Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-93+1247-2		

4. Title and Subtitle	5. Report Date
TRAFFIC AND SPATIAL IMPACTS AND THE CLASSIFICATION OF SMALL HIGHWAY-BYPASSED CITIES	October 1992
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
S. Johann Andersen, Hani S. Mahmassani, C. Michael Walton, Mark A. Euritt, and Robert Harrison	Research Report 1247-2
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Research The University of Texas at Austin Austin, Texas 78712-1075	
	11. Contract or Grant No. Research Study 3-8-91/2-1247
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Interim
Texas Department of Transportation Transportation Planning Division P. O. Box 5051 Austin, Texas 78763-5051	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration
Research Study Title: "Economic Impact of Highway Bypasses and Loops"

16. Abstract

This study analyzed the effects of highway bypass construction on small cities. As this report makes clear, a bypass changes activity patterns within a city, with traffic shifting away from the bypassed route. Increased traffic activity is found on the shortest connector from the bypass to the city center, resulting in increased development along this route. The classification of bypassed cities, one of the key objectives of this study, was developed through cluster analysis. The results of the study suggest that a bypass does not significantly alter the essential characteristics of a city; however, the bypass does have a slightly negative effect on retail sales volumes of the bypassed city.

17. Key Words	18. Distribution Statement
Highway bypass construction, small cities, rural, bypassed route, bypassed cities, control cities, variables, cluster analysis, traffic activity	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	116	

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by

S. Johann Andersen
Hani Mahmassani
C. Michael Walton
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Economic Impact of Highway Bypasses and Loops

conducted for the

Texas Department of Transportation

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U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

October 1992

IMPLEMENTATION STATEMENT

This report shows that shifts in the activity pattern of a small city appear to be predictable. The local community can use this knowledge to adjust to the anticipated effects of a bypass. Where the effects are anticipated or perceived to be negative, they can be counteracted by, for example, the timely relocation of some highway-oriented businesses, the addition of highway road signs advertising amenities the city has to offer, or even by changing the nature of downtown facilities to adjust to new market segments.

DISCLAIMER

Hani S. Mahmassani, P.E. *(Texas No. 57545)*
C. Michael Walton, P.E. *(Texas No. 46293)*
Research Supervisors

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.0765	meters cubed	m^3

NOTE: Volumes greater than 1,000 L shall be shown in m^3.

TEMPERATURE (exact)				
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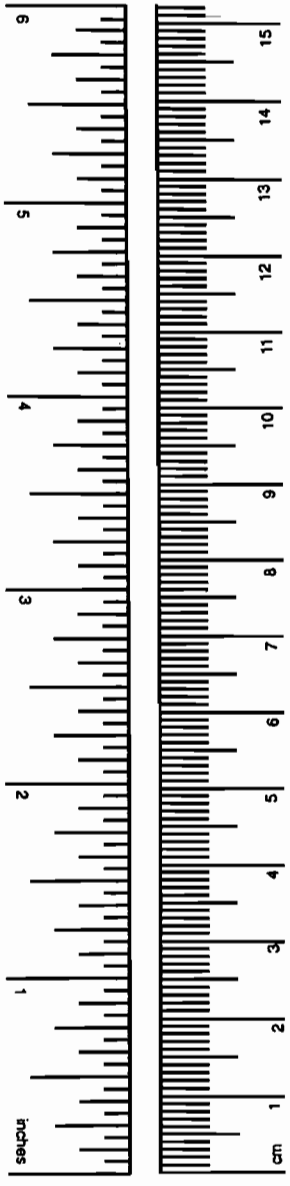

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
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m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.20	square yards	yd^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1,000 kg)	1.103	short tons	T
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
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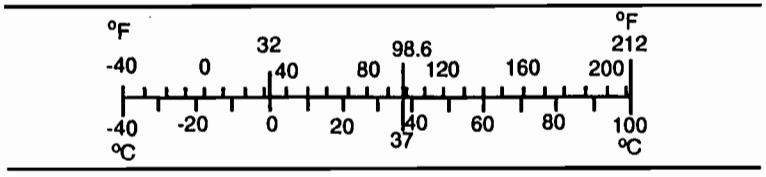

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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SUMMARY

This project studied traffic and spatial changes brought about by highway bypass construction in small cities in a predominantly rural setting. The possibility of an underlying structure within the bypassed cities was also explored. A database was established, containing data on pertinent variables for both bypassed cities and control cities. Control cities were introduced to control for the effect of the bypass. Case studies of several Texas cities were performed to provide insights regarding traffic and spatial changes within a bypassed city. Cluster analysis, a multivariate statistical procedure, was used to explore the possible existence of an underlying structure within the bypassed cities. Conclusions and recommendations derived from this study are also reported.

CHAPTER 1. INTRODUCTION

Historically, transportation has had undeniable effects on communities and their development. The location of communities has often been determined by access to a transportation artery, be it a river or railroad. Since its advent, the automobile has become the primary mode of travel for most individuals in most industrialized societies and has been a prime factor in shaping the settlement patterns of cities.

The increasing number of vehicles led to considerable investment in road infrastructure. Mobility became a key issue in both rural and urban society, and congestion a major problem in most urbanized areas. Traditionally, congestion is relieved by increasing the capacity of the road network through the construction of new facilities or by adding lanes to the existing system. A circumferential loop is a common feature in urbanized areas to enhance both inter- and intracity mobility.

Traffic congestion is also evident in smaller rural areas, though to a much lesser extent. Increased mobility led to an increased use of rural highways, which in turn led to a greater volume of traffic passing through small cities in largely rural areas. Often the through traffic may be composed of a large percentage of heavy vehicles, a situation that has provoked concerns about safety and the environment. Frequent passing through these cities became quite an impediment for the intercity or interstate traveller. A natural solution was to construct highway bypasses that re-routed through traffic around such cities.

Road investment in highway bypass construction normally produces benefits for road users in reduced journey times, decreased vehicle operating costs, and improved safety. It also reduces environmental nuisance from traffic to residents and pedestrians along the bypassed roads.

This movement towards bypasses, however, has not met with unanimous approval. Owners of businesses in the bypassed areas, as a group, have generally resisted efforts to build bypasses in the belief that large numbers of customers would be diverted from the business district and that the community's economic health would be impaired. These effects, it was felt, would not be experienced equally by all establishments. Businesses catering largely to the needs of transient motorists would be adversely affected the most, especially if they remained in their original location near the old route.

This movement in favor of bypasses, as well as that opposing them, was recognized by the Congress of the United States in a 1950 act that mandated public hearings in any city where a bypass was contemplated.[1]*

Many studies have attempted to assess the effects of bypasses on communities, with most of them focusing on business activity. However, business activity is only one area of economic activity, and bypasses have effects on other parts of the community's economic structure. Several of these effects are equally important, although less emphasis might have been placed on them. There is little information on how the shifts in traffic after bypass construction affect land use, commerce, and development in the bypassed towns. The intensity of use of business facilities may be affected in one of two ways: it may stimulate greater use owing to a more pleasant environment (less traffic congestion) and improved accessibility, or else it may cause a decrease in use owing to traffic being diverted away from the business district, thereby losing potential customers. Furthermore, a bypass introduces a new and important physical element into the community's environment. If a relocated highway bypassing a community formerly traversed it, the relationship between the community and the highway is significantly altered.

It is evident that different communities are affected differently by a bypass. Cities that share certain characteristics may respond in similar ways to this new feature. To date, it appears that no attempt has been made to group bypassed cities according to characteristics related to bypass impacts.

* Notes begin on page 63.

STUDY OBJECTIVES

The objective of this study is threefold:

(1) Explore and analyze traffic changes brought about by bypass construction in small cities in essentially rural areas.
(2) Establish and document spatial changes caused by the bypass in these areas. In particular, there will be a focus on spatial changes of highway-related businesses.
(3) Develop a classification of bypassed cities according to relevant characteristics.

These objectives will seek to uncover some of the latent characteristics of traffic and spatial impacts, thereby illustrating how the bypass changes the structure of a community. In concurrence with the classification system, a predictive framework will be provided, allowing planners to anticipate possible impacts resulting from bypass construction around a city (given certain characteristics).

OVERVIEW

This report is structured chronologically, starting with the impetus for this research, continuing through the exploratory analysis of the data, and ending with the development and application of a procedure for classifying bypassed cities in a rural setting.

Chapter 2 presents a literature review that focuses on existing knowledge pertaining to traffic and spatial impacts of bypasses. This is presented against the background of existing trends in rural areas, with emphasis on the importance of the relationship between highway transportation and development. Applicable methodologies for this type of research are also discussed.

Chapter 3 defines various types of bypasses arising from the development of an inventory of bypassed cities in Texas. The development of a database is also discussed and sampling procedures for various types of analysis are presented.

Chapter 4 discusses the general nature of traffic in a bypassed city. Changes in travel patterns, travel behavior and trends are presented in various formats supplemented by knowledge obtained from case studies. It then presents spatial models of city forms, showing the changing face of a bypassed city over time. The difference between highway-oriented and non-highway-oriented businesses is emphasized. This is again supplemented by field data.

In Chapter 5 the classification procedure is discussed. Results of this grouping process are presented (along with the logic behind it).

Finally, Chapter 6 presents a summary of research results and possible applications of the findings.

CHAPTER 2. LITERATURE REVIEW

The following literature review is divided into five sections. The first section provides an overview of literature covering the effect of a bypass on a community in a rural setting and the community leaders' and residents' attitude towards it. The second section discusses existing trends in rural America, providing the context within which bypass-related changes should be seen. Section three deals with current literature on small city traffic and traffic-related impacts on a bypassed city. Spatial changes resulting from the bypass are discussed in the next section. The last section provides an overview of methodologies useful in this study.

2.1 GENERAL IMPACTS OF BYPASSES

There is evidence suggesting that different communities are affected in different ways by bypasses. By changing the nature of trade area boundaries and by altering the relationship of one town to another, the bypasses can decrease economic activity in one community and increase it in another.

Bypass studies to date have mainly focused on business activity, using sales tax data to analyze the effects of bypasses.[2] Many of these studies appear to have been performed for public relations purposes, trying to answer questions regarding bypass effects pertaining to the economic well-being of the community as a whole by looking at specific merchants and types of industry.

Generally bypasses, though highly desired by through travelers, were not welcomed by local business interests on the basis that the community would suffer a reduction in retail trade. A definite decline in business activity was documented by Wootan and Meuth (1960)[3] in their study of bypass impacts on Temple, Texas. However, these authors also state that they cannot ascertain with a high degree of certainty whether this loss in sales was a result of the bypass or whether external factors determined the business pattern. Horwood, Zellner and Ludwig (1965) critically examined 24 bypass studies relating to 72 communities.[4] Business activity was broken into two main categories, namely, highway-oriented and non-highway-oriented businesses. Businesses in the former category were adversely affected the most. Service stations and restaurants were often sufficiently able to adjust to economic changes brought about by the bypass by reorienting their merchandise to local trade. The latter finding is also substantiated by Siccardi (1986)[5] in his assessment of economic effects of highway construction.

It was also found that community size may play an important role in the community's ability to adjust to economic change. The analysis by Horwood et al indicated that the impacts of the bypass were more likely to be visible in small towns than in larger places. Cities having a population of 5,000 or less appear to be affected differently by bypasses than do cities whose population exceeds 5,000. A 1989 study of bypasses conducted by the Iowa Department of Transportation[6] partially substantiated the latter finding. They observed that cities with a population greater than 2,000 would be more likely to benefit from a bypass; conversely, cities with fewer than 500 people would experience the greatest adverse impact. In contradiction to these suggestions, the Glenwood bypass study[7] showed that a city approximating the 1,000 population class can be advantageously served by a highway bypass. It is said that in Glenwood "all observed facets of the local economy have received benefits from the well-designed and efficiently operating U.S. 70 bypass facility." However, as Pashek (1965)[8] pointed out in a later review of the report by Horwood et al, it is not community size that is the important variable; rather, it is the relationship of the community to surrounding areas (e.g., its function as a trade center). It was also suggested that small towns without central-place importance may suffer substantially from a highway bypass.

Previous bypass studies did not document actual traffic and spatial changes, which are essential in analyzing some of the finer consequences

of bypass construction. Furthermore, small cities in rural areas do not operate as closed entities. They are intrinsically part of a larger economic and social fabric, which must be recognized when attempting to draw inferences about bypassed cities. The following section presents an overview of this "bigger picture" with regard to current trends in rural areas, with emphasis on the supply-demand relationship between highway transportation and development.

2.2 CURRENT TRENDS IN RURAL AMERICA

Rural America has undergone fundamental economic and social changes in recent years.[9] The second half of the twentieth century is marked by both intensification and discontinuation of major socioeconomic trends of earlier eras. Garkovich (1989)[10] recognized three trends that are of particular relevance to the restructured population of rural America: continued diffusion of urban influences into rural areas, changes in attitude towards urban living, and continued structural transformations of the economy.

Today these trends are evident in many small cities. These cities have traditionally served as trade and service centers for their rural hinterlands, and have represented important sources of employment opportunities for nearby rural people through commutation or migration. Fewer and fewer residents depend on farming. Agriculture's reorganization, including a reduction of the number of farms, a shift from family-owned-and-operated to corporate-owned farms and increased mechanization contributed to this fact.[11] Migration streams during this era can also be differentiated by the age composition of the streams. A wide variety of studies conducted in different areas of the county confirm that the rural-to-urban migration was essentially a movement of the young. Deconcentration around large cities had extended urban and metropolitan influences outward, penetrating deeply into what was formerly rural areas. The continuing centralization of trade, economic, and social relationships had diminished the importance of many small towns.[12]

For at least 100 years there has been considerable concern about the fate of the declining small city bypassed by trade routes or industry.[13] A common expectation was that small cities were doomed to fail as the automobile and better roads and communications freed rural residents from their dependency on local merchants.[14] Johansen and Fuguitt mention numerous examples supporting earlier predictions of decline, especially among retail trade centers in agricultural areas where, today, empty storefronts abound along once busy main streets. Yet, even in cities with the most deserted main streets one often finds nearly complete occupancy of houses, albeit with fewer and perhaps older people in each. A strong will to survive is evident in many of these communities.

The ability of a community to retain its residents is largely dependent on its economic base.[15] Agricultural communities have experienced a nearly steady loss of population while many mining communities experienced cycles of population growth and decline in response to the demand for their particular resource base. The relative importance of an economic base is also addressed by Humphrey and Sell (1975).[16] They found that small cities most subject to a decline in population are mining communities, single-industry centers, or lumber towns with depleted natural resources. On the other hand, places serving as county seats have been found to contribute to non-metropolitan growth. A place with controlled access was found to have the same effect. They then conclude that the impact of highways was most often secondary to other determinants of nonmetropolitan growth, including the population density of these places, distance to a metropolitan community, and the existence of a college or military installation in the area. Hence, the great diversity in economic bases among rural communities both produced and resulted from differential patterns of migration.

Although one can characterize cities by economic base and other readily available characteristics, this approach may lead to inappropriate generalizations about cities in the changing rural and urban settlement structure. Johansen and Fuguitt (1984)[17] pointed out that such an approach lacks the fine texture of what is happening in these places and also the subjective element provided by local residents themselves.

Transportation improvements must be seen against the background of the changing face of rural America. It has been shown in the geographical literature that the effects of transportation improvements are hard to predict and not necessarily beneficial. Drew (1990)[18] recognized that one must keep in mind that a good transportation system is necessary but not a sufficient condition for development. In a study by Garrison et al (1959),[19] the impact of highway development on small town competitiveness was examined. They showed that for places that happened to be located close to highway intersections, a short-run benefit was experienced, but whether this translated into a permanent stimulus to growth depended on the distance of these places from other larger towns. In some

cases increased competition from these older towns led to a long-run negative impact, despite the fact that the highway had increased the accessibility of these economic establishments. Although not mentioned by these authors, it is realized that accessibility works both ways. Easier access to the larger city would probably cause residents of the small town to seek out opportunities in the larger city.

The interdependence of transportation and economic development was recognized in a study prepared for the Minnesota Department of Transportation (1989).[20] One general observation that was restated in this research is that the spatial economic system is very unpredictable. The unpredictability is said to take two forms. First, the short-term behavior can be very different from what happens in the long run. Second, external factors, such as change in state policy or changes in the international economy, can alter the entire direction of change that is occurring in the system.

Gillis (1989)[21] points out that the transportation networks designed to support the needs of a rural economy decades ago are no longer adequate. Shifts in the rural economic base, policy changes, and technological and organizational innovations have influenced transportation needs in rural areas. As a result of the decrease in agricultural activities and the rapid increase in manufacturing activities, the quantity and type of traffic using rural roads have changed dramatically, requiring major investments for the road infrastructure.

The dynamics of the activity system in the rural local and regional context should be assessed before drawing conclusions about bypass effects. The framework for drawing inferences about traffic and spatial impacts is now set.

2.3 TRAFFIC IMPACTS

The Nature of Traffic in Small Cities

Traffic in small cities in a rural setting is usually different in nature, in magnitude, and in context from that found in larger areas. It is imperative that one understand the character of traffic in these smaller cities and how it differs from traffic generated in the urban context. Traffic changes that occur with the advent of the bypass should be interpreted within this local context.

Generally, trips within a city boundary can be stratified into three groups, namely:

- Internal-internal trips, which are those with both trip ends within the city area. It is normally adequate to characterize small-city trips by the following trip purposes: Home-Based Work (HBW), Home-Based Other (HBO) and Non-Home Based (NHB)
- Internal-external trips, with one end inside the city area and the other outside.
- External-external or through trips, with both ends outside the city boundaries.[22]

The number of through trips is, among other things, a function of the city population. Michael (1953)[23] reported the results of various origin-destination surveys showing how the percentage of through traffic approaching a city decreases as the city size increases, as illustrated in Figure 2.1. This is of particular interest for this study since it shows the need and relative use of bypasses in these cities to a certain extent.

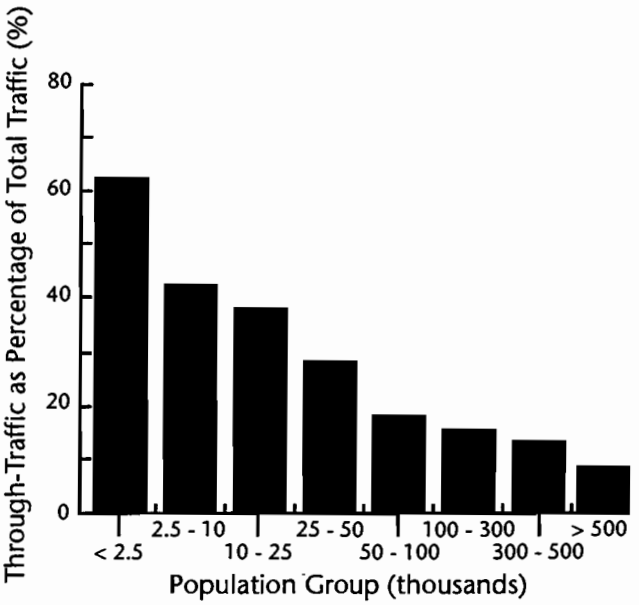


Figure 2.1 Typical through traffic percentages for cities in different population classes[24]

Small communities rely almost completely on the automobile for mobility. Various researchers[25, 26] have documented higher passenger car trip rates for small cities when compared with the trip rates of large urban areas. It is also seen that, in view of the physical size of small communities and the fact that average trip duration is only about one-third of that of the longest trip, trip impedance does not seem to play a significant role in trip distribution. In this regard it is mentioned by Teply[27] that in several small

western Canadian communities the highest traffic peak of the day was experienced around noon, when employees go home for lunch.

Post-bypass Changes in Traffic

With the construction of a bypass it is reasonable to expect quite significant changes in traffic patterns in and around small cities. One would obviously expect the biggest decrease in traffic to occur on the former main route through the city. This occurrence was documented by both Mackie (1983)[28] and Michael.[29] Mackie documented bypass effects on 32 cities in Great Britain (ranging in population between 1,700 and 112,000) that were bypassed between 1970 and 1980. The traffic data presented indicate a relation between the city size and the amount of traffic relief to be expected from the building of a bypass. Only in cities with population less than 10,000 can it be expected that traffic decreases would be greater than 50 percent.

This finding is also substantiated by an investigation of the bypass effects on two cities in Indiana.[30] In the case of Kokomo (35,000 population), only 22 percent of approaching traffic was not destined for the city. Ninety percent of all through traffic, including a large percentage of trucks, used the bypass (decreasing the traffic activity in downtown Kokomo by only 10 percent). It is also noted that a large portion of trips on the bypass were local vehicles, mainly because of its proximity to the city. In the other city, Lebanon, with a population less than 10,000, about 60 percent of approaching traffic is destined for other points. The location of the bypass was away from the developed parts of the city. It is also noted that the bypass did not seem to cause a big decrease in through travellers stopping in Lebanon; through traffic needing a stop would do so whether there was a bypass or not. These data also indicate that less than 25 percent of the total through traffic desired to stop within the cities. It should be noted that Kokomo is a growing industrial city in the center of an agricultural area, while Lebanon, though also situated in an agricultural community, is not heavily industrialized.

In Glenwood, Arkansas,[31] it is reported that the construction of the bypass did not have any significant effect on the growth of traffic entering or exiting the city. An analysis performed on the annual daily traffic counts showed that traffic increased at a consistent rate spanning the time the city was bypassed.

Benefits from Bypass Construction

Traffic changes caused by the construction of a bypass, most notably the relief of through traffic, produce benefits for both users and non-users. Beneficial effects associated with freeway construction were studied and described by Gamble and Davinroy (1978).[32] These beneficial effects can be classified into three main groups: economic, social, and environmental. Generally, economic benefits realized from bypass construction are reflected in improved accessibility (i.e., reduced travel time) and decreased vehicle operating costs. Other direct economic benefits include reduction of accidents, injuries, and fatalities and their associated costs. Benefits are also derived from improved efficiency in all kinds of public services. Environmental effects pertain to the reduction of noise and improvement of air quality through reduction of emissions along the bypassed route. Both economic and environmental effects have been studied and reported and are taken into account in current road appraisal methods in the form of cost-benefit analyses and environmental appraisals. More difficult to quantify are the social benefits accruing to the individuals concerned, such as improved accessibility and freedom of choice, better health and safety, and reduced congestion leading to less irritability and stress.

Various benefits are taken into account when assessing the merits of alternative schemes. Feeney (1984)[33] describes a methodology for small city bypasses using benefit cost analysis. He compares the construction costs of a proposed bypass with the sum of the travel time, operating, accident and maintenance cost savings resulting from it. These same basic concepts form part of the Highway Economic Evaluation Model (HEEM),[34] currently used by the Texas Department of Transportation. Seskin[35] presents a framework for assessing user benefits but expands current techniques by adding an assessment of regional economic benefits. By taking into account changes in business costs and comparing this with areas not affected by the proposed improvement, more significant benefits are included than would have been identified solely by traditional user-benefit analysis.

