coefficients of the dummy variables should be clarified to some extent in order to facilitate more fully the understanding of the implication of these variables. In a regression model, if only one characteristic represented by a dummy variable is to be tested, the estimated coefficient of the dummy variable shows the mean difference in the dependent variable between the presence and absence of the effects represented by the dummy variable. However, when there are more than one characteristic to be tested in a regression model, interpretation of the estimated coefficients of the dummy variables becomes more complicated. If the regression model includes qualitative variable(s) and continuous variables, the estimated coefficients of the dummy variables have even more complicated implications [1]. They have to be interpreted at some given level of the continuous variable.

One possible solution to get around the problem is to test one set of dummy variables at zero level of the continuous variable while setting all the other sets of dummy variables to be zero. Thus, each of the estimated coefficients can be interpreted as the mean difference between the presence and absence of the characteristic represented by the tested dummy variable at zero level of the continuous variable. Because the regression model is formulated in this manner, its estimated coefficients are to be interpreted within these constraints.

Tables 7 and 8 show the estimated results of the regression model using 2SLS and 3SLS, respectively. Among the large number of dependent variables,

Table 7. Estimated Coefficients, Using Two Stage Least Squares

Dependent Variable	Constant	Independent Variable									R^2	F Ratio
		Exogenous Variable						Endogenous Variable				
		DA	LC	SR	SFS	SFN	ADTX10^{-4}	SHP	MHP	COMP		
SHP	15.9431* (6.09)	-5.3771* (-2.03)	-10.2050* (-3.37)	8.5989* (2.64)	15.7813* (4.08)	16.6607* (2.21)			.2138 (-.53)		.2620	5.27
MHP	1.7440* (1.77)	-4.0859* (-3.22)		1.5131 (1.10)	-3.7463** (-1.55)	4.0612** (1.38)				.3963* (3.86)	.3750	10.81
COMP	3.4274* (1.89)			3.1015** (1.40)	8.2992* (2.67)	7.2605* (1.85)	2.4648* (6.44)	-.2006** (-1.29)	-1.0980* (-2.83)		.7100	36.32
INDP	1.6734* (2.64)		-2.9449* (-3.34)	.6717 (.71)	4.1950* (3.75)	5.0917* (2.36)			.3183* (2.78)		.4248	13.29
UDEVP	102.4407* (50.02)	.9463 (.51)		1.8683 (.94)	4.0655 (1.20)	2.5595 (.71)		-1.3510* (-9.33)	-1.1675* (-4.57)	-1.2552* (-8.12)	.9343	178.80

*Significant at 5 percent

**Significant at 10 percent

Table 8. Estimated Coefficients, Using Third Stage Least Squares

Dependent Variable	Constant	Independent Variable								
		Exogenous Variable						Endogenous Variable		
		DA	LC	SR	SFS	SFN	ADTX10^{-4}	SHP	MHP	COMP
SHP	16.548* (6.34)	-7.7758* (-3.08)	-8.3099* (-2.79)	8.7963* (2.70)	15.3543* (3.98)	16.4194* (2.18)			-.2959 (-.73)	
MHP	1.3085** (1.34)	-3.1690* (-2.56)		1.5232 (1.10)	-3.5111** (-1.45)	4.3018** (1.47)				.3843* (3.75)
COMP	3.5886* (2.04)			2.6473 (1.21)	8.9043* (3.01)	5.1946** (1.33)	2.1622* (6.20)	-.2283** (-1.55)	-.6279* (-1.77)	
INDP	1.7732* (2.80)		-3.2234* (-3.68)	.6724 (.71)	4.3229* (3.87)	5.3207* (2.47)			.3143* (2.74)	
UDEVP	103.8327* (56.68)	-.9895 (-.88)		2.1558 (1.12)	3.2552** (1.48)	.7807 (.23)		-1.4109* (-10.99)	-1.0746* (-5.77)	-1.2002* (-18.89)

R^2 = .6032

*Significant at 5 percent

**Significant at 10 percent

some are found to have little significant influence on one other type of land use but significant influence on some others, and some are found to have no significant influence on any other type of land use. A capacity change is found to be in the latter category and, therefore, is eliminated completely in the final model formulated. The resulting model consists of a set of simultaneous equations, with each equation relating one type of land use acreage, in percentage of the total acreage, to one or two influential endogenous variables together with various combinations of mostly significant dummy variables.

An examination of the estimated coefficients in Tables 7 and 8 shows that the two statistical methods (2SLS and 3SLS) have similar impacts on all variables, except that two of the estimated coefficients differ in levels of significance and in magnitudes. The estimated coefficient of SR in the equation for commerical land use, COMP, is significant statistically when 2SLS is used but narrowly misses the level of significance when 3SLS is adopted. The reverse is found true for the estimated coefficient of SFS.