In considering some of the elements for cost-benefit calculations, we examined the effect of a bypass on accident occurrence. Michael[36] reports that accidents on the former route through the cities were fewer in number after the bypasses were opened. However, there were some fatal accidents on the bypass. This led him to believe

that increased speeds on the open highway caused accidents on the bypasses to be more severe than if they had occurred on the old routes. A slight increase in the number of accidents on the new highway configuration was observed when compared with the pre-bypass period. The Iowa DOT reports a dramatic improvement in accident rates along the bypassed route. Accident experience in the city of Pitlochry, a small tourist town in Scotland, is very positive.[37] Total accidents on both the bypass and bypassed route decreased by nearly 50 percent since the opening of the bypass. Increased safety was one of the main reasons cited by the Department of Public Works of the State of California (1959)[38] for the increase in local shoppers in Camarillo. In this way both the road user and non-user benefited from the increased safety resulting from bypass construction.

As mentioned earlier, improved accessibility is another prime consequence of bypass construction, both locally and regionally. Mackie[39] recognized that this occurred particularly in areas close to the bypass interchanges. Improved accessibility in a region-wide context is reported by Garrison and Marts (1958)[40] in a study of the geographic impact of highway improvement in the vicinity of Marysville. This resulted in local residents travelling to a nearby city more frequently than they did prior to the highway improvement.

While the importance of travel time was recognized by Pashek, he suggested that the travel time from a given community to a neighboring community was not changed by the bypass. Often a bypass was constructed along with a general improvement of the highway to neighboring communities. The travel-time savings were thus due to the improved highway link and not necessarily to the bypass.

Garrison and Marts[41] hypothesized that the availability of parking would substantially increase in cities where most of the through traffic is diverted. In this way, local businesses would be made more attractive. No significant change in parking was noted by local residents in Marysville. Studies performed by the Ohio Department of Highways[42] suggested that improved parking for local shoppers was one of the benefits of less congestion on the bypassed route. A before-and-after study of parking conditions was performed in Circleville. Results from the study show that the number of people parking, as well as the time needed to park, increased substantially. In the city of Auburn, California,[43] both parking and the number of shoppers increased on the old route.

With the diversion of through traffic, cities can take advantage of less traffic downtown and increase facilities for pedestrians. Such schemes were found in six of the cities Mackie[44] studied. However, he remarks that the smaller the city, the less likely that such a scheme would be fully utilized.

Highway Characteristics

The classification of the road system as post-bypass is an indication of the relative importance of roads to the user. The experience in Great Britain is that quite often the bypassed routes ceased to be classified as trunk roads when the bypasses were opened.[45] The reclassification was probably due to the decreased activity on the bypassed route.

The presence of proper signing on the highway routes might have quite significant economic impacts on the bypassed city. A report of the Iowa Department of Transportation[46] emphasizes the importance of proper road signs; among other observations, they note that adverse impacts on motels, in particular, will be reduced by advertising on the bypass.

The significant role that the type of access plays proceeds from experience gained in Indiana.[47] At a new bypass location in that state, access points tripled within two years, resulting in substantially higher travel times on these routes. Limited access and service roads were offered as ways to deal with this problem. Limited access roads provide preferred locations for many types of businesses, especially drive-in businesses such as banks, restaurants, and department stores. The highway provided a wide market for these businesses (i.e., proximity to the highway often translates into business visibility, an important form of advertising).

Highway alignment is another highway characteristic that can have a significant effect on a community. This was experienced in the Scottish city of Pitlochry,[48] situated in an area of outstanding beauty. In this case it was essential that any bypass should maintain a view of the city and provide good access to and from the city to continue to attract through traffic. This city was dependent on touring traffic during the summer months and the view from the road was therefore of particular importance. Local residents were satisfied that the new bypass satisfied these requirements (no local businesses suffered any significant losses as a result of the bypass).

It is evident that the advent of a bypass can result in various changes in a small city. Traffic and spatial impacts are deeply intertwined in this context, the one to a large degree dependent on

the other. This will also be evident in the next section, where spatial impacts are reviewed.

2.4 SPATIAL IMPACTS

The economic use of land as a result of the physical expansion of a community has an important effect on the community's economic structure.

The cliché "form follows function" is often used in the context of urban planning. This also applies to the physical form or patterns of a community, although a community is limited by its physical and economic environment. Several geographers and economists have developed economic models of community growth under simplified assumptions. Von Thunen[49] worked with concentric zones of development, as did Burgess and Spratt (1985)[50] much later, though with distinctly different frameworks. Star patterns based on transportation were introduced as modifications of concentric patterns affected by differences in transportation. Other variations in form are the result of variations in terrain and the occurrence of such other physical elements as rivers and lakes. Constructed physical units such as a highway bypass have a definite influence on the form. These physical barriers are important, and the frictions or obstacles they present modify simple models of form. A bypass, then, may act as a physical barrier to growth, particular for a small community (since it is basically one operating unit). Vargha (1960) studied community growth in various areas in Michigan.[51] He pointed out that while a bypass may stymie growth in a particular direction, the overall area may still continue to grow.

The Bypass as a Physical Boundary

The effect of bypass location was documented by Mackie[52] in his study of 32 bypassed cities in Great Britain. If a bypass was built too close to the city, it was often used by the planning authority as a limit to development. It was unusual for development to be allowed to breach the physical boundary of the bypass and this was often given as a reason for refusal to allow development beyond it. A highway and its bypass routes can thus have a considerable impact on the city's growth pattern. The effect of bypass location was also recognized by Skorpa, Walton and Huddleston (1974).[53] They mention that, in order to allow the city to grow in an orderly manner, the bypass should be located a considerable distance away from the community's prime growth center.

The Effect on Residential Development

While land located between the new bypass and the city would ordinarily appear attractive for housing development, there was no indication in the literature that this land was developed in preference to other locations around a city. Relocation of residents necessitated by a new bypass was investigated by Thiel.[54] Investigations in several different locations indicate that displaced residents often improve their living conditions. Planners were reluctant to allow development to breach the bypass; therefore, once any enclosed land was developed, there was then a tendency to prefer other fringe areas of the city. However, Buffington[55] reports in an economic impact study of Interstate 35 in Waxahachie that city limits were extended beyond the bypass.

The Effect on Existing Land Use

It was found that, in general, businesses and residential areas moved out toward the bypass. This generally meant a loss of agricultural land, including the land used for the actual construction of the bypass. A slight loss in agricultural productivity can thus be inferred. In many cases it was possible to minimize the effect on agriculture at the planning stage.[56] The loss of agricultural land was also discussed by Wootan and Meuth.[57] They found in the case of Temple that where land was not taken up for commercial and residential uses, land abutting the new bypass was held for future use.

Another influence of the bypass on development occurred along the old route, where traffic normally decreases significantly. Mackie[58] reported that the consequent traffic implications of proposed new developments accessing these roads were considered less serious than before, and development of small areas of land that would not have been permitted prior to the bypass were permitted after the bypass opened.

The Effect on Businesses

Businesses catering largely to the needs of the transient motorists are said to be adversely affected the most if they remain in their original location near the old route. Development tends to take place at interchange areas and focuses mainly on service stations, restaurants, and motels. The relocation of highway-oriented businesses and development at interchanges were documented in the review of bypass studies in

Iowa.[59] This was required because the decreased traffic volumes could no longer support the businesses on the old route. In some instances these intense roadside and interchange area commercial developments have not appeared. In Glenwood it was observed that the traffic stream consists of a high percentage of vehicles having a local trip-end purpose. It was also found in Glenwood that businessmen are reluctant to bear the financial risk of abandoning a successful, established business location in favor of a new roadside location, where the possibility exists of gaining a small margin of highway traffic trade.

The attractiveness of peripheral sites near bypass interchanges to "super stores" was another occurrence documented by Mackie.[60] However, many planning authorities in Great Britain have resisted such development for fear of weakening businesses in that center. Only 2 of the 32 cities studied by Mackie had seen such development occur.

In the study of Auburn, California,[61] it is interesting to note that the very best business locations were not fronting the highway through the city, but rather were located slightly removed from it. Apparently the heavy traffic along the highway had hampered business growth. It was not until after bypass construction began and the prospect of through traffic removal became a certainty that new retail businesses began building on the old route again.

One should also be aware of the competitive nature of these highway-oriented businesses. For example, the opening and closing of service stations caused by the restructuring of the gasoline retail industry should not be confused with the effects of the bypass. Mention was made of service stations in Glenwood that closed for reasons not related to the bypass.[62]

The Effect on Industrial Development and Its Location Strategies

The location of new industrial development is influenced by the construction of the bypass. This is another phenomenon addressed by Mackie,[63] who observed that new industry located predominantly near the bypass, often on new industrial sites on former agricultural land near bypass access points. It was felt that industry might be particularly attracted in those cases where the bypass formed part of a long-distance national route. Warehousing in particular tended to locate at these new industrial sites close to bypasses (since these provided local labor and good accessibility regionally).

Skorpa et al[64] also studied the location strategies of industry development and stressed the importance of being proximate to a major highway. However, it was found that little priority was given to specific types of highway facilities. If the road was paved and in good condition, it was judged adequate. Wilson et al[65] rated highway location fourth as far as strategic factors affecting industry settlement is concerned. They deemed proximity to a prospective market, proximity to the required raw materials, and availability of labor more important than highway accessibility. This fact is also underscored in the Glenwood bypass study. The location and types of raw material resources had been the controlling factor in the selection of plant locations for the sawmills and mineral processing plants in Glenwood. The bypass did not have much significance in the operation of any of Glenwood's industries, except insofar as the improvement of highways in general facilitates the movement of people, goods, and services for the total welfare of the area. Glenwood also did not have a sufficiently large population to supply the total labor force needed by all the industries. Many commute from neighborhood communities.

2.5 METHODOLOGIES

It is appropriate when investigating impacts related to traffic and spatial changes to employ several methods in order to shed light on as many facets of the problem as practicable. Skorpa et al[66] summarized various methodologies, of which the following are briefly discussed: before-and-after, case study, and the survey-control area method. There is also a short section discussing the validity of opinions as a method. This section then concludes by introducing the concept of classification, focusing on cluster analysis.

Before-and-after Technique

One of the techniques most commonly used to study highway impacts is the before-and-after technique. This methodology was utilized by various researchers and agencies in addressing the impact of a bypass on a community.[70] The main advantage of this technique is that it is simple to apply and easy to understand. The technique measures the value of some characteristic of an area before and then after highway improvement; the difference is then said to be the effect of the improvement. Consequently, the only quantity measured is the change in value between one time period and another. The principal limitation

of this approach is that it cannot relate the measured effect to any specific cause. Thus it cannot determine whether an effect is, or is not, caused by the road improvement.

Case Studies

Case studies are often combined with the before-and-after technique. A case study deals with a rather detailed analysis of specific events which have taken place. While detailed knowledge about the cause/effect relationship in the specific case may be obtained, the findings are not claimed to be general. The value of case studies lies in the possibilities for detailed analysis, and thereby in providing experience on which broader studies can be based.

Survey-control Area Method

The most common technique used to isolate highway improvement is the survey-control area technique.[68] In theory the survey area and the control area would have to be exactly alike in all respects during the period just prior to the highway improvement. Also, the factors affecting development in the two areas should be the same (with the exception of the highway improvement). These requirements are normally difficult to meet, as the spatial limits or distribution of the highway impact are not known in advance; moreover, it is difficult to gather information relating to all non-highway-related factors. The survey-control area approach does not give any information about the spatial distribution of the impact unless the survey area is divided into sectors, bands, etc. The effect of the different factors will not be evenly distributed over the two areas. When the average for each area is used, the character of this spatial distribution is lost, and thus the interpretation of any results of the study would be limited. Generally, the control area was chosen to be part of the city being studied. In such a case it is very difficult to isolate the impact on the survey area from the impact on the control area. Horwood et al[69] noted the extensive use of this method when summarizing the statistics of various bypass studies.

Opinions

Opinions as such can be seen as an extension of any of the previous approaches. Opinions normally do not form an accurate and objective arithmetical measurement of circumstances associated with highway facility construction;[70] however, opinions expressed do often bring to light obscure but highly significant local factors sometimes overlooked by professional planners and highway engineers engaged in selecting the most operable and economical facility location and design.

The Classification of Bypassed Cities

The last section of this review deals with the development of a typology or classification system. This is a fundamental process in the practice of science, since classificatory systems contain the concepts necessary for the development of theories within a science. No attempt has yet been made to classify bypassed cities. One of the most appropriate methods to obtain this classification is cluster analysis.

Cluster analysis is a multivariate statistical procedure that starts with a data set containing information about a sample of entities and attempts to organize these entities into relatively homogeneous groups.[71] There are various ways to compute similarities between entities, including the use of correlation coefficients and distance measures. Different heuristic clustering methods can then be used to obtain the various groupings. Cluster analysis has found application in a variety of fields. The social sciences have long maintained an interest in cluster analysis.[72] In the field of transportation engineering, Townsend (1991),[73] among others, used cluster analysis for the classification and analysis of the multi-day travel/activity patterns of households and their members. He then explored the combination of characteristics that are important in determining the pattern group membership of each individual household.

2.6 CLOSURE

This chapter provided some insight into the general impacts of bypasses. It was seen that different communities are affected in different ways by bypasses. One of the major concerns of a community is the effect of a bypass on highway-related businesses.

Bypass-related changes should be seen in relation to existing trends in rural America. Continued rural-to-urban migration was essentially a movement of the young. Fewer and fewer residents depend on farming. Deconcentration around large cities had extended into what was formerly rural areas. One researcher even observed that the continuation of trade, economic, and social relationships had diminished the importance of many small towns.

Small-city traffic differs from traffic in larger areas. With the construction of a bypass, quite significant changes in traffic around small cities were reported. Several benefits of bypass construction were also mentioned.

Spatial impacts are deeply intertwined with traffic impacts, as was pointed out in Section 2.4. The bypass has an effect on the location and development of many types of land use, including residential areas, various types of businesses, and industrial development.

Lastly, various methods were presented to approach this problem. The before-and-after, case study, and survey-control area method are examples of typical methodologies used to determine the effect of a bypass. Cluster analysis was introduced as a multivariate statistical procedure to categorize bypassed cities.

CHAPTER 3. DATA ACQUISITION

The first part of this chapter identifies and categorizes highway bypasses. It then outlines the procedure followed to obtain the sample of bypasses and control cities in Texas used in this study. The second section presents observations made during site visits to three of these bypassed cities. These visits provided first-hand familiarity with the physical and economic setting of such cities and were a valuable aid in determining pertinent variables for the purposes of this study. The last section introduces these pertinent variables and provides an explanation of the data collection procedure and data sources.

3.1 BYPASS CATEGORIZATION AND SAMPLING PROCEDURE

It is first necessary to give a precise definition of a bypass. A highway bypass is that segment of a new highway intended to reroute though traffic around a central business district, leaving the remainder of the intercity route unchanged. The former route through the central business district is termed the bypassed route. The bypass is formed once it links up with the bypassed route on the opposite side of the city from where the highway entered the city.

A total of 103 highway bypasses with characteristics relevant to the objectives of this study were identified in Texas. The locations of these bypasses are shown in Figure 3.1. All of these bypasses are listed in the appendix.

The interstate bypasses are excluded from this analysis, since the interstate system is largely in place and future bypass construction will involve mainly state and U.S. highways. It is also postulated that the characteristics of the road users on the interstate system are different from those using other highways. State and U.S. highway bypasses were categorized by highway characteristics, geographical location, population characteristics, and year of construction. These categories are discussed below.

Highway Characteristics

The following types of bypasses were defined following a review of Texas district traffic maps and Texas county maps:

Standard Bypass

As illustrated in Figure 3.2, this type conforms to the earlier definition of a bypass. There are currently ninety (90) standard bypasses in Texas.

Multiple-city Bypass

This type is similar to the standard bypass, with the exception that more than one city is bypassed. Generally these bypassed cities are in proximity to each other. Consequently, it is difficult to assess the impacts on a single location, since the cities may be interdependent. This type was excluded from the analysis at an early stage. As a result, bypasses of this type are not listed in the appendix. The multiple-city bypass is illustrated in Figure 3.3.

Multiple-highway Bypass

In some cases, a state or U.S. highway bypass was built after the first bypass. This is often the first stage in the development of a loop. Figure 3.4 illustrates this type of bypass. Currently there are six (6) of these bypasses in Texas.

Partial Bypass

A bypass segment not directly linked to the bypassed route on the other side of the city is called a partial bypass. Typically, the partial bypass connects to another highway also passing through the city. The through traffic demand generally does not justify the development of a standard highway bypass. The partial bypass may also represent a phase of construction, eventually leading to a standard bypass at completion. Because