R^2 for the 2SLS set of estimated equations ranges from 0.2620 to 0.9343, while for the set using 3SLS, R^2 is 0.6032. More detailed results of estimation by 3SLS are presented below by land use type.

Single Residential Acreage. The percentage of single residential acreage to total acreage in the study areas (SHP) is found to be negatively but insignificantly related to the percentage of multiple residential acreage. As expected, the abutting effect (DA) is significant and negative, indicating that the mean percentage of single residential acreage to total acreage is 7.78 percent lower in the abutting area than in the nonabutting area.

Freeway location differences (LC) are also found to be negative and significant in influencing single residential acreage. The mean percentage of

single residential acreage is 8.31 percent lower in the SW Freeway area than in the NW Freeway area. This result is rather surprising, because the SW Freeway area is thought to be more residential on the whole than the NW Freeway area. However, a closer examination of the data reveals that in areas along the first section (SW1) of the SW Freeway, commercial acreage is convincingly dominating, and along the fourth section (SW4) of the SW Freeway, land was left vacant until the latter part of 1960's. The low to zero percentage of single residential acreage must have pulled the mean down far enough to yield an overall lower percentage for the SW Freeway area than for the NW Freeway area.

Single residential acreage is significantly and positively influenced by all three types of freeway construction: the service road alone, the staged freeway segment, and the nonstaged freeway segment. Among the three, the nonstaged freeway segment construction has the greatest influence on single residential acreage. As expected, a freeway with main lanes and service roads constructed by either the staging or nonstaging method influences the percentage of single residential acreage more than by construction of only service roads.

Multiple Residential Acreage. Estimation results reveal that the percentage of multiple residential acreage to total acreage in study area (MHP) is positively and significantly related to percentage of commercial land use, indicating that the more commercial acreage there is the more multiple housing is found. As the percentage of commercial land use increases one percent, MHP increases 0.38 percent. MHP is also found to be negatively and significantly related to DA. The estimated coefficient of -3.17 for DA says that the mean MHP is 3.17 percent lower in abutting areas than in nonabutting areas. Apparently, high abutting land values are more influential than better accessibility to attract more multiple housing developments.

Freeway construction with only service roads opened has no significant influence on this land use category. A freeway with both main lanes and service roads built by the staging method has a negative and significant influence on MHP land use. The nonstaged freeway construction method is positively and significantly related to MHP. Therefore, among the three types of freeway construction, the nonstaged type fares best in influencing this land use category positively.

Commercial Acreage. The percentage of commercial acreage to total acreage in the study area (COMP) is found to be negative and significant in its relation with both SHP and MHP, indicating that as single housing or multiple housing acreage decreases, commercial acreage increases. This result does not agree with what is generally expected. A population increases in an area, residential development expands to meet the demand and one might expect a corresponding positive effect on commercial land uses. However, the negative effect observed from the regression results may be explained by the fact that in narrow strips of land fronting major arterials or thoroughfares, land values become so high that development of commercial uses will be attracted at the expense of the less valuable land uses, such as single or multiple housing acreage. Apparently the abutting and the nonabutting areas defined in the data fit into this category. Therefore, commercial land use and either type of residential land uses are found to move in opposite direction. The estimated coefficients of SHP and MHP are -0.23 and -0.63, respectively. One percent increase in SHP results in 0.23 percent decrease in COMP whereas the same percentage increase in MHP brings about 0.63 percent decrease in COMP.

ADT is found to be positively and very significantly influential to COMP. The estimated coefficient of 2.16 indicates that an increase in ADT by 10,000 results in an increase of 2.16 percent in COMP.

Freeway construction with only service roads opened is found to be positively but barely below the level of significance in its relation to COMP while the other two freeway construction types are found to be positively and significantly influential to COMP. In comparison between the staged and nonstaged freeway construction, it is found that the former type exerts greater influence on COMP than the latter type. This finding is not consistent with what had been expected. However, commercial development is likely to be greatly stimulated along a freeway where the service roads have been built and the main lane construction is to occur soon.

Industrial Acreage. From the estimated results of the regression model, it is found that percentage of multiple residential acreage (MHP) is positively and significantly related to the percentage of industrial acreage (INDP). The coefficient of MHP is estimated to be 0.31, signifying that a one percent increase in MHP results in a 0.31 percent increase in INDP. Freeway location differences (LC) are found to play a significant role in influencing INDP. The estimated coefficient of LC is -3.22, meaning that the mean INDP is 3.22 percent lower in the SW Freeway study area than in the NW Freeway study area.

Among the three dummy variables for freeway construction types, the coefficient of SR is found to be statistically insignificant while those of both SFS and SFN to be positive and significant. The estimated coefficient of SFN is larger than that of SFS, implying that the nonstaged freeway construction is more influential to the mean INDP than the staged freeway construction.

Undeveloped Acreage. The percentage of total undeveloped acreage (UDEVP) to total acreage of each study area is found to be negatively and very significantly related to SHP, MHP and COMP. The estimated coefficients of these variables are -1.41, -1.07 and -1.20, respectively. A one percent increase in each of SHP, MHP and COMP results in corresponding decreases of 1.41, 1.07 and 1.20 percent in UDEVP. In other words, single and multiple residential acreages together with commercial acreage constitute the major elements in developed acreage.

Abutting acreage (DA) is found to have an insignificant effect on UDEVP. The only type of freeway construction that is significant in relating to UDEVP is the staged construction type. The positive estimated coefficient of SFS is surprising since it is expected that any type of freeway construction should have a negative effect on UDEVP. Perhaps, at this stage between construction of service roads and main lanes, many residential properties with older buildings are torn down and become unimproved temporarily. The same could happen to a lesser extent with commercial and industrial properties.

In summary, the type of freeway construction affects differently each land use. How each freeway section is built has a significant influence on each land use category. To both the single and multiple residential use as well as industrial use a nonstaged freeway is found to be more influential than a staged freeway whereas the opposite is apparently true for commercial use. The length of time having a service road present proves to be important in inducing commercial development.

Opinions of Planners, Real Estate Brokers and Investors

Knowledgeable persons living in Houston were interviewed in depth to obtain their opinions regarding the effects, if any, of freeway stage construction on land use and development. SDHPT and city planners who are responsible for planning freeways and other transportation facilities were among those interviewed. In addition, some of the most knowledgeable and prominent real estate brokers and investors in Houston were interviewed.

The persons interviewed were asked not only their opinions about the effects of stage construction but also about their opinions of the effects of other factors on land use and development. Later in the interview, they were asked their opinions on the effects, if any, of stage construction on the two study freeways. The results of these interviews are summarized below.

Effects of Stage Construction. All of those interviewed think that freeway stage construction does affect land use and development in some way. Most of them indicate that stage construction greatly affects development in the area near a freeway. They indicate that certain types of development are especially sensitive to stage construction, one being large office building complexes. One of the planners says that when the service roads are built commercial strip development occurs, and when the main lanes are built regional shopping center and large office building developments occur.

One of the investment consultants indicates that the more evidence that is provided that a freeway will be completed, the greater the land values and attraction for development. This consultant also indicates that the type of access provided by the freeway affects the type of development that will occur and the time when the development occurs. Another real estate investment

consultant thinks that about one-third of the development will occur after the service roads are constructed and about two-thirds of the development will occur after the main lanes are constructed. One of the planners says that the early building of service roads will cause more development to start than the purchasing of the right of way alone will. A preference is expressed by a real estate investment builder that freeways not be staged and that longer sections be constructed at one time. However, one of the planners indicates that the staging of freeways is necessitated by budget constraints.

When asked about the effects of staging the NW and SW Freeways, most of those interviewed indicate that development along the NW Freeway has been slower partly due to staging every section and also due to staging each section over a longer period of time than has been the case for the SW Freeway. A real estate investment builder notes that, since the main lanes of the NW Freeway are being added, several large developments have been started. It is felt by the same source that had everything except the construction schedules been equal, the SW Freeway would have attracted more development.

Other reasons are given for the recent speed up of development along the NW Freeway. A planner indicates that the SW Freeway area is running out of developable land because of the presence of a flood plain. One of the developers now ranks the areas on either side of the NW Freeway first and second in population growth and land development potential. Previously, the areas on either side of the SW Freeway ranked first and second in these categories. This change in ranking is due to many factors, some of which are discussed below.

Effects of Other Factors. Those interviewed agree that the rate of land development has been faster along the SW Freeway than along the NW Freeway. As already mentioned, they indicate that part of the difference in the rates of

land development is due to stage construction. However, several other factors that caused this difference in development rates are also mentioned. These factors are listed as follows:

1. There were large developers and land owners in the SW Freeway area who offered free right of way for a freeway and promoted the construction of a freeway by contacting the State Highway Commission. On the other hand, most of the land owners in NW Freeway area were farmers who were not interested in developing their land.
2. The water districts and sewage systems were more available at first in the SW Freeway area.
3. The NW Freeway area had older developments which were not very attractive.
4. The SW Freeway provides a more direct access to Houston's central business district.
5. The development of regional malls and shopping centers has been slower in the NW Freeway corridor because of less potential demand from out of town population centers.
6. The SW Freeway improved the accessibility to large tracts of developable land, because the NW Freeway has a more direct alternate route (Hempstead Rd.) serving that area.