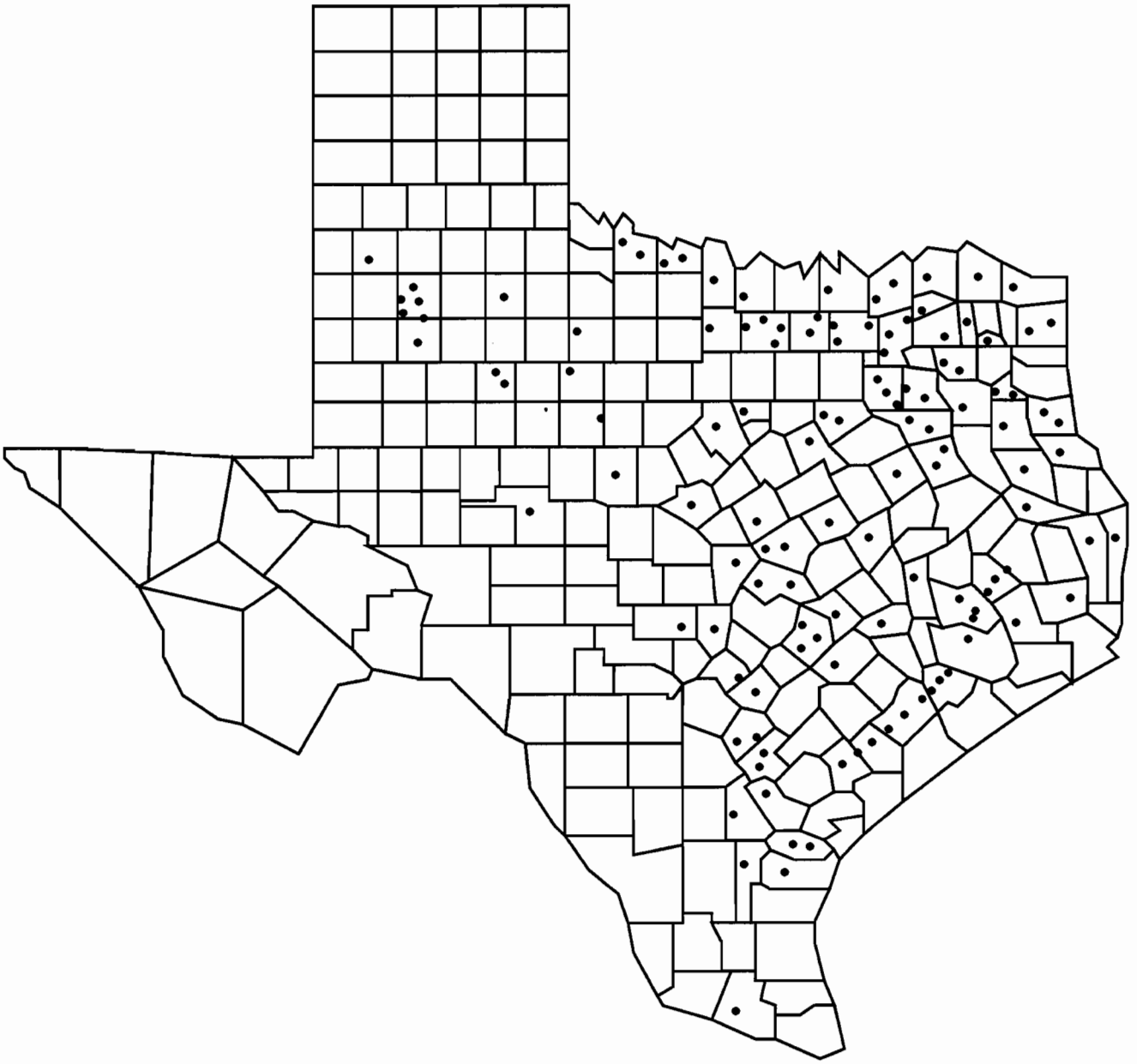


Figure 3.1 Geographical location of bypassed cities in Texas

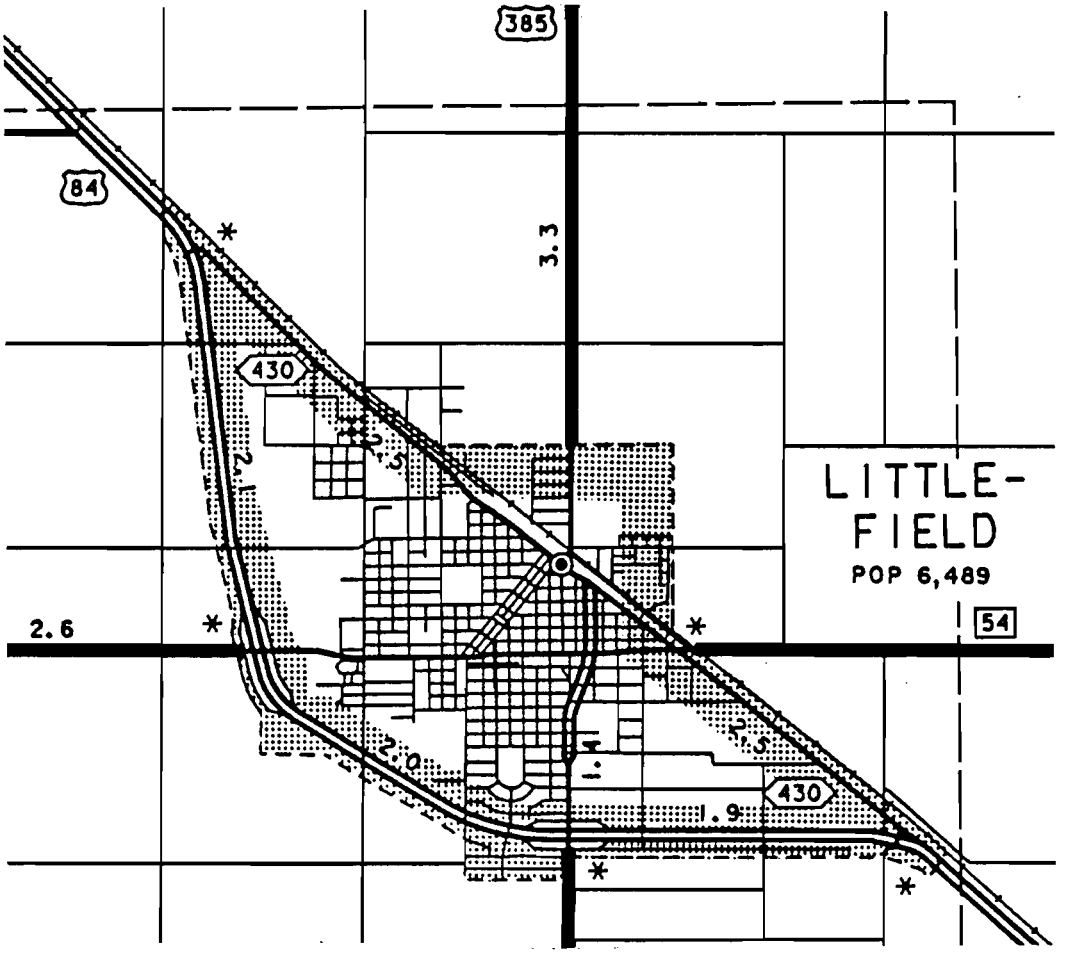


Figure 3.2 A standard bypass

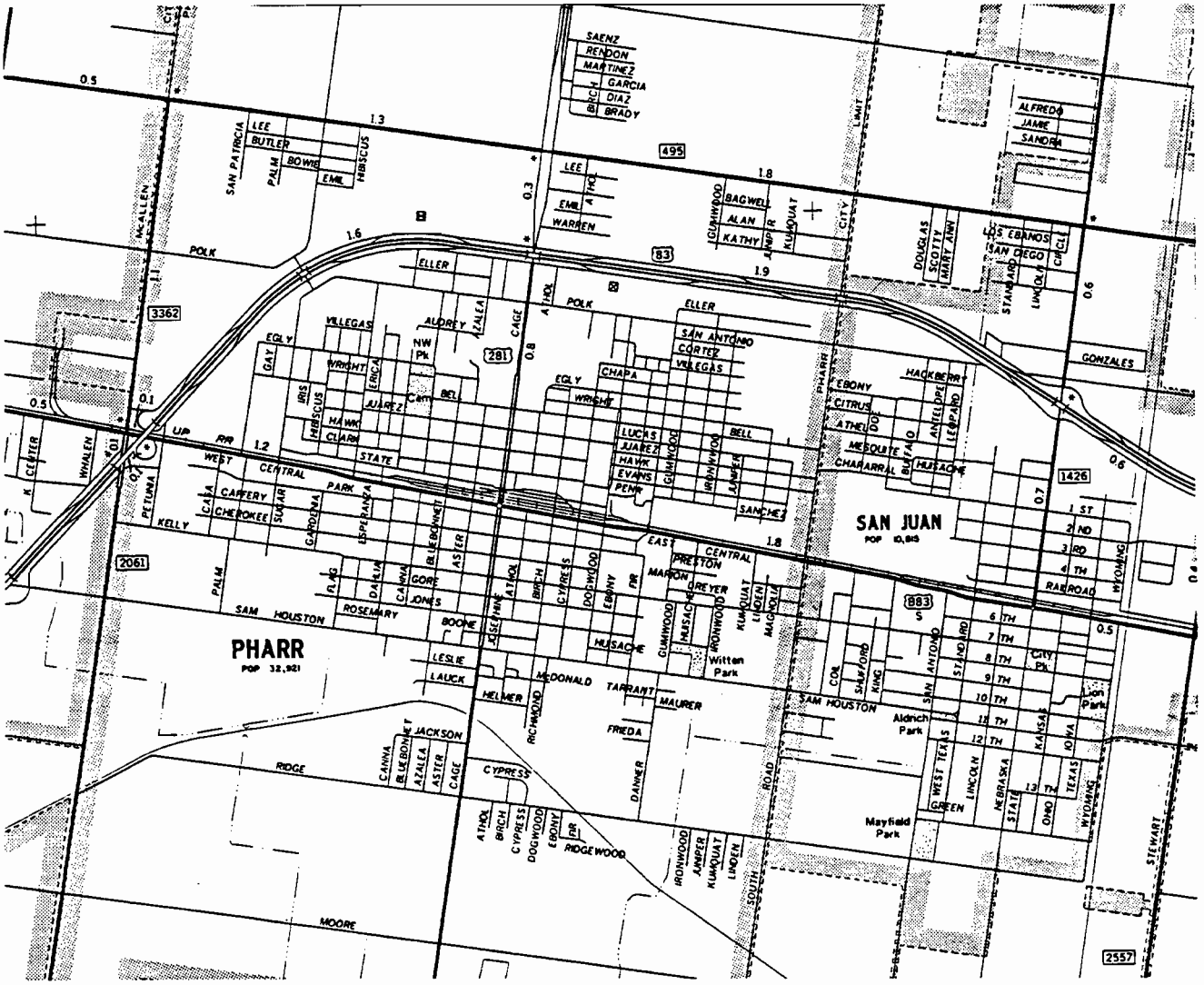


Figure 3.3 A multiple-city bypass

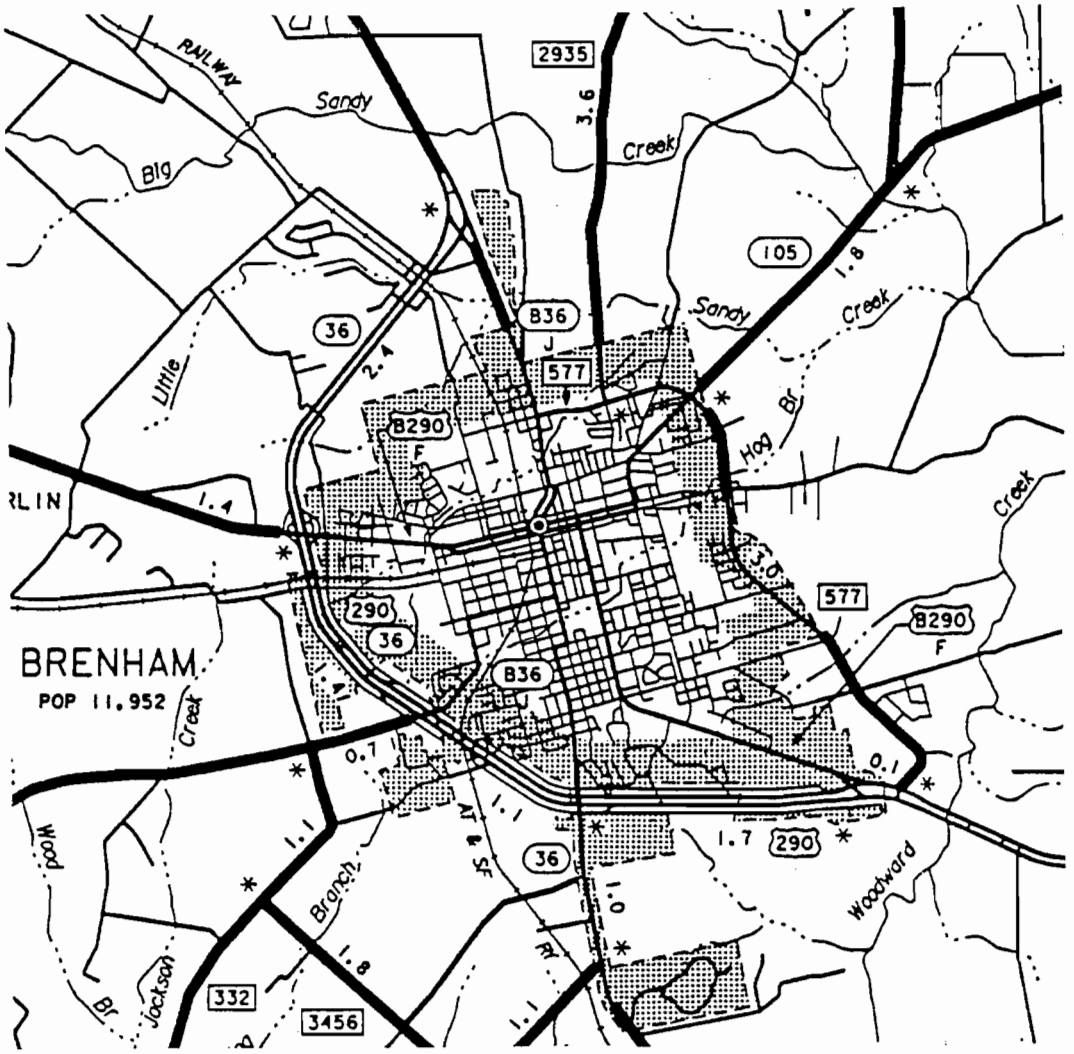


Figure 3.4 A multiple-highway bypass

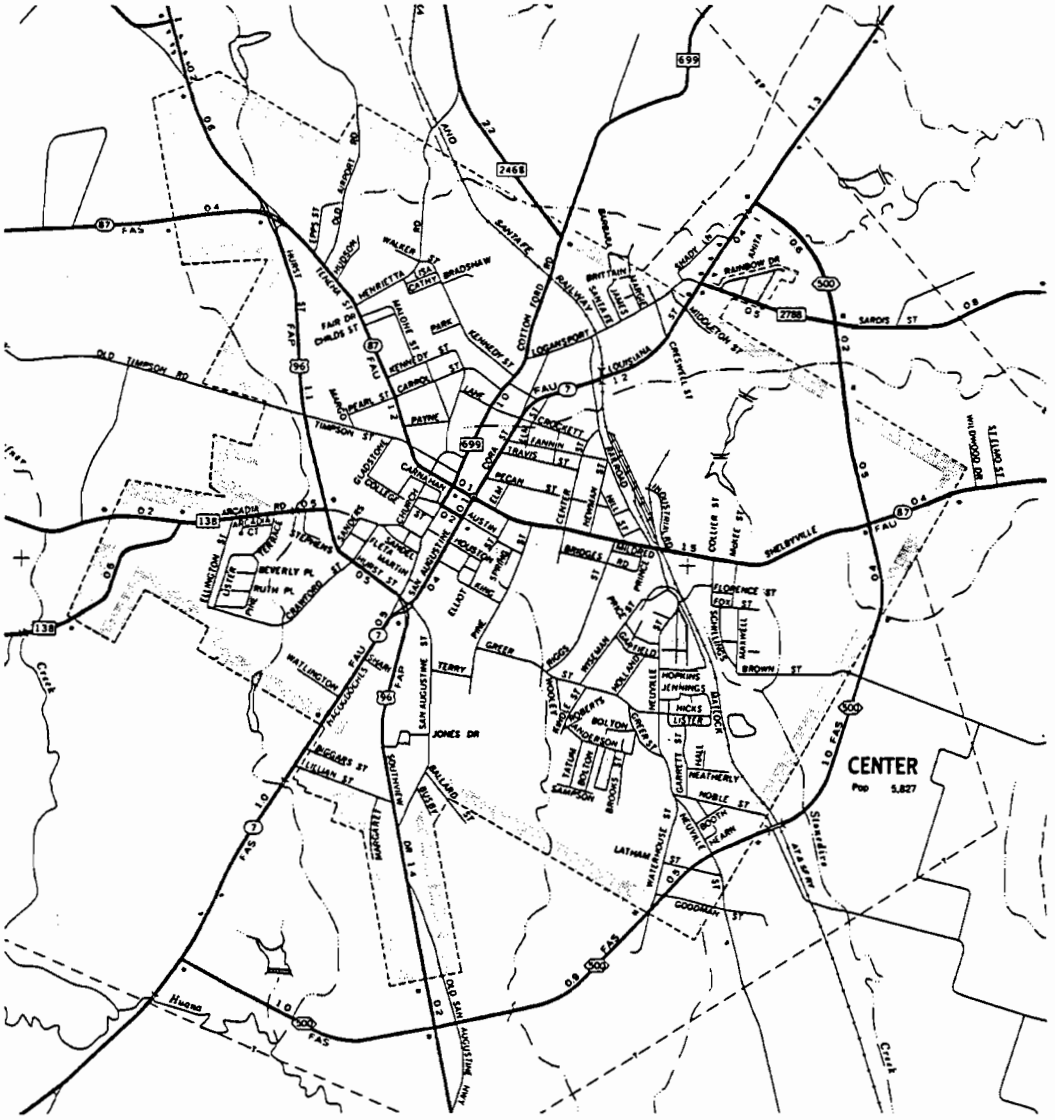


Figure 3.5 A partial bypass

of the ambiguity surrounding its status, this type of bypass is recognized but, for our purposes, is neither listed in the appendix nor considered for further analysis. The partial bypass is illustrated in Figure 3.5.

Loop

Loops are a designated portion of the highway. Typically, they are formed by connecting two or more bypasses (Figure 3.6). Loops are most often associated with areas of rapid development and/or large populations. Land values and uses associated with loops are very different from those associated with bypasses and, thus, fall outside the scope of this study.

Geographical Location

It is convenient to categorize bypasses according to geographical location, with the economic base of a region forming the basis of this categorization. In Figure 3.1 it can be seen that most of the bypasses are in the densely populated northern and eastern parts of Texas. There are only a few bypasses in the western part of the state, where traffic volumes are generally low (as opposed to the more travelled northern and eastern parts). The six different economic regions of Texas are the Plains, Metroplex, East Texas, Gulf Coast, Central Corridor, and the Border.[74] These regions will form the basis for categorizing bypasses in Texas according to

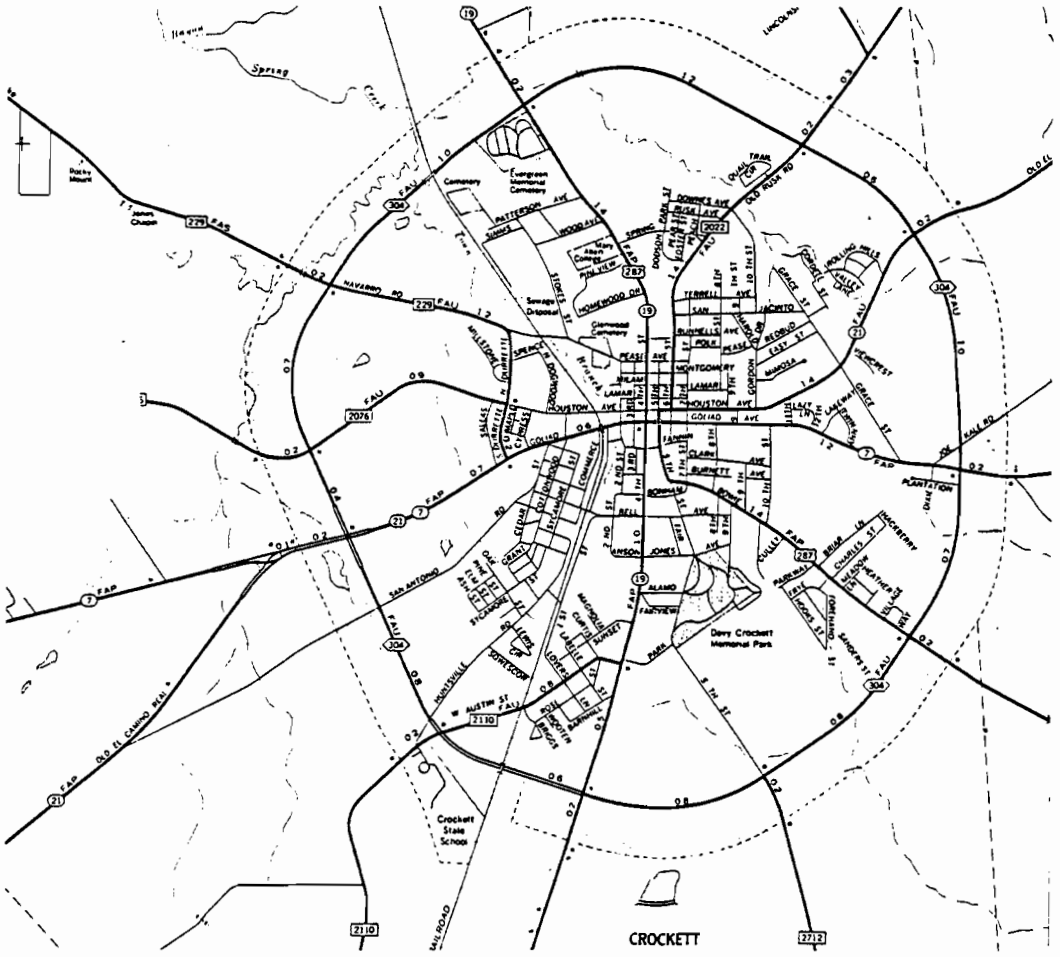


Figure 3.6 A loop

geographical location. A brief discussion of each is presented below.

The Plains: The economic activity of this region is tied closely to its exhaustible natural resources. Oil and gas production dominates the economy in certain parts of this region; farming and ranching also have an important share in the economy.

Metroplex: This is the major manufacturing, trade, distribution, and finance center of the Southwest. It is the most urbanized of the six regions and boasts a healthy manufacturing sector built around the production of high-tech electronics, aerospace, and military hardware.

East Texas: The economy of this region is built on its natural resources, namely, timber, oil and gas, coal, and water.

Gulf Coast: This region's economy is dominated by the oil and gas and petrochemical industries. It also supports a wide range of economic endeavors, including shipbuilding, port activity, and agriculture.

Central Corridor: This region has long been a center of federal and state government and higher education. High-tech manufacturing and services have also increased in importance in this region.

The Border: This is a very distinct region because of its trade, tourism, and economic ties with Mexico. Farming and ranching operations provide large numbers of jobs throughout this region. It also hosts a large government sector.

The locations of these regions are shown in Figure 3.7.

Population Characteristics

The population of bypassed cities ranged from hamlets with less than 500 people to cities with a population of 120,000. Population data were gathered from U.S. Census information and from the Texas Almanac. The distribution of population for bypassed cities is given in Figure 3.8(a).

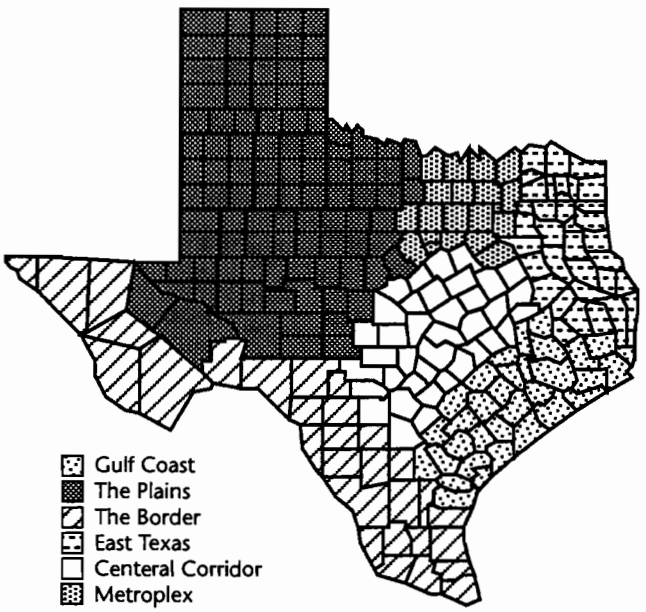


Figure 3.7 Economic regions of Texas

A cumulative frequency distribution for population is depicted in Figure 3.8(b). It can be seen that almost one half of all bypassed cities have a population of 2,500 or less, while approximately 3 percent have a population greater than 25,000.

Year of Bypass Construction

The year of bypass construction was taken as the year when traffic volumes on the bypass first appeared on district highway traffic maps. Figure 3.9 illustrates the number of bypasses opened per year. Very few bypasses date back to the pre-1950 era. Most of the Texas bypasses were constructed in either the late 1950's or in the 1960's.

Bypass Sample

The number of bypassed cities was reduced to allow a more detailed analysis. The scope of this analysis included the following:

(1) cities with a population between 2,500 and 25,000 at the time of the bypass. The lower bound was set at 2,500, since census information is generally not available for cities with a population less than 2,500. The upper bound was set at 25,000, since only six Texas cities remain in the greater-than-25,000-population category;

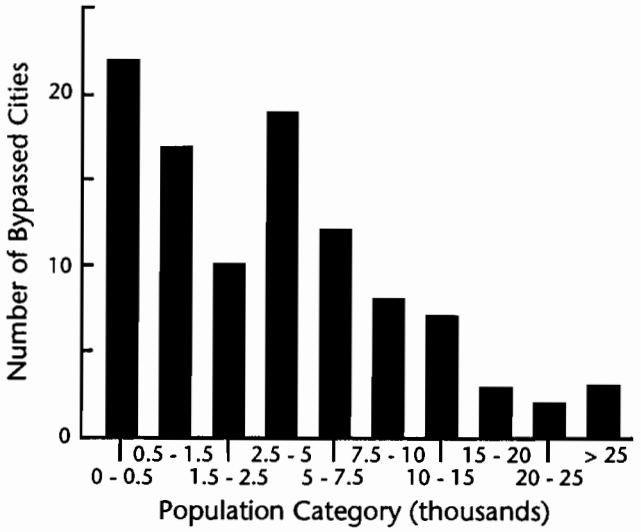


Figure 3.8(a) The population distribution of bypassed cities

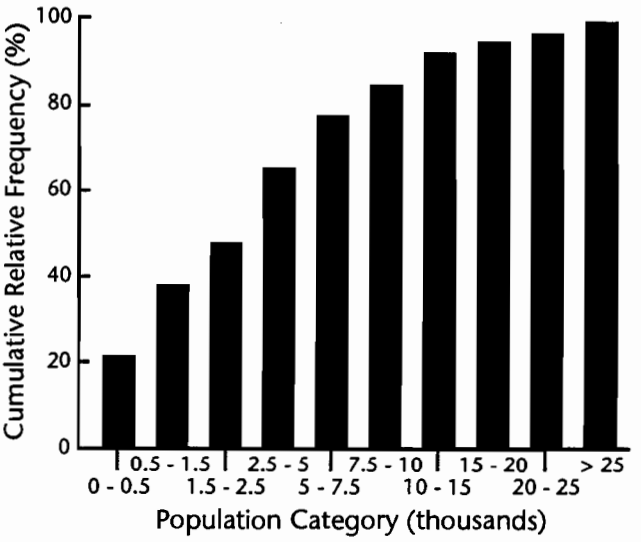


Figure 3.8(b) The cumulative frequency distribution for population size

(2) cities bypassed between 1960 and 1980. This was required so that long-term trends could be obtained and studied for the periods both before and after construction;
(3) cities with only one bypass, conforming to the earlier definition of a bypass; and
(4) cities with highway bypasses that do not bypass more than one city at a time.

These conditions resulted in a final sample of 23 bypassed cities. They are listed in Table 3.1.

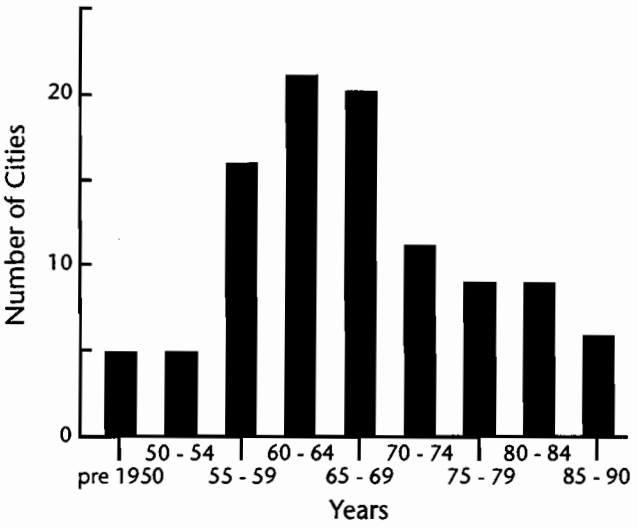


Figure 3.9 Distribution of years of bypass construction

A control city was selected for each bypassed city. This enabled a comparison of changes in the economies of the bypassed cities with the changes in the control cities. Ideally, the control city and the bypassed city should have the following characteristics in common prior to the bypass being opened: highway district, proximity to a larger city, economic base, magnitude and trend of retail sales, population size category and growth trend, and highway network characteristics. For each bypassed city, two to six control city candidates were evaluated, with the one most similar chosen as the control city. It was difficult to find a "perfect" control city: the main discrepancies included a large difference in population size and different trends in retail sales. A control city was chosen for each bypassed city (Table 3.2), with the city numbers for the control cities corresponding to those of the bypassed cities.