In summary, those interviewed express the opinion that staging a freeway's construction does affect land use and developments. It is thought that the differences in the construction schedules of the study freeways did cause differences in land development. Also, several other reasons are given for their belief that the SW Freeway areas have developed faster than the NW Freeway areas.

Vehicle User Impact

The decision to stage a new freeway construction rather than build the entire facility at once should include the additional user costs which would result if access to the facility is delayed for a period of time as the staging progresses.

Obviously there are benefits to staging, mainly from the delay in expenditures for highway construction. However those benefits should be compared to the costs to users of the delayed facility in order to determine the overall direct effects of staging a highway facility.

The additional user costs of staging for a particular highway section can be defined as the difference in user costs between the costs generated while the facility was not open and the costs if the facility had not been staged. In mathematical terms,

$$AUC = \sum_{i=1}^{n} \frac{UC_{Ai} - UC_{Ei}}{(1+r)^i} \qquad (1)$$

where AUC = present value of additional user costs resulting from staging

UC_{Ai} = actual corridor user costs in year i

UC_{Ei} = expected corridor user costs in year i if facility had been open

n = number of years staging delayed opening of facility

r = discount rate (assumed 8 percent)

Calculation of User Costs

Vehicle user costs consist of four major components: time costs, vehicle running costs, speed-change cycling costs, and accident costs. The Highway

Economic Evaluation Model (HEEM) [2] provides equations and parameters to calculate each one of these user cost components in a simple and consistent manner. Therefore these equations are used to calculate the user costs as a result of staging for the two Houston freeways examined in this report, the NW Freeway, US 290; and the SW Freeway, US 59.

The first problem is to choose a particular year to use in comparing user costs and construction costs between alternatives. Since the service roads for the SW1 were opened in 1962, that year is used as the base year for the analysis.

The HEEM's cost equations, as originally adapted for use in Texas, are in 1975 prices, therefore the cost calculations using the HEEM must be adjusted to 1962 prices. The CPI price index is used to make that adjustment. The CPI, with 1967 = 100, in 1975 was 161.2, and in 1962 it was 90.6. The adjustment factor is simply 90.6 divided by 161.2, or 0.562.

The HEEM uses a corridor approach to evaluate proposed highway projects. The total traffic for the corridor is given and that traffic is allocated to the routes within the corridor. Memmott and Buffington [3] have proposed a modification to the HEEM which would improve the accuracy of the allocation process. The technique is based upon minimizing total user cost in the corridor. This allocation method is incorporated into the calculation of user costs in this section.

The corridor for the NW Freeway is defined as the freeway main lanes, the service roads, and Hempstead Road, and is divided up into two parts, from 34th Street to 43rd Street (NW2), and from 43rd Street to Cole Creek (NW3 and NW4). The corridor for the Southwest Freeway includes the freeway mainlanes, the service roads, and South Main. Three sections are examined, from Hillcroft to Beechnut (SW2), from Beechnut to Bissonnet (SW3), and from Bissonnet to the

County Line (SW4). The first section (NW1) of the NW Freeway is deleted from the analysis because of the lack of traffic count station data for the corresponding section on Hempstead Road. The first section (SW1) of the SW Freeway was not staged. Tables A3 and A4 show the annual ADT counts used to calculate the user costs for selected study sections of the NW and SW Freeways. User costs are calculated for the existing corridor traffic and what the user costs would have been for those same vehicles if the service road or freeway had been completed in 1962. No adjustments are made for induced traffic in this analysis. There is evidence that improved capacity induce additional vehicles to use a particular facility. (See for example Memmott and Buffington [4]). Certainly a part of the additional traffic is diverted from other corridor routes. But a significant amount could come from new corridor vehicle trips or additional trips by current corridor users. That would be especially true for a major new-location freeway project.

Therefore using the actual corridor traffic, with no adjustments for induced traffic, will tend to underestimate the user costs of staging. However there is no current method to accurately predict the volume of induced traffic for a proposed facility and more importantly, there is no way to estimate the costs to those vehicles of not using the defined corridor. Since induced traffic could not be handled with any degree of precision, it is not included in this analysis. Therefore the additional user cost numbers reported here should be regarded as a minimum value, since the true value would be higher if induced traffic were included.

Construction cost savings from staging are handled in a similar fashion as user costs. Only construction costs attributable to staging the service roads and/or main lanes are included in this analysis. The costs of right of way, utility adjustments, storm sewers, and preparation of right of way are not

included. The actual construction costs for the selected freeway sections are converted into 1962 dollars using the CPI, then the benefits of delayed construction are calculated using the following formula:

$$BDC = \sum_{i=1}^{n} C_i[1-(1+r)^{-i}] \qquad (2)$$

where BDC = benefits of delayed construction for a given highway segment

C_i = construction cost in year i

n = number of years staging delayed opening of facility

r = discount rate (assumed 8 percent)

The Effects of Staging on Costs

The changes in user costs and construction costs for each freeway as a result of staging are presented in Table 9. The net cost of staging which represents the difference between the additional user costs and the benefits of delayed construction is also presented.

For each of the highway segments, the net cost of staging is positive. This indicates that the costs to users of staging are greater than the benefits of delaying construction expenditures. There is also a significant difference in the effects of staging service roads compared to staging the main lanes. On both sections of the NW Freeway, the net staging costs for the service roads are substantially less than the comparable net staging costs for the main lanes.

The difference between the costs of service road staging and main lane staging is due, in part, to the longer delay in building the main lanes. The

Table 9. Additional Costs as a Result of Staging of NW and SW Freeways

Freeway Section and Design Element	Years	Additional User Costs[1]	Benefits of Delayed Const.	Net Cost of Staging
		- - Thousands of 1962 dollars - -		
Northwest Freeway				
34th to 43rd				
Service Road	62-69	1,085.9	457.5	628.4
Freeway	62-78	4,652.7	1,714.7	2,938.0
43rd to Cole Creek				
Service Road	62-74	3,308.7	2,216.1	1,092.6
Freeway	62-80	13,390.5	8,049.6	5,340.9
Southwest Freeway				
Hillcroft to Beechnut				
Freeway	62-65	1,060.6	79.0	981.6
Beechnut to Bissonnet				
Freeway	62-69	1,664.3	274.7	1,389.6
Bissonnet to County				
Line Freeway	62-74	4,303.6	2,420.8	1,882.8

[1] Assumes 8 percent trucks, value of time for cars of 9¢ per vehicle minute, and a value of time for trucks of 18¢ per vehicle minute.

service roads were opened up sooner and avoided the accumulation of user costs as corridor traffic volume increased in recent years. But an examination of the user costs in the Appendix Table A5-A9 will reveal a significant difference in user costs between the service roads and main lane freeway even in the earlier years. It is, therefore, reasonable to infer that the delay of main lane freeway construction has a greater impact on user costs than delay of service construction. This implies that the current practice of first opening the service roads, then the main lanes may not be the optimal strategy, especially in a rapidly growing area like Houston.

Additional costs as a result of staging are higher for the NW Freeway than for the SW Freeway (Table 9). If the first freeway sections could have been evaluated, the costs of staging would be even greater. In the case of the former facility, all sections have been staged, and the construction of each stage has been spread out over a much longer period of time than in the case of the latter facility.

The results indicate staging decisions should be carefully evaluated and should not be made exclusively on the basis of budget constraints. For example, the decision to delay construction of the SW Freeway main lanes from Hillcroft to Beechnut saved only about 80 thousand dollars in construction costs, yet imposed additional user costs of over a million dollars on motorists. It is believed that this sort of information and tradeoff should be explicitly incorporated into the decision-making process of project selection and construction timetable.

CONCLUSIONS AND RECOMMENDATIONS

This study investigates the economic effects of stage construction of a freeway on users and non-users. The user effects are limited to time costs, vehicle operating costs and accident costs, and the non-user effects include a comparison of land use changes on property adjacent to or near the study freeways. The results of the study are summarized below.

Conclusions

The SW and the NW Freeways are the two freeways chosen for study. The alternate route for the SW Freeway is South Main/US 90A and for the NW Freeway is Hempstead Road. Each of the study freeways are divided into four study sections. All sections, except Section 1 of the SW Freeway, were staged. Various characteristics of the study freeways and areas along them are examined. The results are listed as follows:

1. Construction and Cost Characteristics:
    a. Funds for the purchases of right of way were authorized about the same time, 1958 for the SW Freeway and 1960 for the NW Freeway;
    b. The design of the two freeways and the alternate routes which they replaced are similar, e.g. 6-8 main lanes with 4-6 lane service roads;
    c. Right of way costs (in constant 1962 dollars) are about 28% lower for the SW Freeway because of the two years' time difference when right of ways were purchased and also because of land donations by some developers for the SW Freeway and;

d. Construction cost per mile (in constant 1962 dollars) for the NW Freeway is 2.2 times higher due to the much later construction dates for the NW sections.

2. Traffic Characteristics:

   a. The ADT on the NW Freeway's alternate routes is higher than on the SW Freeway's alternate routes at the same stage of freeway service road and main lane construction and

   b. The ADT of the NW Freeway is also higher than that of the SW Freeway at the same stage of service road and main lane construction, with the exception of the third and probably the fourth stages of main lane construction.