3.2 SITE VISITS AND INTERVIEWS

Site visits and interviews with local businessmen were conducted in six bypassed cities in Texas, four of which are part of the sample of 23, and two of which fall in the "under 2,500" population category. The geographical locations of these sites are shown in Figure 3.10.

Table 3.1 Bypassed cities in the sample

City Number*	Bypass City	County	Traffic District	Economic Region
1	Bonham	Fannin	1	Metro
2	Bridgeport	Wise	2	Metro
3	Vernon	Wilbarger	3	Plains
4	Electra	Wichita	3	Plains
5	Henrietta	Clay	3	Plains
6	Bowie	Montague	3	Metro
7	Littlefield	Lamb	5	Plains
8	Slaton	Lubbock	5	Plains
9	Tahoka	Lynn	5	Plains
10	Snyder	Scurry	8	Plains
11	Alvin	Brazoria	12	Gulf
12	Wharton	Wharton	13	Gulf
13	El Campo	Wharton	13	Gulf
14	Edna	Jackson	13	Gulf
15	Taylor	Williamson	14	Central
16	Bastrop	Bastrop	14	Central
17	Beeville	Bee	16	Gulf
18	Teague	Freestone	17	Central
19	Navasota	Grimes	17	Gulf
20	Atlanta	Cass	19	East
21	Silsbee	Hardin	20	Gulf
22	Edinburg	Hidalgo	21	Border
23	Coleman	Coleman	23	Plains

* This City Number Corresponds to the Numbering System of the Data Base.

Table 3.2 Selected control cities

City Number*	Control City	County	Traffic District	Economic Region
1	Clarksville	Red River	1	East
2	Comanche	Comanche	23	Plains
3	Graham	Young	3	Plains
4	Childress	Childress	25	Plains
5	Memphis	Hall	25	Plains
6	Nocona	Montague	3	Metro
7	Post	Garza	5	Plains
8	Brownfield	Terry	5	Plains
9	Morton	Cochran	5	Plains
10	Stamford	Jones	8	Plains
11	Angelton	Brazoria	12	Gulf
12	Bay City	Matagorda	13	Gulf
13	Eagle Lake	Colorado	13	Gulf
14	Cuero	De Witt	13	Gulf
15	Lockhart	Caldwell	14	Central
16	Giddings	Lee	14	Central
17	Alice	Jim Wells	16	Border
18	Hearne	Robertson	17	Central
19	Cameron	Milam	17	Central
20	Gilmer	Upshur	19	East
21	Liberty	Liberty	20	Gulf
22	Rio Grande City	Starr	21	Border
23	Brady	McCulloch	23	Plains

* This city number corresponds to that of its paired bypassed city.

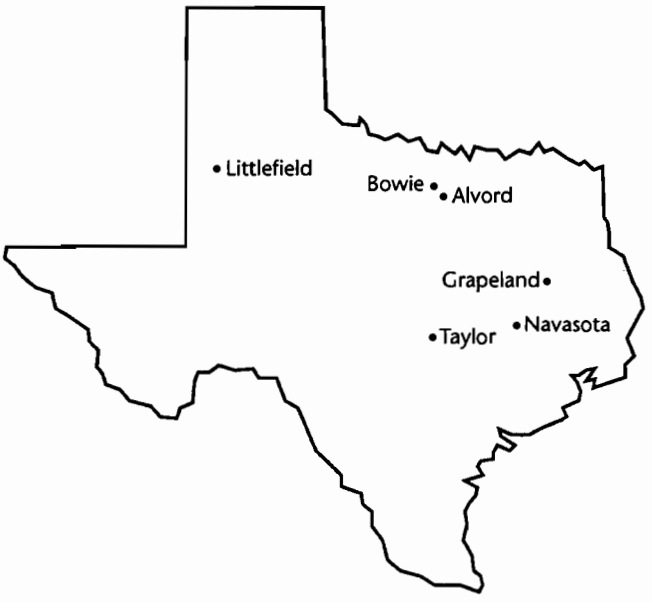


Figure 3.10 Location of bypassed cities where site visits were made

An account of visits to Alvord, Bowie, and Littlefield is given in this section. Site visits and interviews were also performed in Taylor, Grapeland, and Navasota and are discussed elsewhere.[75] These sites reflect differences in geographical location, population, economic base, type of highway, traffic volumes, and trends in business volumes. In the case of Alvord and Bowie, an attempt was made to determine the extent of similarity of cities in proximity to each other.

Actual site visits and interviews were preceded by a literature review of the cities' history and general characteristics. In addition, changes in the spatial distribution of highway-oriented businesses were studied by examining old telephone directories. An account of the spatial changes is presented in Chapter 4.

Interviews were mostly held with the local chambers of commerce and local businessmen contacted through the chambers of commerce. These interviews focused on the current economic viability of the city, the effect of the bypass on growth and on businesses, adjustments to the bypass, and on opinions of local people regarding the desirability of the bypass. An example of the questionnaire used as a guideline is provided in the appendix.

A summary of these aspects for the three cities follows.

Bowie

Background Information

Bowie is part of Montague County, situated within the Metroplex Economic Region. Bowie lies

90 miles northwest of Dallas, 67 miles north of Fort Worth, and 49 miles south of Wichita Falls. The distance to the nearest interstate is 50 miles.

Bowie was bypassed by U.S. 287 in 1978 as part of a major construction project undertaken between Fort Worth and Wichita Falls. The existing facility was upgraded from an undivided two-lane highway to a divided four-lane freeway. Current traffic volume on the bypass is 10,000 vehicles per day, while the volume on the bypassed route varies between 3,000 and 4,000 vehicles per day. Bowie is also served by U.S. 81 and State Highways 59 and 101, as shown in Figure 3.11.

Bowie was established in 1882 as a shipping point for cattle and cotton.[76] It was part of the oil boom in the 1920's. By 1950 it was the largest town and chief commercial center in the county. It was the center for a diversified industry and had 258 businesses by 1967.

In the late 1970's, Bowie was considered a growing town.[77] At that time Bowie was seen as the hub of a trade area directly dividing Wichita Falls and the Dallas-Fort Worth area. Whereas Bowie's economic life was previously tied to agriculture, the backbone of the city at that stage was seen to be oil. Many well-serving companies operated from Bowie because of its location. When Bowie was bypassed in 1978, there were some concerns about the bypass hurting the economic viability of the city. After some months, however, it was reported that the downtown area was more peaceful (since noisy trucks were no longer routed through the city) and business was still booming.

The *Fort Worth Star-Telegram*[78] reported that the city annexed 19 acres of land in the area of the bypass before it was opened, and that the chamber of commerce was stepping up its campaign to

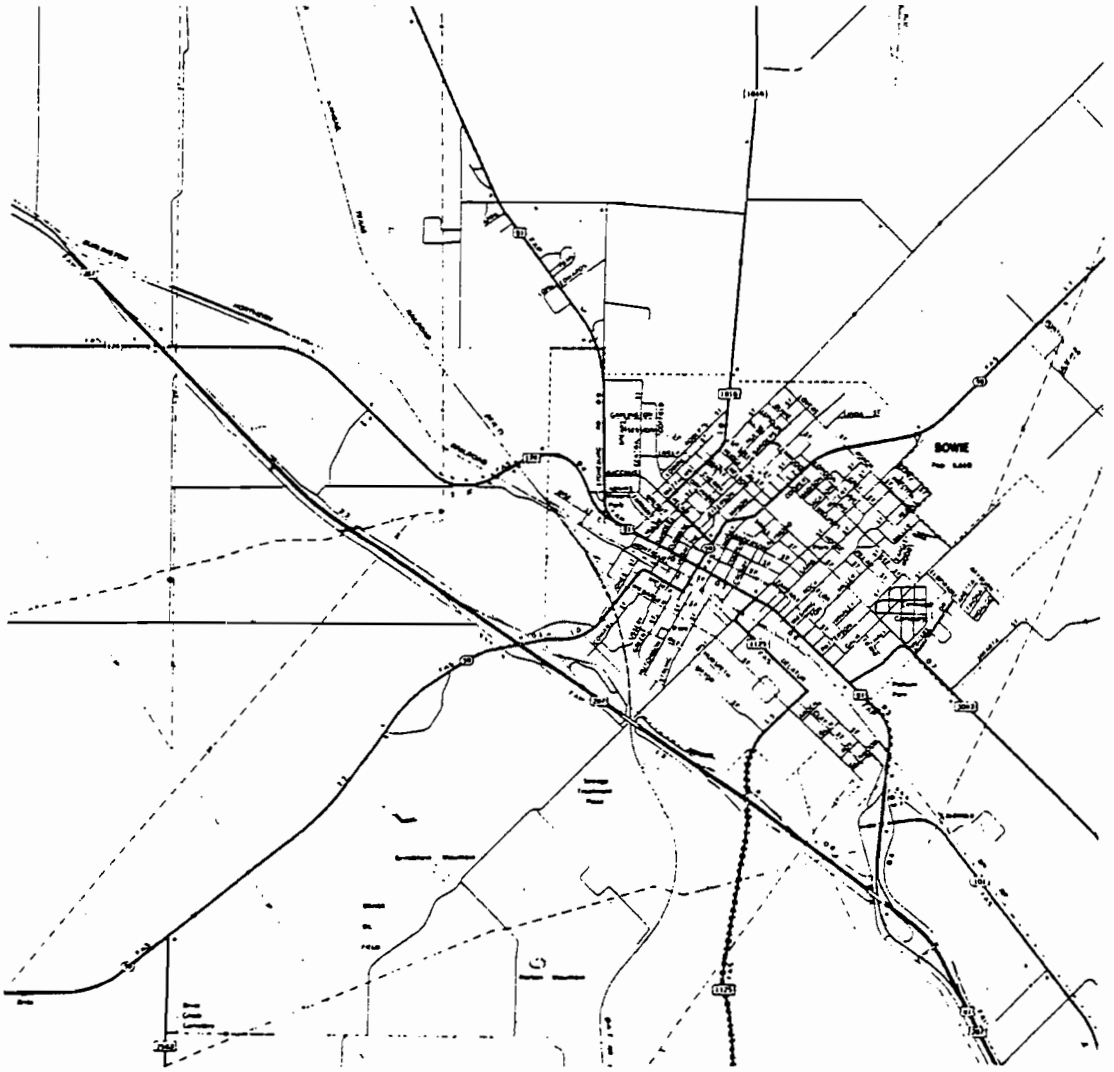


Figure 3.11 City map of Bowie

attract industry to that area. Some businesses, mainly service stations and restaurants, were in the process of moving out of the center of town to locations along the expressway service road.

Today industry, ranching, agriculture, oil, and retail trade form a diversified base for Bowie's economy. Farming and agricultural activities are mostly centered around watermelons, peanuts, cantaloupes, peaches, and the cattle business. About 80 percent of the agricultural income is derived from livestock (beef and dairy cattle). The oil business has declined since the boom in the early 1980's. There are seven manufacturing facilities employing 430 workers. The largest industrial activity in town is Haggar's Slacks, which employs 300 people.

The population of Bowie has been relatively stable over the last 40 years. However, there have been some minor fluctuations in trends, with an apparent drop in the last decade. The changes in the population of Bowie since 1950 are reported in Table 3.3.

Table 3.3 Population of Bowie and Montague County, 1950-1990

Year	Bowie	Montague County	Population of Bowie as % of County
1950	4,544	17,070	0.27
1960	4,566	14,893	0.31
1970	5,185	15,326	0.34
1980	5,610	17,410	0.32
1990	4,990	17,274	0.29

Site Visit and Interviews

Meetings were held on 24 July 1991 with the president of the Chamber of Commerce, a past-president of the Chamber, and the president of the local Rotary Club in Bowie. We also met informally with several members of the local Rotary Club.

The president of the Chamber of Commerce declared that the city was "dying a slow death." He felt that the decline in the oil business was the biggest contributing factor to this state of affairs. The oil boom took place between 1978 and 1984. Since the oil bust in 1985, people have been leaving the city, many of them previously employed by the oil supply business. In many instances, people were forced to commute to either Wichita Falls or Fort Worth, since there were no buyers for their houses. It was the opinion of those interviewed that the large percentage of senior citizens (±40 percent) in the community contributed to the apathetic attitude of the local people. The opening of a large retail store apparently harmed many of the locally owned businesses. The metropolitan areas also were too far away for Bowie to experience their positive effects. Closed businesses downtown were becoming a frequent sight, and it could be foreseen that even more would be forced to close if the existing trend continues.

In general, it was felt that the oil bust and general recession were a greater set-back for Bowie than highway construction, although the bypass seemed to have had some detrimental effect as well. Local people consider the bypass to be too far outside the city for them to support businesses located there, and also too far for passers-by to be attracted to the city. Bowie is also not tourist-dependent and, consequently, does not have tourist-type activities to lure people into the downtown.

Businesses responded in different ways to the bypass. For example, service stations, a motel, and a restaurant located on the bypass and are apparently doing good business. Two motels on the bypassed route have gone out of business since the opening of the bypass. There were no obvious reasons for their closing, although it was felt that they would have done better if the bypass had been located closer to the city. A restaurant on the northern end of the bypassed route is doing well. It draws its clientele from a radius of approximately 30 miles and also attracts some business from the highway. The restaurateur feels that he would have done even better if the bypass had been located closer to the city. General highway improvement caused many local customers to be drawn away to the larger metropolitan areas, where greater shopping variety is available. Local businesses increased both their inventory and floor space to stay competitive with the new retail store. Many local businesses eventually went out of business, resulting in a multiplier effect all over town (i.e., the reduction in circulating currency led to a gradual decrease in business activity).

Community involvement in the bypass issue was characterized by a lack of interest. Few attended public meetings that addressed the bypass issue. Only a small group of local people, led by the Chamber of Commerce, was involved in discussions with the Department of Transportation. From the interviews it was evident that within this small group, the bypass was a hotly contested issue. It in fact generated much discord, some of which is still not completely forgotten. After lengthy discussions, the current alignment was approved by the local representatives, with the condition that the Department construct a loop on the north side of the city to deal with heavy

oil-related truck traffic. The cost of the right-of-way was shared equally between the city and state.

It seems that the local chamber of commerce plays an active role in trying to maintain the city's viability. For example, that group initiated a main street beautification project in the early 1980's (a project which later stalled because the chamber could not gain the support of the community; the result was even more deterioration in parts of the downtown area). Additionally, the chamber plays an active role in trying to attract new industries to the area. They also play a significant part in organizing special events in Bowie, including the monthly "Second Monday Tradesday" and the annual Jim Bowie Day celebration, which is scheduled for the last weekend in June. Their annual advertising budget of $25,000 allows them to advertise in a daily newspaper in one of the nearby metropolitan areas. The chamber is also responsible for putting up six billboards along the highway advertising activities in Bowie.

Because of the excessive distance between the bypass and city, the city limits remained unchanged and were not extended toward the bypass following its opening. The small city could not afford the enormous expenses involved in extending utilities towards the bypass. To date no sewer or electrical hook-ups are available in the area close to the bypass. These constraints not only kept many businesses from moving out to the bypass; they also limited expansion of existing facilities on the bypass. Development along the bypass is found toward the middle of the bypass. Some development is taking place along the bypassed route, the most significant being the establishment of a major retail store in the northern part of the bypassed route.

The construction of a limited-access highway to bypass Bowie has had a significant impact on traffic in the city. A lessening of downtown congestion was experienced. Safety also improved, with most of the heavy vehicles being diverted to the bypass. Traffic in the downtown area has picked up since the opening of the bypass (i.e., to the extent that parts of the bypassed route in the downtown area are currently being widened). Business activity in the downtown area is found on roads perpendicular to the bypassed route, and not so much on the bypassed route itself. The bypassed route experiences heavy traffic, with only parallel parking allowed in the downtown section. The heavy traffic and lack of parking access on this section are probably reasons for businesses not focusing on this part of the bypassed route.

While the extension of the limited-access freeway to metropolitan areas both north and south of Bowie made these areas much more accessible to local people, it also changed the character of Bowie as a shopping environment. Before construction of the new facility, Highway 287 to Fort Worth used to be windy and relatively dangerous, with infrequent passing zones. The new facility is said to bring about time savings of as much as 30 minutes for trips between Bowie and Fort Worth. Many local residents are now inclined to visit the larger metropolitan areas for their greater retail variety. Bowie also used to be a natural stop between the metropolitan areas of Fort Worth and Wichita Falls, a situation that changed completely since the advent of the bypass.

Alvord

Background Information

Alvord, located in Wise County, is situated within the Metroplex Economic Region. It is located 47 miles north of Fort Worth, 69 miles south of Wichita Falls, and 20 miles south of Bowie. The distance to the nearest interstate is 36 miles.

Alvord is served by only one major highway, U.S. 287. Current AADT[79] is 13,000. It was bypassed in 1982 in a project that was part of the overall effort to upgrade the route between Fort Worth and Wichita Falls (as was the case with Bowie). AADT on the bypassed route is approximately 1,500. The layout of the city is shown in Figure 3.12.

The city was established in 1883 and served as a trade center before the railroad was built.[80] By 1946 it had 17 businesses and a population of 821 people. Alvord, along with the surrounding area, is known for growing and shipping watermelons. Cattle and dairy farming is also found in the area. Oil production in the area has declined since the oil bust in the mid 1980's.

Today businesses in the city include a large ice company, five beauty shops, a lumber yard, a grocery store, a service station, and a flower shop.

The population of Alvord remained relatively stable over the last few decades. Population trends for Alvord and Wise County are given in Table 3.4. It is evident that Alvord did not experience the kind of population growth that took place in other parts of the county.

Site Visit and Interviews

Meetings were held on 23 July 1991 with the vice-president of the Alvord Chamber of Commerce, the secretary of the Chamber of Commerce, and the assistant vice-president of the Alvord Branch of the First National Bank of Bowie in Alvord.

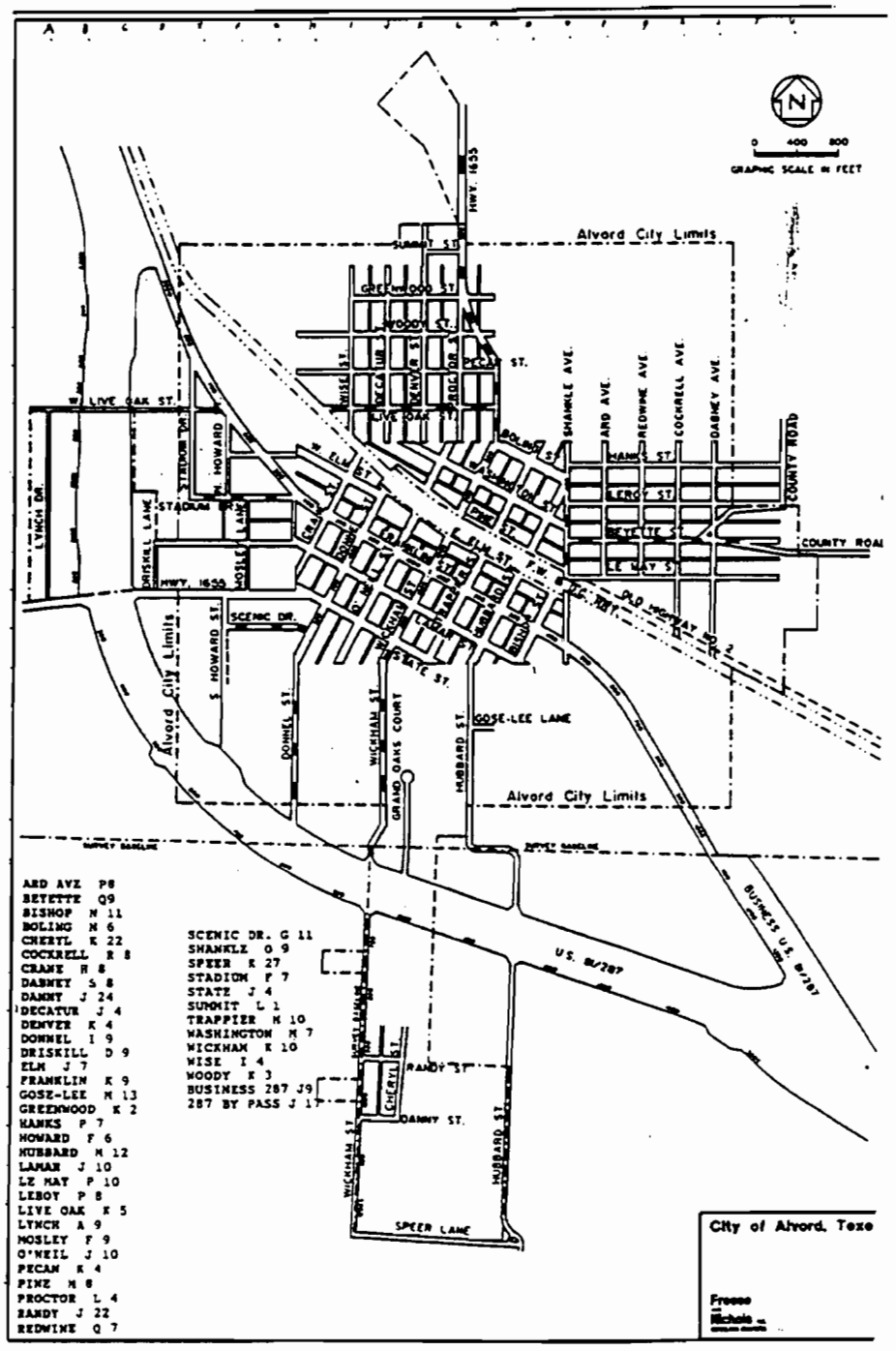


Figure 3.12 The city of Alvord

Table 3.4 Population of Alvord and Wise County, 1950-1990

Year	Alvord	Wise County	Population of Alvord as % of County
1950	735	16,141	0.046
1960	694	17,012	0.041
1970	791	19,687	0.040
1980	874	26,575	0.033
1990	850	35,469	0.024

There has been a gradual decline in population and business activity over the past few years. Many businesses closed down, including a drug store, mini-mall, grocery store, and service stations. The establishment of a major discount retail store in Decatur, located 10 miles south from Alvord, apparently had a devastating effect on small businesses and is believed to be the single most important reason for many businesses closing down.

Local residents generally did not perceive the bypass to have a negative effect on the city. The city appreciated the fact that the Department of Transportation provided it with a new sewer system (necessitated by the bypass construction). No increase in retail business customers was experienced after the bypass opened. The bypass and major freeway actually made larger cities more accessible and as such took clientele away from Alvord. There was no observed adjustment as far as businesses reorienting towards local customers. Alvord, a city having no tourist attractions, was not hurt by the bypass.