3. Socio-Economic Characteristics:

   a. Population changes in the before construction period are faster in the SW study areas. The gap widens in the during and after construction period when the SW study areas experienced 4 times as much an increase as the NW study area;

   b. Housing unit changes follow closely the population trend in both periods and in both areas;

   c. Housing values and rental charges in both periods are higher in the SW study area and

   d. Family income levels are comparable in both study areas.

The land use impacts of stage construction are measured by means of regression analysis and interpreted by interviews with knowledgeable persons and results are given separately below:

1. Regression Analysis - Historic land use data for one-half mile on each side of the study freeways for six separate years are used in the regression analysis. Results of the analysis reveal that single and multiple residential acreages as well as industrial use are more sensitive to nonstage freeway construction whereas the opposite is apparantly true for commercial use. The length of time having a service road present proves to be important in inducing commerical development.
2. Interviews - Interviews with planners, real estate brokers and investors in Houston indicate that staging a freeway's construction does affect land use and development. The differences in the construction schedules are believed to be influential in the development of different land uses.

The user impact of stage construction is evaluated by calculating vehicle user costs with the HEEM's equations for the existing corridor traffic in 1962 and what the user costs would have been for those same vehicles if the service road or freeway had been completed in that year. No induced traffic is considered. The results obtained indicate that costs to users of staging the study freeways are greater than the benefits of delaying construction expenditures. Also it is found that the delay of main lane freeway construction has a greater impact on user costs than delay of service road construction.

It should be pointed out that not all of the benefits and costs of stage construction are included in this study. However, the benefits and costs not included are insignificant and/or very difficult to quantify, especially in dollars. For example, a possible reduction in the highway agency's work load due to stage construction and/or having only enough funds in the budget to construct the facility in stages could be possible benefits of stage construction.

On the other hand, increased driving discomforts and/or slower development of the whole area served by the facility due to constructing the facility in stages could be possible costs of stage construction.

The additional costs of stage construction are probably much greater than the additional benefits of stage construction. Therefore, if such additional benefits and costs of constructing a freeway in stages could be measured in dollars and combined with those measured in this study, the impact of stage construction would likely be more dramatic than the findings indicate.

Recommendations

Several recommendations seem to be in order based on the findings of this study. They are listed as follows.

1. Freeway staging decisions should not be made exclusively on the basis of budget constraints. Other factors such as land use impacts, vehicle user impacts, and overall project costs should be carefully evaluated.
2. Staging effects of other types of highways should be studied. The effects of staging are likely to differ significantly for highways of varying designs.

REFERENCES

1. Kmenta, J., Elements of Econometrics, New York: The Macmillan Co., 1971.

2. Texas Department of Highways and Public Transportation, "Guide to the Highway Economic Evaluation Model," (developed by McKinsey and Co. of Dallas, Texas), Austin, Texas, February 1976.

3. Memmott, Jeffery L. and Buffington, Jesse L., "The Evaluation of High Occupancy Vehicle Projects in the HEEM," Research Report 225-24, Texas Transportation Institute, Texas A&M University, College Station, Texas, January, 1982.

4. Memmott, Jeffery L. and Buffington, Jesse L., "Predicting Traffic Volume Growth Rates Resulting From Changes in Highway Capacity and Land Development," Research Report 225-23, Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1981.

APPENDIX

Table A1. Right of Way and Construction Costs of the NW Freeway by Year and Section

Type of Cost by Year[a]	Cost by Freeway Section[b] 1	2	3	4	Total Cost
	- - - - Thousands of Dollars[c] - - - -				
Right of Way Costs					
1960	87	151	151	271	660
Construction Costs[d]					
1967	346	605	243	-	1,194
1968	367	728	408	-	1,503
1969	-	-	420	1,312	1,732
1970	9	15	7	-	31
1971	-	-	4	273	277
1972	1,319	272	1,151	2,576	5,318
1973	-	-	7	24	31
1974	1,740	-	-	-	1,740
1975	468	3,557	5	15	4,045
1976	-	1,085	3,133	-	4,218
1978	-	-	1,271	4,743	6,014
1979	-	-	19	60	79
1980	-	-	4,665	12,264	16,929
Total Construction Costs	4,249	6,262	11,333	21,267	43,111
Total Cost	4,336	6,413	11,484	21,538	43,771

[a] Year of authorization to purchase right of way or year of letting construction contract.

[b] Some of the costs are prorated among sections on a mileage cost basis.

[c] Rounded to the nearest one thousand.

[d] Includes traffic signal and lighting costs.