Effects on local businesses were manifested in different ways. Of the highway-oriented businesses, service stations were probably affected the most. Three service stations on the bypassed route closed following the opening of the bypass. According to local residents, the bypass is not solely responsible for their closing. The death of one of the owners was given as a reason for the closing of one service station. Another station relocated to the intersection of the bypass and a FM road leading into the city approximately four years after the bypass was opened. A third station moved to the southern end of the bypass upon learning of plans to construct it. Produce stands along the highway in town were all closed after the bypass opening, with only one relocating on the new freeway (where it is doing good business). A motel opened on the bypass but closed down about a year ago. According to local residents, business was not too bad but the manager had some internal problems. Many non-highway-related businesses in town closed, since it was felt that local people do not have enough buying power to support these businesses. Business activity in the town, such as the five beauty shops, reflects the activity and preferences of the large percentage of elderly people in the community.

There was not much community debate regarding the bypass issue. One reason for this lack of involvement might have been that only a small portion of the bypass actually goes through city limits. Another reason might be its demographic structure. The interviewees reported that there was a lack of cohesiveness in the community, possibly owing to the facts that Alvord is, on the one hand, a city for senior citizens and, on the other hand, a bedroom community for younger people. It can be expected that senior citizens become less active in community activities, while the younger generation's focus is directed toward activities in the metropolitan areas, the result of which is less involvement in local activities.

The local chamber of commerce seems to be quite active. Local activities are featured in the local newspaper as well as on the local county radio station. Funds are too limited to have any extensive advertising campaign. The chamber organizes an annual watermelon festival the second weekend in August and an annual chili cookoff in October. They also initiated a storefront beautification project in 1984 as part of their centennial-year celebrations.

Some land development did occur following the opening of the bypass. City limits were extended beyond the western side of the bypass to incorporate a new residential area.

The traffic in Alvord has changed character since the bypass opened. Little traffic is now experienced in the town. Increased safety in the downtown area is seen as one of the major benefits by the local residents. Heavy vehicles and speeding traffic through the town had previously been cited as factors in several accidents (in some cases involving pedestrians). There are now three exits from the bypass into town, with the preferred route into town being the FM road and not the bypassed route.

Littlefield

Background Information

Littlefield is part of Lamb County and falls within the Plains Economic Region. It is located 120 miles south of Amarillo, 35 miles northwest of Lubbock, and 350 miles west of Dallas. The distance to the nearest interstate highway is 35 miles.

Littlefield was bypassed by U.S. 84 in 1966. This highway was upgraded to a four-lane divided highway facility running from the border of New Mexico to Lubbock. Currently, the AADT on the bypass is approximately 4,000; on the bypassed route, it varies between 1,200 and 1,700. Littlefield is also served by U.S. 385, which runs through the city in a north-south direction. A city map of Littlefield in Figure 3.13 shows this configuration.

The city was established in 1913 mainly as a farming and ranching community.[81] It became the county seat in 1946, by which time it served as a commercial and retail center for the county. Toward the end of the 1950's, population started to drop, retail sales declined, and the downtown area slowly began to deteriorate. But in a dramatic turnaround, Littlefield received in 1965 national recognition for its accomplishments in remodelling, renovating, and beautifying its downtown area (through financing provided by local businessmen and property owners).[82] In an almost half-million dollar project that lasted several months, curbs and gutters were torn out, new paving and gutters were put in, new sidewalks were laid, and a downtown shopping mall was built (complete with rest areas). Flowers and trees were planted and soft music piped in to all downtown shopping areas. In addition, parking meters were taken out and utility lines were placed underground. This all resulted in Littlefield being named an "All American Finalist" in a national competition.

Today the region around Littlefield is devoted to the irrigated farming of cotton, grain sorghums, and vegetables. Industrial development has gradually taken its place in the area.

There has not been much growth in population in the city. There were some spurts of growth but nothing dramatic that changed the face of the city. These periods of growth were often followed by periods of decline. These small fluctuations are

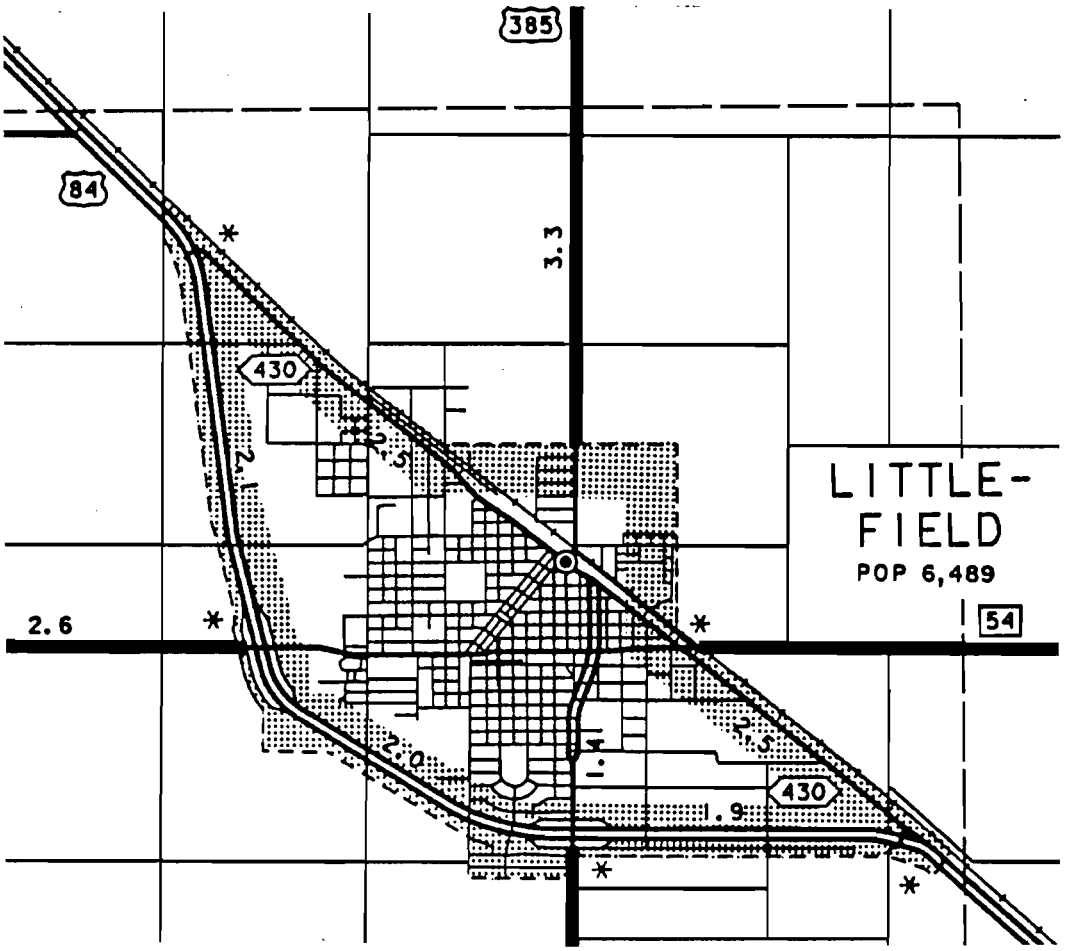


Figure 3.13 City map of Littlefield

portrayed in Table 3.5. Also presented are the population figures for Lamb County. A decline in population is noted in the last decade in both Lamb County and Littlefield.

Table 3.5 Population in Littlefield and Lamb County, 1950-1990

Year	Littlefield	Lamb County	Population of Littlefield as % of County
1950	6,540	20,015	0.33
1960	7,236	21,896	0.33
1970	6,738	17,777	0.38
1980	7,409	21,896	0.34
1990	6,200	15,685	0.40

Site Visits and Interviews

Meetings were held on 25 July 1991 with local businessmen, including Kenneth Ware from Ware's Department Store, Ernest Connell from Connell Realtors, and David Keithley from Keithley Insurance in Littlefield. All interviewees were life-long residents of Littlefield.

Littlefield is seen to be in a process of slow decline. There are many closed businesses and there is no demand for real estate. Businesses depend largely on local customers. It is felt that Littlefield is to a large extent dependent on the buying power of employees of the local denim plant.

Reasons for this decline include the mechanization of farming equipment, the proximity to Lubbock and the shopping variety it offers, the good highway system, and, to a lesser degree, the establishment of a discount retail store in Levelland. Littlefield is predominantly a farming community. The trend has been for farms to merge in the pursuit of economies of scale, resulting in fewer owners and a loss of population. Littlefield also has a large percentage of senior citizens who typically do not have substantial buying power.

Local residents are divided on the issue of the effect of the bypass on the city. With the highway improvements completed, residents in small towns to the north and northwest of Littlefield now drive past Littlefield on the way to Lubbock for shopping excursions. They are prepared to make a slightly longer trip in order to have access to a much larger selection of products. It is said that the probable trade area for the local Littlefield shop owners is now only 20 miles. The local shop owners have started to direct their businesses towards the older community in Littlefield. The younger generation prefers the wider and more modern selection of products offered in Lubbock.

The bypass had a definite impact on businesses in town. Service stations and restaurants on the bypassed route have closed down. A shopping center was established on the bypass, together with some service stations, restaurants, and two motels. In the downtown area, non-highway-related business owners mention the multiplier effect the closing of highway-related businesses has had on their business. However, it is difficult to tell how much of this deterioration is due to the bypass. Shop owners find it increasingly difficult to make a "decent" profit. If they decrease their inventory, they lose their customers. Three downtown grocery stores have also closed—probably a result of the strip development on the bypass.

The local chamber of commerce seems to be very active and has a full-time manager and secretary. On their initiative, a city beautification committee was formed, with one of their responsibilities being the decorating or painting of windows of closed businesses. The main street beautification project of 1964 is still visible and gives a good impression. The main street is well maintained by the city. Littlefield takes pride in the fact that the famous country and western singer, Waylon Jennings, is originally from Littlefield. The chamber is also involved in organizing the annual free Waylon Jennings concert on the Fourth of July. The city provides a free camping site with free electrical hook-up in the city—another effort of the local authority to attract people to their city.

Some spatial changes have occurred since the opening of the bypass. The city limits moved out past the western side of the bypass, where a new residential area was established. The bypass is thus within the city limits and the right-of-way was furnished by the county at that time. Hardly any business activity is found at the two ends of the bypass. No new activity is found along the bypassed route. Most of the business activity is taking place in the area where the bypass intersects with U.S. 82/62. This highway is lined with restaurants and service stations.

Local businessmen felt that the biggest change brought about by the new highway facility was to make Lubbock more accessible to local residents. Safety on the new highway definitely improved, since the old highway used to be a narrow two-lane highway. Safety in the downtown area also improved. However, this was not such a severe problem because the main shopping area was not located on any of the main highways, and downtown shoppers were not particularly aware of heavy truck traffic. Grade separation exists at the

intersections of the bypass with both U.S. 385 and FM 34. The bypass does not have full control of access, since access to abutting businesses on the bypass is obtained from the bypass. No frontage roads are provided.

Summary of Key Findings from Site Visits and Interviews

The site visits and interviews elucidated much of the inner functioning of small cities in rural areas. Several of these observations have a direct impact on the economic well-being of a community, with effects pertaining to the bypass quite often playing a role. The key findings are summarized below.

1. In general, the bypass is perceived not to have had a devastating impact on any community. Although there is agreement that its effect was not necessarily positive, there are other, much more important factors that determine the economic stability and vitality of a city within a region and the viability of local business activity. Some of these factors are:
   - a nationwide recession or a regionwide decline in a key sector of economic activity (such as the oil business);
   - a continuing urbanization trend;
   - the growth of nearby centers; and
   - the establishment of large discount stores in nearby centers or in the bypassed city itself, which quite often results in the closure of several small local businesses.
2. The removal of a portion of through traffic from the downtown streets, especially heavy vehicles, is seen in a very positive light. Improved safety and cleaner air are seen as the most important benefits.
3. There are ways to enhance and encourage downtown shopping. It is beneficial if the main shopping area is off the bypassed route, i.e., on a street perpendicular to the bypassed route. Parking is often difficult on the bypassed route; widening of this route is often an alternative. Road signs on the highway advertising amenities the city has to offer is a way to lure people into the city.
4. Spatial changes are often confined to increased activity at the point where another highway intersects the bypass. Few establishments were found at the split between the bypass and bypassed route.
5. Spatial development toward the bypass is often constrained by factors that may not be evident to an outsider. Excessive distance between the bypass and bypassed route can result in utilities not being extended to the bypass because of cost. Physical obstructions (such as a creek or hilly terrain) may have the same effect.

3.3 DATABASE

A database was established by assembling data on pertinent variables that would form the basis for further analysis. These variables were obtained by reviewing the literature on the subject, with their pertinence confirmed by observation during several site visits. They are deemed sufficient to describe the characteristics of the individual cities that would reflect changes with the advent of the bypass. All variables are introduced below and categorized. Variables are first divided into dependent and explanatory variables.

The changes of business activity will be captured in the dependent variable. Typically, total retail sales will be used as a short-term indicator reflecting the economic viability of the city as a whole. Also, as seen in the literature, it is expected that a bypass should specifically affect highway-oriented businesses. Consequently, data for gasoline sales, restaurant sales and hotel and motel receipts are pertinent. U.S. Census data were used as the source for these variables. However, data on hotel receipts were only available when there were more than three hotel/motel establishments in a city. Since many of the cities under consideration had fewer than four hotels or motels, this variable had to be disregarded.

The Standard Industrial Classification (SIC) code was used to categorize business activity. The SIC codes used were SIC-code 58 (referring to eating and drinking places) and SIC-code 554 (referring to gas station sales). All sales figures were corrected for inflation by applying the Consumer Price Index (CPI), with the base year taken as 1987. U.S. Census data for sales are available for the following data years: 1948, 1954, 1958, 1963, 1967, 1972, 1977, 1982, and 1987. The objective was to have three data points before and three data points after the bypass was opened. This was possible in most cases, except when the bypass was completed after 1977.

Explanatory variables reflect the characteristics of a city. Their respective categories, as well as a short description of all explanatory variables for which data were collected, are listed in Table 3.6. The variables are subdivided into the following categories: demographic, geographic, economic, and highway.

When the value of an explanatory variable was not available for one of the specific years mentioned above, linear interpolation between the

Table 3.6 Explanatory variables and their categories

Category	Variable Description
Demographic	Population within the city boundaries; Annual growth in population before the bypass was opened.
Geographic	Distance in miles to a city of larger size; Economic regions in Texas according to geographical location, namely, The Plains, East Texas, Border, Metroplex, Gulf Coast and Central Texas.
Economic	Average personal income in the county in 1987 dollars; Annual growth in income before the bypass was opened; Retail employment within city boundaries; and Growth in retail employment.
Highway	Annual average daily traffic volumes on all incoming highways; Growth in daily traffic on incoming highways prior to bypass; Average daily traffic on bypass; access type for the bypass (= 1 if a bypass has limited access and grade separation; 0, otherwise); Number of highways entering the city; Length of the bypassed route in miles; and Length of the bypass in miles.

existing data was used to estimate the missing value in the analysis.

Various sources were used to obtain this data. Information on population and retail trade was obtained from the U.S. Department of Commerce, Bureau of Census; personal income was found in the Texas Almanac; county maps were used to obtain all highway characteristics; and annual road and traffic maps from the Texas Department of Transportation provided all required information on traffic volumes.

Several variables were deemed important but proved to be unavailable or too difficult to obtain. For example, a demographic variable not included is the percentage of elderly people in the community. The probable effect of this variable was raised at various occasions during site visits. However, it is very difficult to obtain accurate census information for this variable for smaller-sized cities. This variable was thought to have some effect on the economic viability of a town (a large percentage might imply a more stagnant community). An economic variable not listed is one termed "Central Place Importance." This refers to the importance of a city in its immediate surroundings, be it a county seat, a trade center, or a gathering place for local farmers. The relative importance of a city in the region may cause it to react in a different manner to the construction of a bypass. Another variable excluded from the formal analysis was a social variable termed "outreach activities." This refers to the activity exerted by local residents, such as the intensity of the chamber of commerce's efforts to attract industry to the city, plan festivals, or beautify the city. A high degree of activity may cancel out negative effects brought about by other factors. Again, this is an intangible variable. A highway variable that was excluded was the presence of informative road signs. In some instances it was found that amenities the city had to offer were advertised on billboards or even put on official road signs located at the exits on the bypass. Passers-by would then be more inclined to visit that city. In other instances no signs were seen. Data for this variable were not available from secondary sources.

3.4 CLOSURE

This chapter described the data acquisition phase. First, the procedure to obtain an inventory of Texas bypasses was outlined. From the resulting information on population of bypassed cities, six cities were selected for further investigation and visited. One of the key findings of the site visits was that there are other factors more important than bypass construction influencing business activity and economic stability. A sample of bypassed cities and control cities in Texas was obtained. Lastly, pertinent variables for the purpose of the study were defined and data were collected for all cities in the sample.

The next chapter focuses on various traffic and spatial changes in the bypass sample brought about by bypass construction. A more detailed account of these changes within the cities that were visited is also given.

CHAPTER 4. TRAFFIC AND SPATIAL IMPACTS

This chapter focuses on traffic and spatial changes that may occur when a city is bypassed. The first section of the chapter deals with traffic impacts and explores the magnitude of changes in traffic volume at specific points within the city limits. A hypothetical example is used to show the effect of the bypass, which is then validated by observed data. The second section traces the spatial location and number of highway-related businesses in certain bypassed cities. Observed trends are discussed, focusing on the link between transportation and development.

4.1 TRAFFIC IMPACTS

This section deals first with the system of roads and the nature of traffic in a rural setting. It is then followed by a hypothetical example, using a simplified approach to predict traffic flow distribution trends following bypass construction. Lastly, observed data are explored to validate the reasoning of the hypothetical example.

The System of Roads

A city in a rural setting[83] generally has a clearly defined system of roads, with each class of road directed toward a specific road user.

The upper part of the hierarchy of functional systems consists of rural arterials. Principal and minor arterials collectively serve substantial statewide travel, focusing on movement between urban areas. Included in this class are all interstate, U.S., and state highways. In a rural setting, these types of highways are often found in pairs, one catering to travelers in the east-west direction, the other handling north-south demand. These typically intersect at the city square, where most of the city's business activity is normally focused. In the rural context, these arterials primarily accommodate through traffic. As demand increases, a bypass is constructed to divert the through traffic around the city.

The rural collector system serves travel of primarily intra-county importance and typically comprises farm-to-market roads. Trips are more likely to terminate in the city as opposed to being through trips.

The local roads provide access to land adjacent to the collector network and serve travel over relatively short distances. These streets largely serve traffic generated locally.

In Figure 4.1, a typical road system of a city in a rural setting is shown.

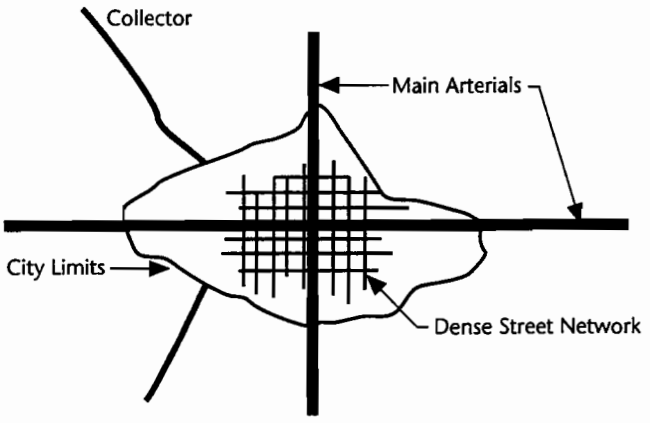


Figure 4.1 System of roads at a city in a rural setting

Traffic Patterns in a City in a Rural Setting

Traffic in a city generally has two sources, namely: (1) external traffic (originating outside the city limits), and (2) internal traffic (generated locally). Traffic can be further categorized into one of the following types:

- *external-external:* traffic that passes through the city en route to a destination outside city limits;
- *external-internal:* external traffic terminating inside the city limits;
- *internal-external:* locally generated traffic having a destination outside the city boundaries; and

- *internal-internal:* local traffic that has its origin and destination within the city. The usual trip purposes are associated with this type, namely, home-based work (HBW), home-based other (HBO), and non-home-based (NHB) trips.

Traffic patterns within a city can be expected to equilibrate toward a specific pattern, with the type and relative proportions of traffic exhibiting some regularity over time, on average. With the construction of a bypass, this pattern is disturbed, and a new equilibrium may eventually be reached. The magnitude of the difference in traffic patterns is explored by comparing the nature of traffic for both the pre- and post-bypass cases.

The Hypothetical City

The nature and magnitude of the shift in traffic toward the bypass are best explained by a simple example. Expected travel patterns for cities are illustrated for both the pre- and post-bypass periods, leading to several conclusions about the effect of a bypass on a city. The following general assumptions are made with regard to this hypothesized city:

- business activity is located at the city center;
- the local population is evenly distributed within the city limits;
- the local streets form a dense grid street network; and
- motorists select their travel path in such a way as to minimize their travel time.

Traffic Patterns for the Pre-bypass Case

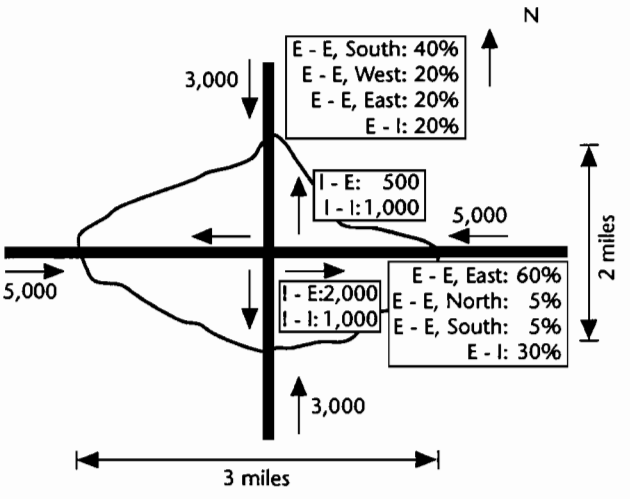
Most of the traffic activity tends to be concentrated on the main arterials. External-external traffic would drive through the city, staying on the main arterial which is presumably the shortest route through the city. External-internal traffic consists most commonly of business people heading toward the central business district in the city center, or else of a local resident on the way home. In both cases the motorist would utilize the main arterial for most of the way to reach his/her destination. Internal-external traffic would also make use of the main arterial for the most part and would leave the city via the main arterial. Since most of the business activity takes place near or at the city center, internal-internal traffic would be focused on the main arterials. It is evident that the main arterials play an important role in providing accessibility to all types of traffic within the city.

Traffic Patterns for the Post-bypass Case

A bypass significantly alters the road system in the city, providing a convenient, less congested route to traverse a city. External-external traffic on the main arterial would generally divert onto the bypass, perceived as the quickest route through the city. Depending on the local road system, external-internal and internal-external traffic would partially use the bypass if it could minimize travel time. Internal-internal traffic generally would not use the bypass, since the traffic activity is focused on the city center.

Traffic Assignment

Certain assumptions are made with regard to the traffic volumes and traffic composition within a typical city. Assumed volumes are depicted in Figure 4.2, showing the trip purposes and traffic sources. The city has approximate dimensions of three miles by two miles. The road system consists of two major arterials, one running in a north-south direction and the other east-west. The traffic volumes are thought to be representative of the traffic set up in cities in the sample described in Chapter 3. The relative magnitude of the traffic volumes was obtained by studying actual traffic volumes for many of the bypassed cities on the annual road



Legend:
E - E: External-External Traffic
E - I: External-Internal Traffic
I - E: Internal-External Traffic
I - I: Internal-Internal Traffic

Note: All Volumes and Trip Purposes can be Duplicated on the Other Side of the City.

Figure 4.2 The hypothesized city, showing magnitude of traffic volumes and trip purposes

and traffic maps of the Texas Department of Transportation. For example, it was observed that the component of incoming traffic (implying a large percentage of external-external traffic for small cities) was much larger than internal-internal or internal-external traffic. However, it is not possible to infer origin-destination information from traffic volumes. Assumptions regarding trip purposes were derived from informal discussions with personnel of the Texas Department of Transportation and from our own observations recorded during site visits to some of the bypassed cities.

The assumed volumes are now assigned to this simple network on an all-or-nothing basis, with all volume assigned to the shortest time route and without taking congestion into account. Results for both the pre- and post-bypass cases are discussed below.

Discussion of Results

Pre-bypass

Most of the traffic activity is found on the main arterials (since they form part of the minimum time routes through the city). The traffic volumes are depicted by a bandwidth plot (see Figure 4.3), which is useful for comparison with the post-bypass situation.

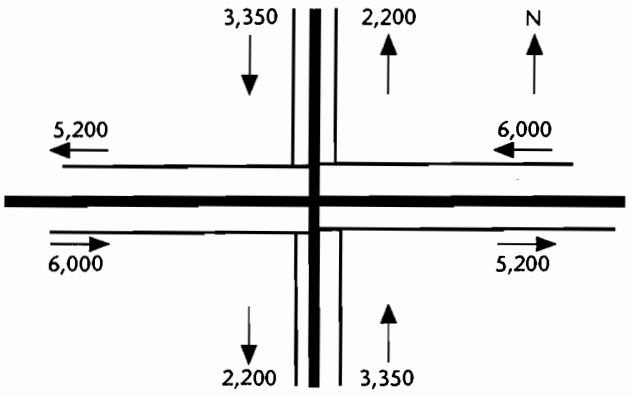


Figure 4.3 Bandwidth plots for the pre-bypass case

Post-bypass

Assume that the bypass is constructed on the east-west arterial, starting approximately 0.5 miles outside the city boundary. The traffic configuration is greatly altered by this addition. Internal and external sources of traffic are the same as in the pre-bypass case. Road users now have a choice of route depending on the actual position of their origin or destination within the city limits. One can determine the boundaries for these choices. It is assumed that the average speed on the bypass is 55 mph while the running speed inside the city limits is taken as 25 mph. Consider the case where a road user inside the city limits would like to leave the city for a destination east of the city. Depending upon his/her position within the city limits, the road user will have three options:

(1) continue along the bypassed route at 25 mph and exit the city at the eastern city limit,
(2) continue along the north-south arterial, driving at 25 mph and exiting the city at its southern limit (from that point, the journey will be continued along the bypass at 55 mph), or
(3) continue along the bypassed route at 25 mph, exiting at the western city limit.

At that point the road user will get on the bypass and drive the full length of the bypass in an easterly direction. Assuming that the local streets form a dense grid network, and given the dimensions of the city and travel speeds, one can calculate shortest travel time paths from anywhere in the city. In this manner, travel time boundaries can be obtained within the city limits. An account of this derivation is presented in the appendix. This yields the travel time boundaries depicted in Figure 4.4.

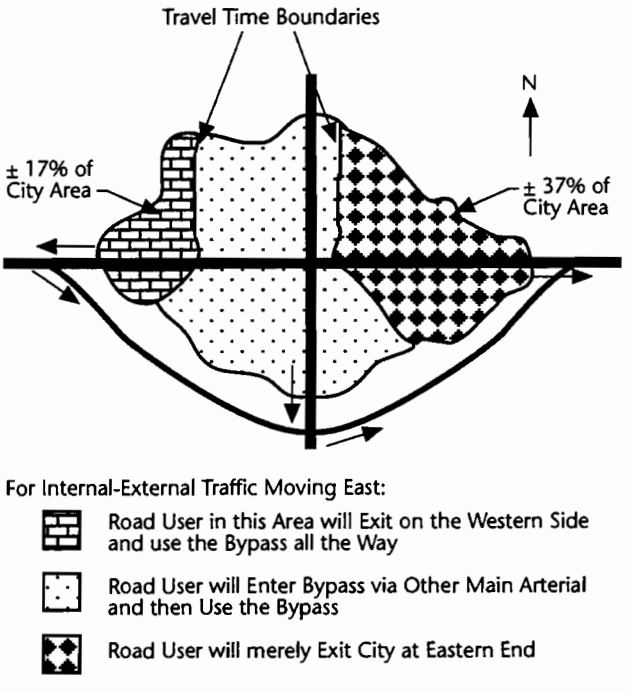


Figure 4.4 Travel time boundaries within the city limits

The choice of route for most trip types is affected by the addition of the bypass. The effect on each trip type is discussed next.

External-external

Travel time is shorter on the bypass than on any other route. Although it is slightly longer than the route through the city, the bypass does not expose the road user to traffic signals and the interference of other vehicles. It is assumed that all through travelers would use the bypass on the east-west arterial. External-external traffic on the north-south arterial, heading east or west, will use the bypass from the point where the two arterials intersect.

External-internal

Road users heading toward the CBD would use the bypass up to the intersection with the north-south arterial. If one assumes that the population is evenly distributed within the city limits, it can be seen from Figure 4.4 that ±37 percent of local residents terminating their trips at their place of residence will use the bypassed route on the side closest to their residence when entering the city from the eastern side. Forty-six percent of local residents will use the bypass up to the intersection with the north-south arterial. A further 17 percent will use the bypass the whole way and enter the city on the opposite side of their original approach. (See the appendix for a more detailed account of how these boundaries were obtained.)

Internal-external

The same travel time boundaries apply to the internal-external trips, originating within city limits and leaving the city on the eastern side.

Internal-internal

Trips made within city limits would, in most cases, not make use of the bypass. One can expect a slight increase in local trips, brought about by the enhanced traffic environment. The relative magnitude of the increase in local trips is assumed to be small and was not included in this analysis.

Traffic bandwidths for the post-bypass case are portrayed in Figure 4.5. Comparing this with Figure 4.3, a significant decrease in traffic on the bypassed route is detected. The leg of the intersecting highway linking it with the bypass picks up a substantial amount of traffic.

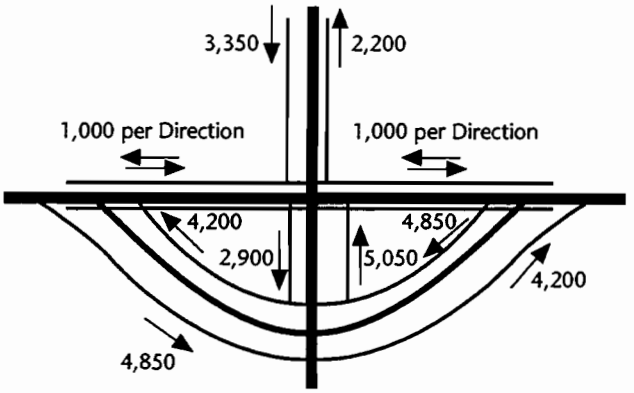


Figure 4.5 ***Bandwidth plots for the post-bypass case***

Comparison Between Pre- and Post-bypass Volumes

Traffic volumes for the pre- and post-bypass periods are compared at two points close to the city center: one on the bypassed route and the other on the section of the intersecting highway connected to the bypass. The total two-way ADT on the bypassed route is reduced from 11,200 to 2,150 (an 80 percent decrease), under assumptions previously made. At the same time, the volume on the section of the intersecting highway connected to the bypass increased from 5,550 to 7,950 (a 30 percent increase). From these data, it can be inferred that there is a shift in traffic away from the bypassed route and toward the north-south arterial linking the bypassed route with the bypass.

Validation of Hypothetical Results with Observed Data

The meaningfulness and validity of the hypothetical case are explored by comparing the hypothetical results with observed changes at the bypassed cities. Changes in traffic volumes owing to the bypass are explored at the two locations mentioned in the previous paragraph. These locations typically represent the highest daily traffic volumes close to the city center.

Traffic data were available at these locations for most of the bypassed cities. Data were available only for certain years, forcing one to make projections of the desired volumes. Traffic volumes at the specified points were collected for as many data years as possible spanning a 20-year period (10 years preceding the bypass and 10 years after completion of the bypass). Pre-bypass data were used to project a volume for the bypassed year. Projections were made in two ways:

(1) an overall annual traffic growth rate for the city is calculated, taking into account volumes on all major roads entering the city during the pre-bypass period. This growth rate is then applied to the most recent data year before the opening of the bypass, resulting in a projected volume for the year of the bypass; and
(2) a least square fit is performed through all available points. A predicted volume for the bypassed year is then obtained by this relation.

The final projected value is then obtained by taking the average of the results from the steps above. However, if the discrepancy between the numbers obtained is too great, judgment is used to obtain a reasonable projected volume. In the same way post-bypass data are used to obtain a volume for the bypassed year. The difference between the post-bypass and pre-bypass volumes obtained for the bypassed year now represents the change in volume owing to the bypass. This methodology is graphically illustrated in Figure 4.6.

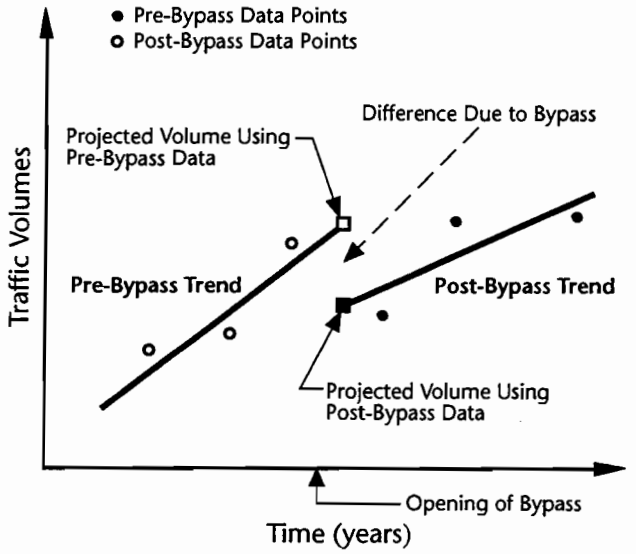


Figure 4.6 ***Procedure to obtain projected volumes for the bypassed year***

First, this methodology is applied to determine the change in traffic on the bypassed route in proximity to the city center. Generally, all observations are significantly lower in the post-bypass period. The reduction in traffic on the bypassed route is as much as 65 percent in some cases. On average, there is a 25 percent decrease in traffic at this location. This is depicted graphically in Figure 4.7. When comparing these results with the hypothetical case, the trend is consistently decreasing, though there is a difference in magnitude.

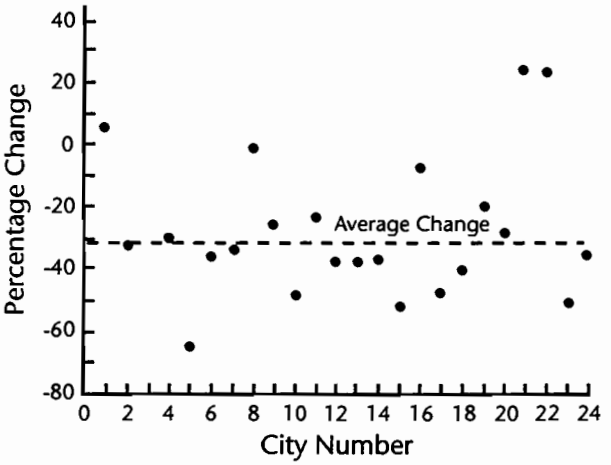


Figure 4.7 ***Observed changes in traffic on the bypassed route***

In the same way, the change on the connection along the most "major" arterial[84] crossing the bypass is investigated. Results show variation between a decrease of about 15 percent to an increase of over 60 percent. On average there seems to be no significant change. These results are depicted in Figure 4.8. Results from the observed data differ from those of the hypothetical case. The observed data do not show a general increase on this route. The local road network configuration may be an explanation for this apparent discrepancy.

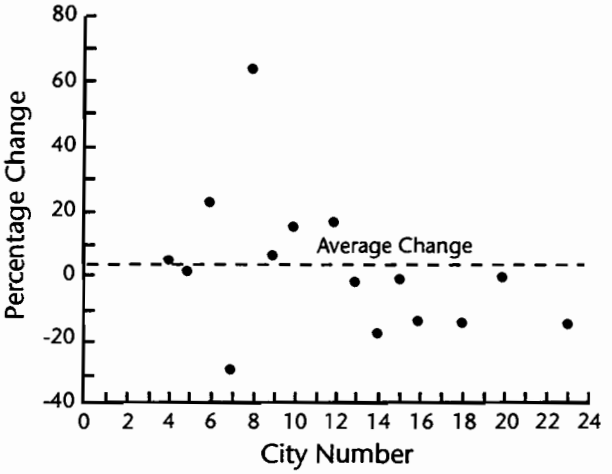


Figure 4.8 ***Observed changes in traffic on the most major arterial connecting to the bypass***

Although there is some broad correspondence with the hypothetical case, traffic changes resulting from the bypass at the two locations are not as evident as in the hypothetical example. This is partially due to the way the hypothetical case is set up, assigning traffic volumes in an "all-or-nothing" way on the respective routes. Further

caution should be exercised when drawing these comparisons, since few of the sample cities conform to the ideal configuration of the hypothesized bypassed city. Also, an intersecting highway is not always present; moreover, the local street network close to the city center may not be comparable at all to the simplified approach of the hypothesized city. Results obtained from this analysis should be interpreted as broad indicators of changes resulting from the bypass.

Considering the above, it was thought that a more meaningful indicator would be the ratio of traffic on the shortest connector to the traffic on the bypassed route. A shift in traffic would be better captured in this way, taking into account the relative changes on these two routes. The results of this analysis are portrayed in Figure 4.9. There is a consistent increase in this ratio for the post-bypass period. The only city not showing this increase is Taylor (city #16), and even then the difference does not seem to be significant. It is evident that there is a general shift toward the connector leading to the bypass, reducing the importance of the bypassed route as the major route in the city. These results are also portrayed in Figure 4.10, showing the difference in ratio for the pre- and post-bypass cases. The shift away from the bypassed route is again substantiated by this representation.

In conclusion, traffic analysis indicates a shift away from the bypassed route, with more traffic using the shortest connector from the city center to the bypass. Both the hypothetical example and the observed data confirm this statement. Historically it has been shown that development follows shifts in traffic. The next section will explore whether development actually followed these shifts in traffic at some bypassed cities in Texas.

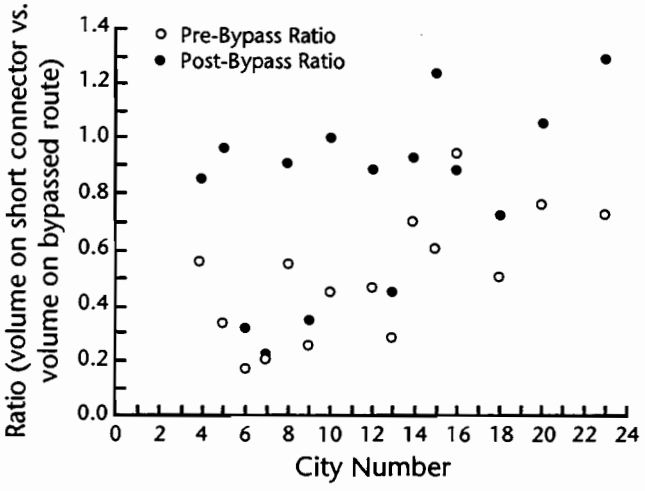


Figure 4.9 ***Ratio between the volume on the intersecting highway and the bypassed route***

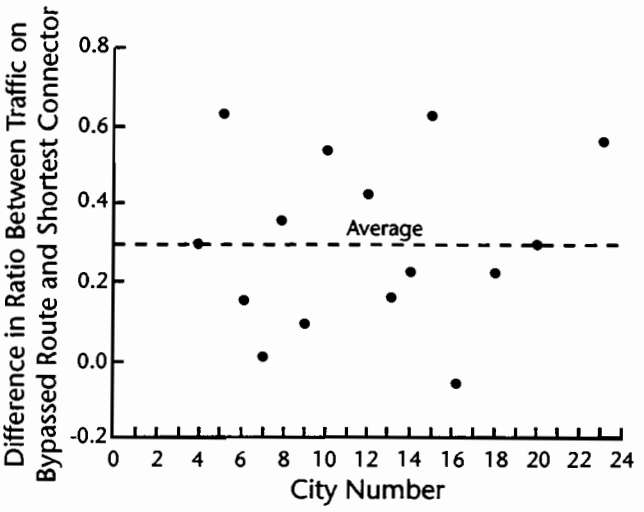


Figure 4.10 ***The difference in ratio between the volume on the intersecting highway and the bypassed route***

4.2 SPATIAL IMPACTS

This section explores changes in spatial distribution of businesses in bypassed cities. The emphasis is on highway-related businesses. The previous section pointed out the shift in traffic away from the bypassed route to the shortest connector leading to the bypass. One can expect highway-related businesses to recognize this fact and take advantage of the spatial shift of the market. Discussed below is whether a shift of business activity actually materialized at the bypassed cities chosen for further investigation.

Six cities were chosen for a more detailed analysis. The three cities discussed in the case study section of Chapter 3, namely, Littlefield, Bowie, and Alvord, were included. The other three cities are Taylor, Navasota, and Grapeland. A detailed account of findings for the latter three cities is given by Helaakoski[85] elsewhere. A detailed analysis for the first three cities is presented below. Changes in spatial location and the number of highway-related businesses were obtained from old telephone directories. Data were collected for approximately the last two decades (approximately 1970-1990).

For analysis purposes, highway-oriented businesses are comprised of three groups: service stations, restaurants, and motels. The spatial location of these businesses was differentiated in four ways:

(1) businesses along the bypassed route,
(2) businesses along the bypass,
(3) businesses along the other main arterial, and
(4) businesses on other streets.

A summary of the number and location of businesses for the three cities are presented below.

Littlefield

Data are presented in Figure 4.11. It can be seen that there is a very clear decline in business activity along the bypassed route relative to activity along the other main arterial. There is not much evidence of business activity on the bypass, while there seems to be a general decline in the number of businesses in Littlefield.

Bowie

Similarly, data for Bowie are presented in Figure 4.12. Once again, a slow decline in business activity in the city is evident. A decline in business activity along the bypassed route is evident, with a lot of activity on the bypass. There is a small increase in businesses along the other main arterial.

Alvord

Similarly, data for Alvord are presented in Figure 4.13. Since Alvord is a very small city and there is no other main intersecting arterial, data are only given for the bypass and bypassed route. The population is too small to support much business activity. The number of businesses stayed relatively constant, while there is a shift of businesses from the bypassed route to the bypass.

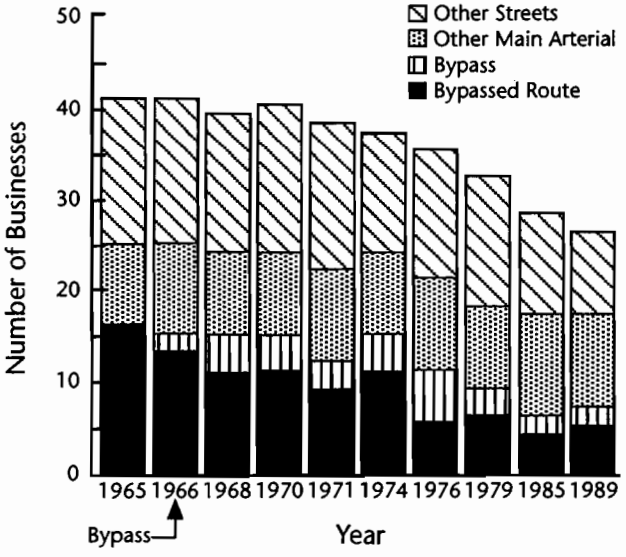


Figure 4.11 Number and spatial location of businesses in Littlefield

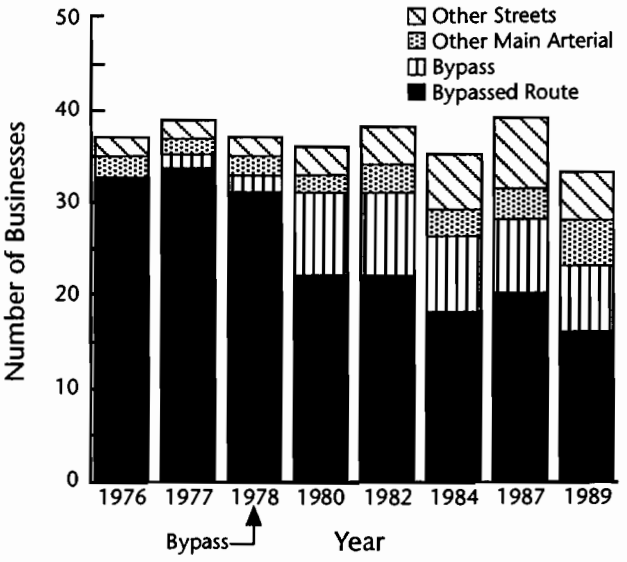


Figure 4.12 Number and spatial location of businesses in Bowie

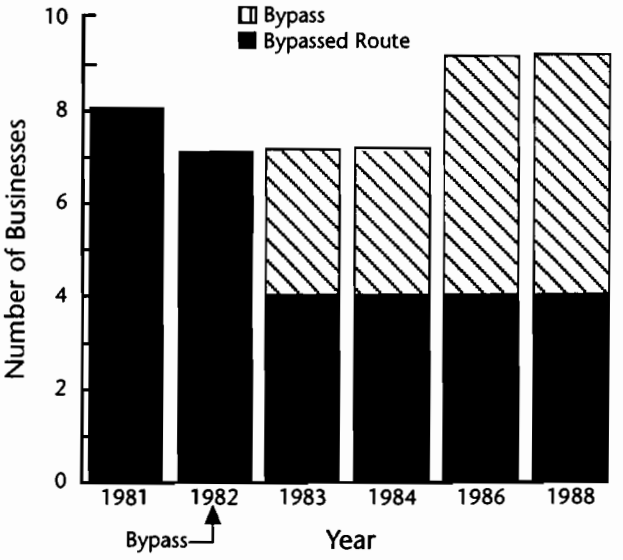


Figure 4.13 Number and spatial location of businesses in Alvord

Data for the above-mentioned cities and the cities of Navasota and Taylor were combined to determine the change in ratio of businesses on the other main arterial (the most "major" arterial connecting the bypass to the city) vs the bypassed route. Data from the cities of Alvord and Grapeland could not be used, since no other main arterial exists at those cities. Figure 4.14 shows how the mentioned ratio varies over time.