Table A2. Right of Way and Construction Costs of the SW Freeway by Year and Section

Type of Cost by Year[a]	Cost by Freeway Section[b] 1	2	3	4	Total Cost
	- - - - Thousands of Dollars[c] - - - -				
Right of Way Costs					
1958	485	64	36	64	649
Construction Costs[d]					
1958	91	352	258	458	1,159
1959	255	-	-	-	255
1960	1,265	1,900	397	478	4,040
1961	124	38	-	-	162
1962	-	179	21	-	200
1963	250	538	-	-	788
1964	29	312	263	189	793
1965	-	100	516	450	1,066
1967	-	62	904	1,576	2,542
1968	-	-	-	864	864
1969				5	5
1971				4,001	4,001
Total Construction Cost	2,014	3,481	2,359	8,021	15,875
Total Cost	2,499	3,545	2,395	8,085	16,524

[a] Year of authorization to purchase right of way or year of letting construction contract.

[b] Some of the costs are prorated among sections on a mileage cost basis.

[c] Rounded to the nearest one thousand.

[d] Includes traffic signal and lighting costs.

Table A3. Twenty-four Hour ADT Counts Used to Calculate User Costs for NW Freeway Study Sections

Year of Count	ADT Counts for Sections of Freeways			
	Section 2		Sections 3 and 4	
	Hempstead Rd	NW Freeway	Hempstead Rd	NW Freeway
1962	17,150	--	9,330	--
1963	20,010	--	10,850	--
1964	20,820	--	11,000	--
1965	21,080	--	13,770	--
1966	21,240	--	13,000	--
1967	23,110	--	14,750	--
1968	22,950	--	15,630	--
1969	24,440	--	18,210	--
1970	23,470	--	19,350	--
1971	22,510	12,400	22,050	--
1972	24,050	13,450	20,320	--
1973	26,060	18,070	25,320	--
1974	26,860	18,010	25,300	21,350[a]
1975	22,770	34,130	14,110	26,380[a]
1976	19,845	34,890	15,207	31,400[a]
1977	18,209	45,530	13,217	36,430[a]
1978	20,182	53,580	19,705	41,460[a]
1979	21,296	61,810	20,851	47,080
1980	19,078	63,000	22,349	51,000

[a] Estimated by trend line.

Table A4. Twenty-four Hour ADT Counts Used to Calculate User Costs for SW Freeway Study Sections

Year of Count	ADT Counts for Sections of Freeway					
	Section 2		Section 3		Section 4	
	South Main	SW Freeway	South Main	SW Freeway	South Main	SW Freeway
1962	12,310	--	17,980	--	11,310	--
1963	10,970	--	10,500	9,700	9,980	7,700
1964	11,410	31,750[a]	10,180[a]	11,120	9,480[a]	9,040
1965	10,410	39,900[a]	9,050	10,700	9,270	9,820
1966	9,940	48,550[a]	8,380	12,060	8,670	10,840
1967	10,210	57,190[a]	8,400	16,170	8,600	14,600
1968	11,090	70,380	8,970	15,860	9,060	14,200
1969	12,510	74,490[a]	9,510	17,870	9,280	15,700
1970	13,260	83,140[a]	9,940	24,210	8,810	16,590
1971	18,810	91,780[a]	14,940	33,780	11,390	20,070
1972	17,850	100,430[a]	14,320	35,570	13,220	21,580
1973	19,610	109,080[a]	16,580	42,580	15,200	28,070
1974	18,950	117,730[a]	14,700	46,610	11,700	26,060
1975	18,370	126,380[a]	15,850	58,570	13,920	33,870
1976	21,560	123,060	15,620	66,910	13,660	35,960
1977	25,530	140,010	16,610	80,490	14,650	45,920
1978	28,360	149,990	19,090	85,980	17,000	48,860
1979	31,160	170,000	22,320	109,070	18,690	60,290
1980	21,000	174,000	16,600	112,000	17,400	56,000

[a] Estimated by trend line.

Table A5. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 2 of NW Freeway from 34th to 43rd Streets[a]

Year	Existing Road		Completed Service Road		Completed Freeway	
	Hempstead	Service Rd	Hempstead	Service Rd	Hempstead	Freeway
	- - - - - - - - - - - - - Thousands of Dollars - - - - - - - - - - - - -					
1962	1,246.1	0	0	1,103.2	0	949.1
1963	1,355.5	0	0	1,201.0	0	1,027.5
1964	1,308.5	0	0	1,159.7	0	990.5
1965	1,227.5	0	0	1,088.0	0	928.8
1966	1,145.6	0	0	1,015.5	0	866.6
1967	1,159.5	0	0	1,028.6	0	874.3
1968	1,065.8	0	0	945.4	0	803.8
1969	1,054.9	0	0	936.3	0	793.5
Total 62-69	9,563.4			8,477.5		
1970	935.7	0			0	705.0
1971	828.9	394.3			0	979.2
1972	823.2	397.0			0	975.8
1973	830.1	499.7			0	820.3
1974	793.9	461.1			0	776.4
1975	616.7	703.2			0	1,115.2
1976	469.5	666.0			0	991.7
1977	397.3	811.0			0	1,076.7
1978	409.7	889.0			0	1,162.7
Total 62-78	15,668.4	4,821.4				15,837.1

[a] Using 8% discount rate and 1962 prices.