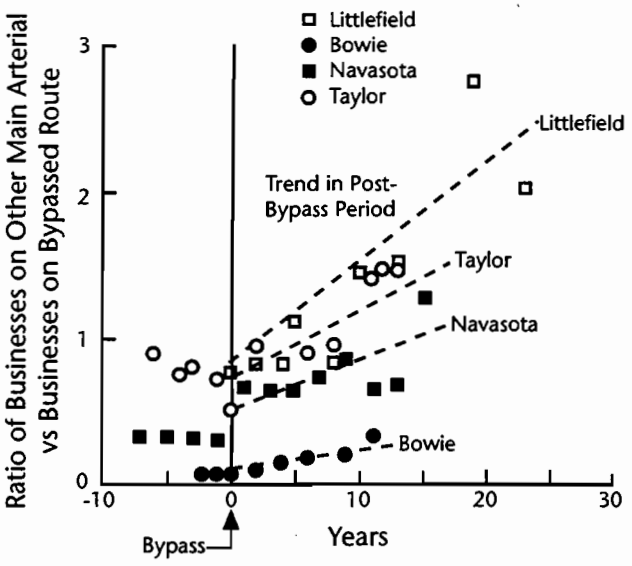


Figure 4.14 The ratio of businesses on the other main arterial vs businesses on the bypassed route

It is clear that there is a general decline in business activity on the bypassed route relative to the other main arterial. The ratio increases for all four cities, indicating a relative increase of business activity on the other main arterial. This increase seems to materialize a number of years after the opening of the bypass. Intuitively, this lagging response can be expected, since business location or relocation cannot happen overnight. It also appears that the ratio continues to increase over many years; no quick stabilization with regard to business location appears to have occurred. Note that data were available for only four cities. Thus, because all inferences are drawn from a very limited data set, one cannot make statements with a high level of confidence. However, some very clear and consistent trends are present.

In conclusion, there is a definite trend present in business location. In the previous section the shift in traffic toward the other main arterial was presented. Data from four bypassed cities confirm that developers spotted the shift in traffic and adjusted accordingly.

4.3 CLOSURE

This chapter presented some very clear trends in traffic activity as well as in business location and relocation. Analysis of observed traffic volumes and a hypothetical example confirmed the shift in traffic within city limits from the bypassed route to the other main arterial. The number and location of highway-related businesses were then explored for some Texas cities. These data were then used to establish the interaction between transportation and land development. It is clear that the development of highway-related business follows the shift in traffic, though the response is a delayed one.

CHAPTER 5. CLUSTER ANALYSIS

In this chapter, cluster analysis, a multivariate statistical procedure, is used to group bypassed cities with similar characteristics, as well as control cities with similar characteristics. The problem addressed is to determine whether a taxonomy of bypassed cities provides a useful and reliable basis for drawing inferences about the probable impact of highway bypass construction on a specific city. Such a taxonomy will be developed by means of the cluster analysis procedure.

Cluster analysis involves the grouping of entities that are similar to one another. It does not require prior knowledge about the category structure. This problem is frequently stated as one of finding the "natural groups." Cluster analysis may be used as a tool to explore and reveal structure and relations in the data.

Although the intuitive idea of clustering is clear enough, the details of actually carrying out such an analysis entail a host of problems. Cluster analysis consists of a collection of heuristic procedures and various statistical elements. It is not a recipe with a unique set of prescribed steps. Its application to a particular data set requires the analyst to make a series of judgmental decisions as to which elements of the cluster analysis repertory should be utilized. The decisions taken at various steps of the analysis can shape the outcome profoundly. These steps include the choice of data units, the choice of variables, the homogenizing of variables, the defining of similarity measures, the choice of a clustering criterion, deciding on the number of clusters, and, lastly, the interpretation of results.

The first section of this chapter deals with the clustering of bypassed cities, emphasizing the conceptual steps of the clustering procedure. This includes determining the relevance and a prior role of all variables used in the analysis. The complete linkage method, a hierarchical agglomerative clustering method, is applied to obtain clusters within the data. These clusters are then used to introduce categories of bypassed cities. The second section deals with the clustering of the control cities, applying the same procedure. The third section compares the clusters obtained in the previous two sections, in an attempt to identify characteristics inherent to the bypass group.

5.1 CLUSTER ANALYSIS APPLIED TO BYPASSED CITIES

The Cluster Analysis Procedure

The Choice Set

The set consists of the 23 bypassed cities in Texas that constitute the sample described in Chapter 3.[86]

The Choice of Variables

The choice of variables to be used in a cluster analysis is one of the most critical steps in the process. Ideally, variables should be chosen within the context of an explicitly stated theory that is used to support the classification. However, practical considerations and judgment also affect the variables selected.

In defining relevant variables, the approach for this procedure is somewhat similar to that followed in econometric analysis. Variables that assume similar values for all data units have little discriminatory power, whereas those manifesting consistent differences from one subgroup to another can induce strong distinctions. The variables identified represent characteristics of a city that are believed *a priori* to reflect the different behaviors of cities when the latter are bypassed. These are termed explanatory variables, as introduced in Chapter 3,[87] and are likewise categorized in four different categories.

The first category consists of demographic variables. Population and growth in population are the two variables considered. Cities with a relatively small population are expected to react in a different way to the advent of a bypass than larger cities. This is thought to be particularly true in a small city with little local traffic. The adverse effect on local business volumes resulting from

the diversion of through traffic should be much more evident in this case. The population growth variable represents the annual growth in population over the 8-10 year period prior to the bypass. Although all variables are cross-sectional by virtue of the sample design, this variable and the other growth variables to follow introduce a notion of trends over time. The population growth variable is intended to reflect external factors that are difficult to capture otherwise, such as the establishment of a large, new industry. Such an event can dramatically change the composition of smaller cities.

Geographic characteristics are captured by the second category. The first geographic variable is the distance to a larger city. Proximity to a larger city will cause less through traffic to consider the bypassed city as an intermediate stop and may also induce an outflow of buying power from one city to the other (usually from the smaller to the larger city). The second geographical variable is a locational one, dividing the state into the six economic regions,[88] each corresponding to a binary variable. The extent to which cities with comparable economic bases react in similar ways to the bypass should become evident with the introduction of these variables.

The economic variable category consists of four variables. The first is personal income, reflecting the average wealth of the community. A higher value for this variable would suggest lesser dependence of local businesses on highway traffic. This variable was available only at the county level and is assumed to reflect a consistent income status across the county. This variable was adjusted to 1987 constant dollars by the Consumer Price Index (CPI). The growth rate for personal income was also determined and used as a indicator of change in the buying power of the community that may have been caused by some external factors. It was calculated in the same way as the population trend variable. Retail employment is a third variable in this category and is used as an indicator of business activity. The corresponding trend variable captures a decline or rise in business activity. It is assumed that a city with a high level of business activity would be less likely to be affected adversely by a bypass.

Four variables were explored in the highway and traffic-related category. The total incoming AADT,[89] as well as a corresponding growth variable, was determined. Total incoming AADT was determined by adding all the traffic entering the city on major highways. This variable reflects the traffic activity within the immediate region, while the growth variable accounts for changes in this activity. High values for these variables should have a positive effect on business activity. Another variable in this category is the distance between the bypass and the bypassed route, measured as an average distance along the length of the bypass. Proximity of the bypass to the bypassed route also implies proximity to local businesses. The further away the bypass from the bypassed route, the fewer clientele local businesses will attract from the bypass. A binary access variable is introduced next, indicating the presence or absence of limited access. Limited access may discourage through travellers from stopping, since local businesses are made less accessible.

Exploratory analysis for all mentioned variables was performed as an aid in the selection of pertinent variables for cluster analysis. Descriptive statistics for all preceding continuous explanatory variables are summarized in Table 5.1. The number of observations for all binary-coded variables in the sample of 23 is listed in Table 5.2.

Table 5.1 Descriptive statistics for all continuous explanatory variables

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value	Median
Population	7,261	4,052	2,759	18,703	6,834
Growth in Population	0.72	1.46	-1.4	5.34	0.38
Employment	530	307	146	1,120	496
Growth in Employment	1.31	2.90	-3.03	9.71	0.93
Income	5,439	1,413	3,131	8,757	5,400
Growth in Income	1.93	2.29	-5.07	5.56	2.63
Distance to a Larger City	26.4	12.18	8	54	25
Total Incoming Traffic	16,689	7,460	5,514	35,016	16,001
Growth in Traffic	3.21	2.02	-1.18	6.84	3.22
Distance between Bypass and Bypassed Route	0.70	0.22	0.2	0.9	0.8

Table 5.2 The number of observations for all binary variables in the sample

Variable Number	Variable	Frequency
12	PLAINS	3
13	EAST	8
14	BORDER	1
15	METROPLEX	1
16	CENTRAL	3
17	GULF	7
18	ACCESS*	10

*This refers to the number of cities with controlled/limited access

The existence of a high degree of association between two variables is identified by examining the product-moment correlation coefficient between the variables, calculated in the standard manner.[90] The correlation matrix is presented in a separate table in the appendix. All variables of Tables 5.1 and 5.2 are included in this analysis.

The set of explanatory variables was reduced after careful consideration of all applicable statistics. Variables used in the cluster analysis should exhibit a certain level of variability (if they are to be useful in the discriminatory process). Because this property was not that evident with the variable reflecting the distance between the bypass and bypassed route, it was consequently excluded. In a further attempt to identify redundant variables, the degree of correlation between variables was examined. In their attempt to classify metropolitan areas with respect to their transportation needs, Golob et al[91] eliminated variables with a correlation coefficient greater than 0.90. This level of correlation still seems to be very high; however, one must keep in mind that when a relevant variable is omitted, some clusters may merge into an "amorphous and confusing mass."[92] Correlation analysis indicates a high level of correlation between population and retail employment (0.86), as expected. We therefore decided to do away with the retail employment variable. Although the level of correlation between growth in retail employment and growth in population (0.56) is not as high as is the case with retail employment and population, the growth variable for retail employment was also excluded. Its discriminatory power is believed to be captured by the other growth variables. The final list of variables used for cluster analysis is shown in Table 5.3.

Defining Validity Criteria for Clusters

One variable, termed a dependent variable, was chosen to serve as an indicator of overall economic and business activity. This variable is not an explicit part of the cluster analysis procedure. However, it plays an important role in establishing the validity of this procedure, since it provides the benchmark against which cluster groupings are judged.

Table 5.3 The list of variables used for cluster analysis

Variable
Population
Growth in Population
Income
Growth in Income
Distance to a Larger City
Total Incoming Traffic
Growth in Traffic
Economic Regions of Texas:
The Plains
East Texas
Border
Metroplex
Gulf Coast
Central Texas
Access Control

Data on total retail sales were collected for each bypassed city spanning approximately 20 years. In general, three data points were collected over the 8-10 year period prior to the bypass. Data for the post-bypass period were collected in a similar fashion. Trends in the latter period would then be indicative of the effect the bypass has had on the economic activity in the city, *ceteris paribus*.

Each city is characterized by a trend for the pre-bypass period, extrapolated to yield a trend for the post-bypass period. This trend can have:

(a) a positive slope,
(b) a negative slope,
(c) zero slope, or
(d) an undetermined slope (data points are too scattered to indicate a specific trend).

The trends are indicated by +, –, ± and ~ respectively. Actual data for the post-bypass period are next compared with the projected trend for the post-bypass period. Relative to the projected trend, actual data points can be:

(1) higher,
(2) as expected,
(3) lower, or
(4) undetermined (data points are too scattered to provide a strong conclusion).

As an example, the trend and data points for the city of Bonham are graphically depicted in Figure 5.1.

It is evident from Figure 5.1 that a positive trend prevails for the before period; thus the expected trend is also positive. Relative to the projected trend, data points for the post-bypass period are higher. One might come to the conclusion that the bypass has had a positive effect on the city of Bonham, *ceteris paribus*. A retail sales trend and data for the post-bypass period relative to the projected trend can be established in the same way for all other bypassed cities. Retail sales data for all bypassed cities are graphically depicted and shown in the appendix. A summary of this data is also reported in Table 5.4.[93]

All variables, both explanatory and dependent, have now been defined. All relevant explanatory variables will be used as an input to the cluster analysis procedure. The dependent variable will then be used to determine whether elements of a specific cluster exhibit similar trends. This would then be used as a starting point for drawing inferences about the effect of a bypass.

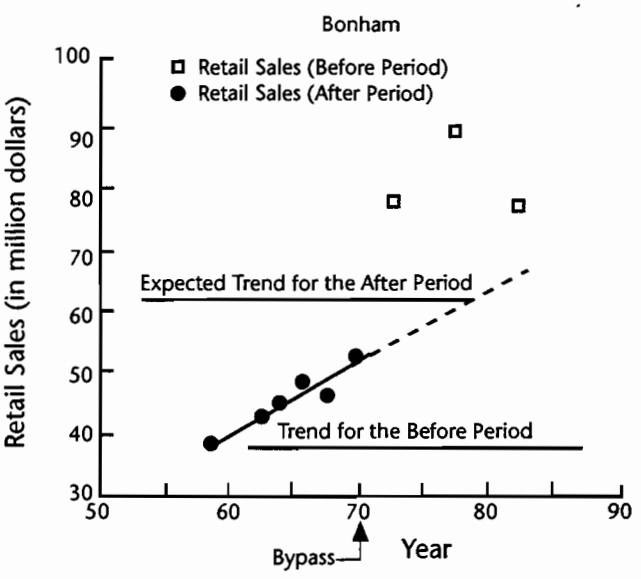


Figure 5.1 ***Total retail sales trend for the city of Bowie, 1962-1982***

Table 5.4 Total retail sales trends for bypassed cities

City Number	Bypassed City	Pre-Bypass and Projected Trend	Actual Data Points Relative to Projected Trend, Post Bypass
1	Bonham	+	Higher
2	Bridgeport	+	Higher
4	Vernon	±	Higher
5	Electra	−	As Expected
6	Henrietta	~	Lower
7	Bowie	+	Lower
8	Littlefield	±	Lower
9	Slaton	+	As Expected
10	Tahoka	−	As Expected
11	Snyder	±	Higher
12	Alvin	+	Higher
13	Wharton	+	Lower
14	El Campo	+	Indifferent
15	Edna	+	As Expected
16	Taylor	+	Higher
17	Bastrop	±	Higher
18	Beeville	+	As Expected
19	Teague	+	Indifferent
20	Navasota	+	Lower
21	Atlanta	±	Higher
22	Silsbee	+	Lower
23	Edinburg	+	Higher
24	Coleman	+	Lower

Homogenizing Variables

Homogenizing all variables is an important step towards obtaining valid results. Under the assumption that all variables carry the same weight, all variables are required to be of the same type and scale. Neither the scale nor the type of variable is consistent for this dataset, which also includes both binary and continuous variables. Efforts to homogenize variables are discussed below.

Conversion of variables to the same scale is first dealt with. We decided to express all variables in a comparable manner by confining their values to between zero and one. Binary variables already have unit range and will not be altered in this step. Continuous variables are equalized by indexing all observations in the following way:

$$\frac{|x_{ij} - x_{i\,min}|}{\text{range } xi}$$

where x_{ij} is the jth value of variable i,
x_{imin} is the minimum value for the ith variable, and
range x_i is the range of the ith variable.

In this manner the variables are all indexed to the same scale.

Conversion of all variables to the same type is the second aspect of homogenizing variables. Variables used as input to the clustering procedure are assumed to be of the same type. This is not the case for the variables described earlier. Various ways to approach this problem were considered. One approach is to convert all variables to one type, preferably the dominant type. No dominant type is evident, since there are seven variables in both categories. It is generally not recommended that one convert continuous variables to binary variables[94] (because of the associated loss of information). Similarly, methods to convert binary variables to continuous ones may impose too much information on the data. When cluster analysis is performed with all types of variables bounded between zero and one, the binary variables tend to be the dominant criteria in the resulting clusters. The binary variables yield more discriminating power, since typical values are either one or zero, representing the maximum distance between two values for the variable. By the nature of the clustering algorithm, this is seen to maximize the difference between observations and would strongly influence the composition of the clusters. On the other hand, differences on the continuous variable scale are not so salient because the values are distributed between zero and one.

The approach taken in this analysis is to reduce the effect of the binary variables, i.e., make the difference between the binary variables less dominant when combining them with the continuous variables for the clustering procedure. This can be achieved by decreasing the scale of the binary variables or by increasing the scale of the continuous variables. The latter is not recommended because it would disturb the unique relationship between variables and also implies some kind of weighing of variables. We decided to reduce the scale of all binary variables. However, there was no theoretical justification of what the magnitude in this reduction of scaling should be. An empirical approach was taken: A sensitivity analysis would be performed, assessing the effect on the outcome of the clusters after each stepwise reduction of the difference between the binary variables. At first the binary variables were introduced, being coded as either zero or one. Cluster analysis was then performed. These variables were reduced in steps of 0.05, the first step recoding binary variables to 0.05 and 0.95, and so on. Cluster analysis was performed after each stepwise reduction. Results were analyzed and their validity investigated for each step.

Clustering Criterion

Many families of clustering criteria exist. Hierarchical agglomerative methods and hill and valley methods are two of the most widely used methods. They are explored and briefly discussed below.

Hierarchical agglomerative methods are well-suited for finding clearly separated groupings. As a starting point, all objects are considered individual points. Clusters are built up by successively joining points at certain levels of similarity. Hill and valley methods are the second family of methods that were used. This family of methods is used when clusters are believed to be present though not clearly separated.

Eventually the complete linkage clustering method, part of the family of hierarchical clustering methods, was used for this analysis. At each stage in this method, after clusters p and q have been merged, the similarity between the new cluster (labeled t) and some other cluster r is determined as follows:[95]

$$s_{tr} = \max(s_{pr}, s_{qr})$$

The quantity s_{tr} is the distance[96] between the most distant members of clusters t and r. If clusters were merged, then every entity in the

resulting cluster would be no farther than s_{tr} from every other entity in the cluster. The value of s_{tr} is the diameter of the smallest sphere which can enclose the cluster resulting from the merger of clusters *t* and *r*. The method is called complete linkage because all entities in a cluster are linked to each other at some maximum distance or minimum similarity.

Applying Cluster Analysis to the Data

All required input is now available for applying the clustering method. The input and initial exploratory steps are presented below.

- All variables deemed relevant in characterizing a bypassed city are introduced in the procedure as a first step.[97]
- The next step was to determine which criteria to use for clustering. For this situation one would like to believe that there are clear clusters, but that they are probably not clearly separated. The family of density methods are most appropriate for such cases. However, after applying various of these methods, no clear clusters emerged. One had to turn to the hierarchical agglomerative methods, which are suited to data that have little noise present. Again, various methods were applied, with the clearest clusters emerging by using the complete linkage method. Three clearly distinguishable clusters were obtained from this initial analysis, consisting of 6, 8, and 9 cities, respectively.
- A sensitivity analysis with respect to the values of the binary variables was performed. Initially, binary variables were coded as (0,1). By incrementally reducing its value (as explained in the previous section), the transition point was found to be between the values (0.8,0.2) and (0.75,0.25). For the latter configuration, clusters that emerged were less clear. Before that point, all clusters remained constant, although there was some evidence that the discriminatory power of the binary variables was reduced. At this stage we decided to code all binary variables as (0.8,0.2). Although the clusters remained constant with the binary variable coded between (1,0) and (0.8,0.2), the dendogram[100] showed that clusters were joined at different levels of similarity. There is still enough discriminating power within the binary variables coded as (0.8,0.2) for this sample. However, this may not be true for another sample. By recoding the binary variables, the bias towards these variables in the discriminating process is reduced.

The meaningfulness of the clusters obtained was explored by observing their respective total retail sales trends and variation between clusters. It should be emphasized that retail sales was not used as an explanatory variable in the clustering procedure. It merely serves as a figure of merit against which cluster groupings are judged. The three clusters of cities are reported in Table 5.5, along with their characteristic trends in total retail sales. The three clusters appear to represent three distinct trends with respect to total retail sales, as is discussed below.

Table 5.5 ***Initial results of cluster analysis for bypassed cities, indicating retail sales trends for the pre- and post-bypass periods***

Cluster #1		
City	Pre-Bypass Trends	Actual Data Relative to Projected Trend, Post Bypass
Bonham	+	Higher
Bridgeport	+	Higher
Atlanta	±	Higher
Taylor	±	Higher
Bastrop	±	Higher
Teague	+	Undetermined

Cluster #2		
City	Pre-Bypass Trends	Actual Data Relative to Projected Trend, Post Bypass
Bowie	+	Lower
Alvin	+	Higher
Wharton	+	Lower
El Campo	+	Undetermined
Silsbee	+	Lower
Edna	+	As expected
Beeville	+	As expected
Navasota	+	Lower
Edinburg	+	Higher

Cluster #3		
City	Pre-Bypass Trends	Actual Data Relative to Projected Trend, Post Bypass
Vernon	±	Undetermined
Snyder	±	Higher
Electra	–	As expected
Tahoka	–	As expected
Henrietta	~	Lower
Slaton	+	As expected
Littlefield	±	Lower
Coleman	+	Lower

- Cluster #1 represents cities with retail sales higher than expected, relative to the projected trends for the post-bypass period. This might be attributed to several factors, of which bypass construction may be one. It is noticed that the pre-bypass trends are on average slightly positive, ranging from having zero slope to a positive slope. Judging from retail sales trends, this cluster appears to represent cities with a stable and healthy economic base, both for the pre- and post-bypass periods.
- Retail sales trends are less clear for the cities in cluster #2. One notices that all the cities exhibit positive trends in the pre-bypass period. The pre-bypass trend for cluster #2 is on average slightly greater than that of cluster #1. Actual data points for the post-bypass period tend to be negative on average, relative to the projected trend. There is thus an apparent reversal in the post-bypass period, with the projected trend generally not being realized. This reversal can be the result of many underlying factors, of which the bypass may be one. Retail sales trends for cities in this cluster suggest that, on average, little or no growth was experienced in the post-bypass period.
- Cluster #3 represents cities with retail sales generally lower than expected in the post-bypass period, relative to the projected trends. The pre-bypass trends are generally negative, differing in this sense from cluster #2, thus indicating a declining economy at the outset. Generally the absolute trends for the after period remain negative. Certain aggravating factors seems to be present in these already declining economies. Again, bypass construction may be one of them.