Table A6. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Sections 3 and 4 of NW Freeway from 43rd Street to Cole Creek[a]

Year	Existing Road		Completed Service Road		Completed Freeway	
	Hempstead	Service Rd	Hempstead	Service Rd	Hempstead	Freeway
	- - - - - - - - - - - - Thousands of Dollars - - - - - - - - - - - -					
1962	2,305.5	0	0	2,038.7	0	1,781.6
1963	2,490.7	0	0	2,202.7	0	1,921,1
1964	2,338.8	0	0	2,068.4	0	1,803.6
1965	2,727.8	0	0	2,413.2	0	2,095.9
1966	2,380.4	0	0	2,105.6	0	1,830.9
1967	2,510.8	0	0	2,221.5	0	1,926.6
1968	2,468.5	0	0	2,184.5	0	1,891.8
1969	2,679.2	0	0	2,372.5	0	2,045.7
1970	2,643.3	0	0	2,341.4	0	2,014.8
1971	2,807.5	0	0	2,489.3	0	2,131.2
1972	2,385.4	0	0	2,113.7	0	1,815.6
1973	2,786.7	1,547.2	492.3	3,747.1	0	3,506.1
1974	2,578.1	1,909.6	636.0	3,823.8	0	3,661.3
Total 62-74	33,102.7	3,456.7	1,128.3	32,122.4		
1975	1,295.7	2,217.7			0	2,925.6
1976	1,231.2	2,484.4			0	2,933.3
1977	986.1	2,716.9			0	2,901.3
1978	1,383.1	2,919.2			0	3,344.8
1979	1,359.1	3,143.2			0	3,461.0
1980	1,354.0	3,210.0			0	3,477.3
Total 62-80	40,711.9	20,148.1				47,469.5

[a] Using 8% discount rate and 1962 prices.

Table A7. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 2 of SW Freeway from Hillcroft to Beechnut Streets[a]

Year	Existing Road		Completed Freeway	
	S. Main	Service Rd	S. Main	Freeway
	- - - - - - - Thousands of Dollars - - - - - - - -			
1962	1,564.9	0	0	1,204.8
1963	1,287.4	0	0	992.9
1964	1,241.1	2,668.1	0	3,680.8
1965	1,046.1	3,179.5	0	4,048.1
Total	5,139.6	5,847.6		9,926.6

[a] Using 8% discount rate and 1962 prices.

Table A8. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 3 of SW Freeway from Beechnut to Bissonnet Streets[a]

Year	Existing Road		Completed Freeway	
	S. Main	Service Rd	S. Main	Freeway
	- - - - - - - Thousands of Dollars - - - - - - - -			
1962	1,077.8	0	0	829.0
1963	802.8	647.5	0	1,202.5
1964	720.2	688.6	0	1,175.2
1965	591.4	613.1	0	1,007.6
1966	506.3	641.0	0	966.1
1967	470.0	800.4	0	1,079.4
1968	465.2	726.6	0	1,010.3
1969	457.2	760.3	0	1,033.9
Total	5,139.6	5,847.6		9,926.6

[a] Using 8% discount rate and 1962 prices.

Table A9. Discounted User Costs for Existing or Proposed Travel Alternatives Involving Section 4 of SW Freeway from Bissonnet Street to County Line[a]

Year	Existing Road		Completed Freeway	
	S. Main	Service Rd	S. Main	Freeway
	- - - - - - - Thousands of Dollars - - - - - - - -			
1962	1,621.7	0	0	1,250.1
1963	1,321.1	888.7	0	1,820.1
1964	1,160.7	967.7	0	1,766.7
1965	1,050.5	974.2	0	1,687.1
1966	908.6	997.1	0	1,597.1
1967	834.3	1,249.9	0	1,764.4
1968	814.6	1,124.9	0	1,638.1
1969	773.0	1,154.1	0	1,631.5
1970	678.8	1,130.7	0	1,536.6
1971	817.2	1,273.2	0	1,772.1
1972	881.8	1,270.6	0	1,820.6
1973	943.0	1,547.1	0	2,112.4
1974	666.8	1,325.3	0	1,675.4
Total	12,472.2	13,903.6		22,072.2

[a] Using 8% discount rate and 1962 prices.