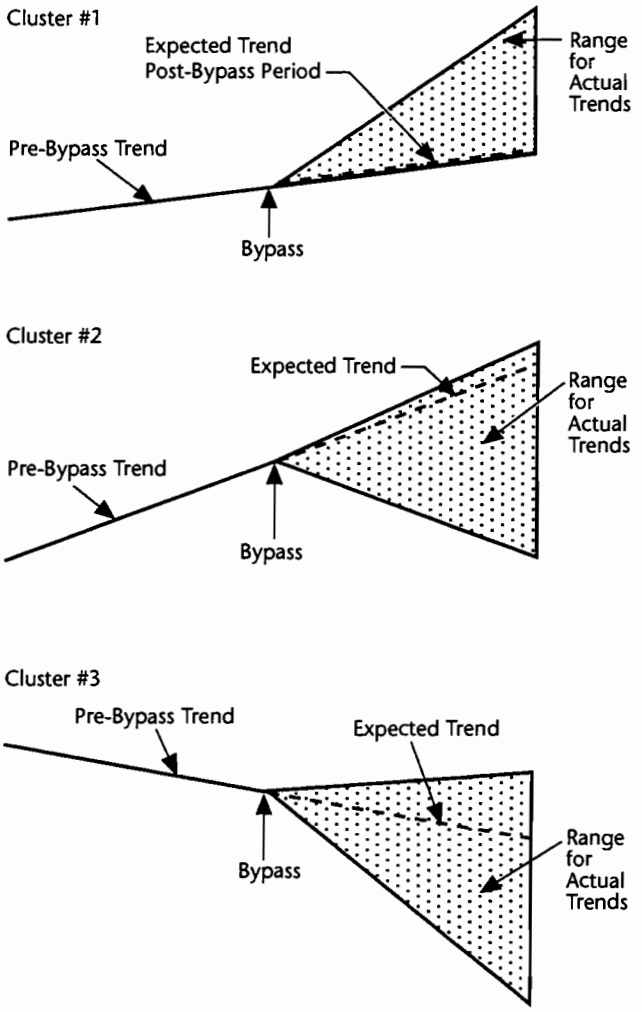


Figure 5.2 Schematic representation of trends for pre- and post-bypass period

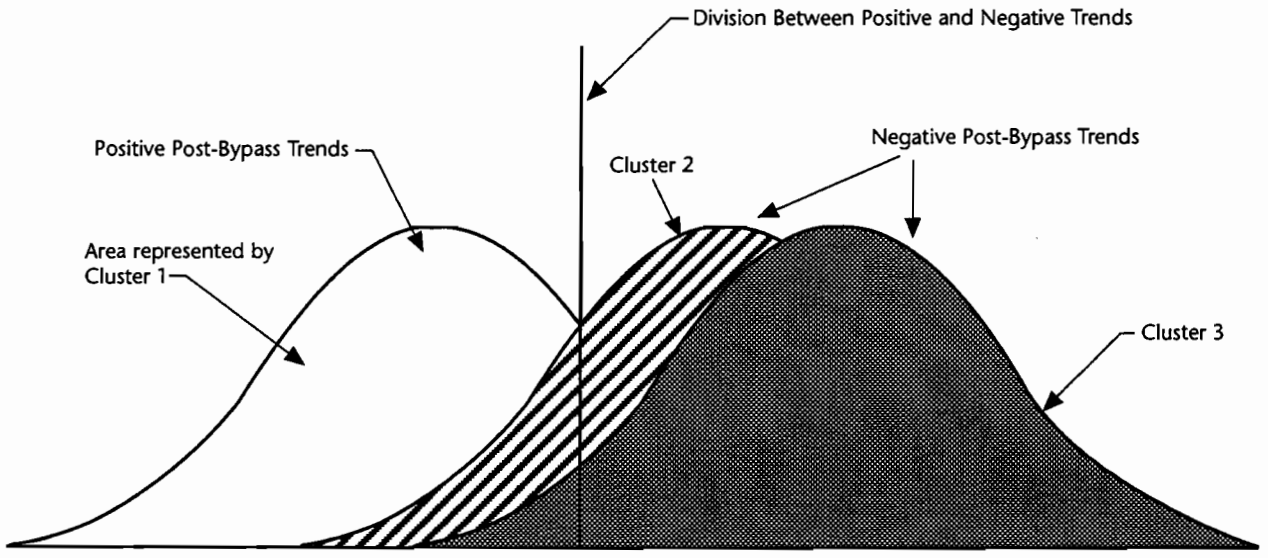


Figure 5.3 The distribution of trends for the post-bypass period

It is significant that the groupings were obtained without using retail sales as a cluster variable. In all three clusters, external factors seem to be present, causing a divergence from the projected post-bypass trend. The magnitude of the contribution of the bypass to this divergence cannot be made explicitly without controlling for these external factors. The trends captured by the clusters are presented graphically in Figure 5.2, which depicts the average trends for the pre-bypass period and indicates the approximate ranges of the actual data points for the post-bypass period.

Actual data points relative to the projected trend for the post-bypass period can be depicted as the distribution of two types, positive and negative, and an overlapping area in between. As depicted in Figure 5.3, cluster #1 represents positive effects. The effect of clusters 2 and 3 are not so clear but are generally negative.

The robustness of the clusters was tested in an exploratory manner. Sensitivity of the procedure to the exclusion of variables or different combinations of variables, as well as the sensitivity to outliers, was tested. Variables were excluded from the clustering procedure alternately. Several combinations of variables were also excluded. The analysis revealed that the most important variable for clustering purposes is the geographical location variable. This was the only variable that changed the composition of the clusters significantly when excluded from the analysis. The same core observations remained present in each cluster, while the other variables were alternately excluded from the analysis. There were three "floating" cities—cities moving around between the different clusters with different variables being used. These cities are Edinburg, Navasota, and Bowie. Although the importance of the geographic location variable is emphasized, cities are characterized by much more than just this variable; all other variables are consequently retained as part of further analysis.

It was mentioned in a previous section that the complete linkage method is very sensitive to outliers. A procedure available on the Statistical Analysis Systems (SAS) package is applied to trim variables by 10 percent, reducing the effect of outliers. By applying this procedure three cities were deleted from the clusters: Bowie, Navasota, and Edinburg (corresponding to the "floating" cities mentioned in the previous paragraph). However, there is no theoretical justification for treating these cities as outliers, as they are a legitimate part of the data and should be utilized in the clustering process. Reasons for their behavior as outliers will be discussed in the next section. The following section discusses individual characteristics of clusters and cities.

Interpretation of Results

This section explores the individual characteristics of each cluster by analyzing the attributes of individual cities and the descriptive statistics for each explanatory variable within a cluster. The geographical location of the three clusters are depicted in Figure 5.4. Characteristics for each cluster are reported in Tables 5.6 through 5.8. Discussion of these results for each cluster follows below.

Cluster #1

The geographic location and the access variable exhibit very definite trends in this cluster. The other variables do not appear to be as significant, although some consistent trends are revealed.

The importance of the geographic location variable has already been noted in previous discussions. This cluster represents cities from the Metroplex Region (2), Central Region (3), and the East Economic Region (1). The Metroplex and Central Regions generally represent stable economic regions, with their respective economic bases less dependent on fluctuation of agricultural markets. The East Region is dependent mainly on timber and oil but has diversified its economy to the extent that it may be less sensitive to fluctuation in the respective markets. Cities in the first two regions are clearly associated with this cluster. More caution should be exercised with regard to cities in the East region, which are not as strongly associated with this cluster. Other aspects such as local economic base and the cities' economic role in the surrounding region need to be considered.

The access variable seems to be quite significant, since all cities in this category are characterized by bypasses with uncontrolled access. Compared with limited access, uncontrolled access provides greater visibility and better access from the highway to businesses located on the bypass. For these reasons it can be expected that through travellers will be more inclined to stop along the bypass, and that this will result in a positive effect on the local economy. However, in the case of Taylor (city #16) this variable should probably not be regarded with the same degree of importance (since it has few businesses on the bypass).[99] Its relatively large population should probably carry more weight in contributing to the positive trends.

Certain trends are exhibited by the rest of the variables. Population at the time of the bypass was smaller than 10,000 for all cities in this cluster, with the mean population the smallest of all clusters. Also, population growth has been relatively

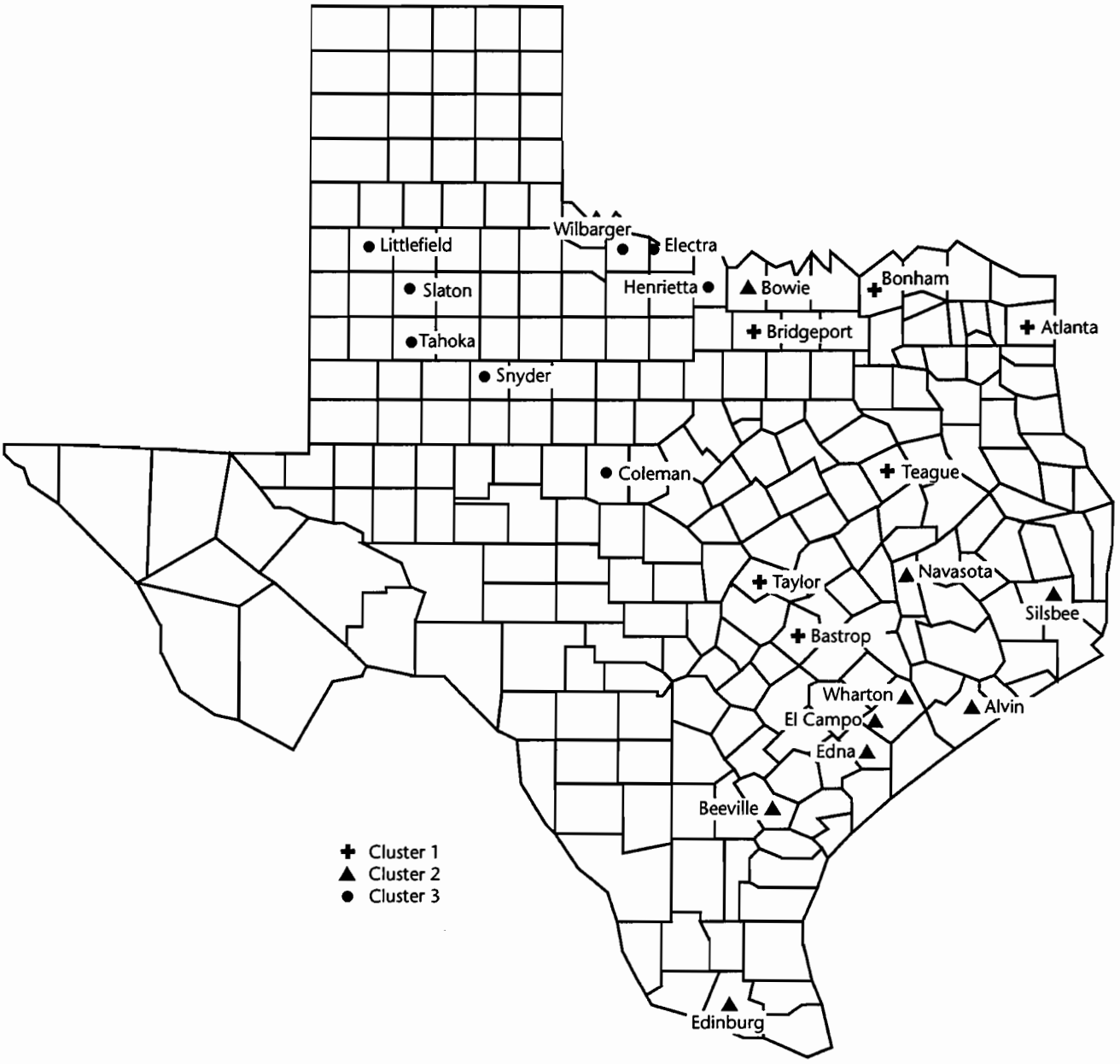


Figure 5.4 The geographical location of the three clusters obtained for the bypassed cities

Table 5.6 Individual characteristics of bypassed cities in cluster #1

City	Population	Growth in Population (%)	Income per Capita ($)	Growth in Income (%)	Total Incoming Traffic (vehicles)	Growth in Traffic (%)	Nature of Access Control (= 1 if limited; 0, otherwise)	Distance to a Larger City (miles)	Pre-bypass Trend	Post-Bypass Trend Relative to Projected Trend
Bonham	7,708	0.45	4,040	1.31	14,520	2.65	0	28	+	Higher
Bridgeport	3,457	3.18	4,890	3.32	8,886	6.84	0	11	+	Higher
Atlanta	4,254	1.34	3,260	1.60	16,043	6.53	0	23	±	Higher
Taylor	9,869	0.38	5,030	4.25	16,114	3.18	0	35	+	Higher
Bastrop	3,100	0.33	3,785	2.85	8,741	3.41	0	17	±	Higher
Teague	2,759	-0.39	4,220	3.19	5,514	5.03	0	14	+	Undetermined
Mean	5,191	0.88	4,204	2.75	11,636	4.61		21.3		
Stdev	2,911	1.25	670	1.11	4,499	1.80		9.09		
Range	2,800	-0.4	3,000	1.30	5,514	2.5		10		
	10,000	3.18	5,000	4.50	16,000	7.0		35		

Legend:
+ Positive Slope
± Zero Slope
– Negative Slope
~ Undetermined

Table 5.7 Individual characteristics of bypassed cities in cluster #2

City	Population	Growth in Population (%)	Income per Capita ($)	Growth in Income (%)	Total Incoming Traffic (vehicles)	Growth in Traffic (%)	Nature of Access Control (= 1, if limited; 0, otherwise)	Distance to a Larger City (miles)	Pre-Bypass Trend	Post-Bypass Trend Relative to Projected Trend
Alvin	7,330	5.34	5,770	0.93	19,444	3.87	0	26	+	Higher
Wharton	8,521	2.71	5,470	3.50	21,453	4.70	0	25	+	Lower
El Campo	9,135	1.30	5,470	3.50	25,000	3.22	0	38	+	Undetermined
Silsbee	7,707	0.81	7,350	3.15	27,168	4.68	0	18	+	Lower
Edna	5,454	0.57	6,860	5.56	20,454	2.93	1	26	+	As expected
Beeville	13,537	-0.12	5,225	3.53	23,438	4.82	1	54	+	As expected
Bowie	5,540	0.93	8,757	4.00	28,209	3.91	1	45	+	Lower
Navasota	5,048	0.23	3,131	-0.46	14,557	0.27	1	24	+	Lower
Edinburg	18,703	-0.26	3,466	2.86	35,016	5.81	1	8	+	Higher
Mean	8,614	1.77	6,024	3.36	22,826	4.04		31.2		
Stdev	2,719	1.99	869	1.47	2,929	0.82		12.9		
Range	5,048	-0.12	3,131	-0.46	14,557	0.27		8		
	18,703	5.34	8,757	5.56	35,016	5.81		54		

Legend:
+ Positive Slope
± Zero Slope
– Negative Slope
~ Undetermined

Table 5.8 Individual characteristics of bypassed cities in cluster #3

City	Population	Growth in Population (%)	Income per Capita ($)	Growth in Income (%)	Total Incoming Traffic (vehicles)	Growth in Traffic (%)	Nature of Access Control (= 1, if limited; 0, otherwise)	Distance to a Larger City (miles)	Pre-Bypass Trend	Post-Bypass Trend Relative to Projected Trend
Vernon	11,827	-0.47	5,266	-0.42	16,000	0.42	1	50	±	Undetermined
Snyder	13,252	0.26	5,970	-0.57	13,216	-1.18	0	38	±	Higher
Electra	4,066	-1.40	7,000	1.23	13,604	1.04	1	14	–	As expected
Tahoka	2,978	-0.03	6,550	1.93	9,830	1.32	1	25	–	As expected
Henrietta	2,924	-0.25	6,480	2.45	17,980	3.60	1	20	~	Lower
Slaton	6,834	1.70	6,575	-1.22	9,027	2.44	1	15	+	As expected
Littlefield	7,218	0.43	5,400	-0.30	11,206	1.60	0	24	±	Lower
Coleman	5,794	-1.02	5,120	2.63	8,412	2.67	0	30	+	Lower
Mean	6,861	-0.10	6,045	0.72	12,049	1.49		27		
Stdev	3,876	0.95	709	1.52	3,413	1.48		12.2		
Range	3,000	-1.5	5,000	-1.2	8,000	-1		15		
	13,500	2.0	7,000	2.7	18,000	3		50		

Legend:
+ Positive Slope
± Zero Slope
– Negative Slope
~ Undetermined

small in the pre-bypass period. The mean value for income is the smallest of the three clusters, with no intuitive reasoning behind this. The mean traffic growth variable is high, possibly reflecting much interregional activity. The variable capturing distances to a larger city is the lowest of the three clusters. Cities within the higher populated metroplex or central regions are more likely to be close to a larger city than cities in some of the less populated regions. All growth variables are generally positive, reflecting a healthy economy. The somewhat indifferent post-bypass sales figures (relative to the projected figures) observed for Teague may be linked to a negative population growth rate as well as to a considerably lower volume of traffic.

Cluster #2

Most cities in this cluster are situated in the Gulf Economic Region (7 out of 9 cities). Because their economic base is dominated by the oil industry, they are subject to that industry's fluctuation and general decline since the early 1980's. The positive trends in the pre-bypass period can be related to the time when the oil industry was still booming, with declining trends in the post bypass period reflecting the oil bust. The interpretation of actual and extrapolated trends should carefully consider the effect of the oil industry on cities in this region. One city in each of the Metroplex and Border regions also appears in this cluster.

When compared with the other clusters, cities in this cluster appear to have a slightly higher mean population. Only one city has negative population trends, while the rest are on the low side (less than 2 percent), except for the city of Alvin (city #12), which has an annual growth rate higher than 5 percent. Alvin is the only Gulf city that has shown upbeat business performance in the post-bypass period, suggesting that it has been positively influenced by the bypass. One should also note that this city lies just outside the Houston metropolitan area and is situated on the way to Galveston. It was learned that, during the oil bust, most oil companies consolidated by relocating to Houston, recalling many of their workers from the rest of the state and from neighboring states. This led to an influx of primarily white-collar workers, creating a demand for housing in the middle-income range.[100] Once targeted by real estate developers for housing development, Alvin now serves as a bedroom community to the Houston area. This uncharacteristic growth explains the seemingly contradictory positive trend. The construction of a bypass probably helped this process by making Houston more accessible.

Traffic volumes and the distances to a larger city are the highest of all clusters. These variables are perceived to have a positive effect on business. The type of access control does not exhibit any clear pattern. Most of the growth variables are positive, also supposedly indicative of a healthy business environment.

All of the "floating" cities mentioned earlier are found in this cluster. They are Bowie, Navasota, and Edinburg. Seemingly out of place, Bowie is the only city from the Metroplex in this cluster. It was reported in Chapter 3 that Bowie's economic base, consistent with that of the other cities in this cluster, is closely tied to the oil industry. The economic base of Edinburg, the city in the Border region, is also closely linked with petroleum operations and thus conforms to the same economic base as other cities in this cluster. It is also the city in the sample that has by far the largest population. Navasota, the third "floating" city found in this cluster, is situated in the Gulf region. Its diversified economic base (very little dependence on oil production) is not typical of cities in this economic region, a fact that created some uncertainty in our analysis.

Cluster #3

The most important and significant feature of this cluster is its geographical location. All cities within this grouping are situated in the plains of West Texas, with each of their economic bases tied to the fluctuations of agricultural and energy products. A general decline in this part of Texas is substantiated by the following characteristics of cities in this group:

- a small decline in population
- low growth in income
- low growth in ADT

Two cities show higher than projected sales trends in the post-bypass period. This seems to be related to a population higher than other cities in this cluster (>10,000). Also, they are somewhat further away from larger cities and are more apt to keep local clientele from shopping in the larger centers.

No clear patterns emerged from the other variables to characterize cities according to business trends.

From the above analysis it is clear that the geographical location variable is the most consistent variable among clusters. Some of the other variables did not seem to have as much explanatory and differentiating power as might have been expected. Although one might feel inclined to do away with some variables, intuitively there are

some basic variables that collectively describe a city and contribute towards sufficiently differentiating between cities. It is felt that this was attained with the collection of variables used in the cluster analysis procedure.

Contemplating variation in trends amongst variables, the following concluding observations can be made:

- The population variable does not exhibit as much discriminatory power as perhaps was expected. Also (somewhat surprisingly), larger populations in the sample were more prone to negative business trends than smaller cities on average. This, however, may just be a characteristic of the sample. Factors other (and more important) than population affect business trends. A large population seems to have a different effect in different economic regions.
- Population growth is generally consistent with business trends. A large value for this variable may have a substantial positive impact on business trends, overriding the effect of some of the other variables.
- The income variable does not seem to be very significant. The mean value for income in the cluster of cities that experience the bypass effect in a positive manner is the lowest of all clusters. This is slightly counterintuitive. One possible explanation might be that the variable reflects the income of the county, which may be vastly different from the city income.
- The growth in income is consistent with business trends, except for cluster #2, where growth remains positive despite negative business trends.
- Traffic volumes generally appear not to have a dominant effect on business trends. High volumes are observed in cities which exhibit negative retail sales trends in the post-bypass period and vice versa.
- Growth in traffic is generally positive, although trends in cluster #3 are slightly lower than average values.
- Investigating the distance to a larger city allows for some mixed interpretation. Effects of this variable may also be dependent on its geographical location.

From the above analysis, it can be inferred that retail sales trends relative to a projected trend can, to a large extent, be explained by geographic location. Other descriptive variables can be utilized to explain deviations from projected trends. By virtue of this detailed analysis, a categorizing procedure can now be developed.

Categorization of Bypassed Cities

This categorization procedure will focus on the most consistent variables for each group. Geographical location was seen as the most significant variable for the clustering procedure. This is then the starting point for the categorization procedure. Thus there are six categories, conforming to the number of economic regions. Characteristics for five of the six regions are listed in Tables 5.9 through 5.13.

Table 5.9 Category 1 - The Plains

Business Trend Relative to Projected Trend	
No Change or Negative	
This is Consistent with:	
Variable	Characteristic Value of Variable
Population	< 10,000
Population Growth Rate	Negative or Low (2%)
Income Growth Rate	Negative or Low (2%)
Incoming Traffic Growth Rate	< + 3%
Distance to a Larger City	< 35 Miles
Analysis Unaffected by:	
Type of Access Control	
Income per Capita	
Incoming Traffic Volume	
Inferred Trend May be Altered if:	
Variable	Characteristic Value of Variable
Population	> 10,000
Distance to a Larger City	> 35 Miles

Table 5.10 Category 2 - Gulf Coast Region

Business Trend Relative to Projected Trend	
No Change or Negative	
This is Consistent with:	
Variable	Characteristic Value of Variable
Population	5,000 < Population < 14,000 (Population < 5,000 will probably yield the same result.)
Population Growth Rate	Negative or Low (2%)
Analysis unaffected by:	
Type of Access Control	
Distance to a Larger City	
Incoming Traffic Volumes	
Income per Capita	
Inferred trend may be altered if:	
Variable	Characteristic Value of Variable
Population Growth Rate	> 5%

Table 5.11 Category 3 - Central Texas

Business Trend Relative to Projected Trend	
Positive	
This is Consistent with:	
Variable	Characteristic Value of Variable
Nature of Access	Uncontrolled
Population Growth Rate	Positive
Income Growth Rate	Positive
Incoming Traffic Growth Rate	Positive
Distance to a Larger City	< 35 Miles
Analysis unaffected by:	
Population	
Income per Capita	
Inferred trend may be altered if:	
Variable	Characteristic Value of Variable
Population Growth Rate	Negative
Distance to a Larger City	> 35 Miles
Nature of Access	Controlled

Table 5.12 Category 4 - The Metroplex

Business Trend Relative to Projected Trend	
Positive	
This is Consistent with:	
Variable	Characteristic Value of Variable
Nature of Access	Uncontrolled
Population Growth Rate	Positive
Income Growth Rate	Positive
Incoming Traffic Growth Rate	Positive
Distance to a Larger City	< 35 Miles
Analysis Unaffected by:	
Population	
Income per Capita	
Incoming Traffic Volume	
Inferred Trend May be Altered if:	
Variable	Characteristic Value of Variable
Nature of Access	Controlled
Distance to a Larger City	> 35 Miles

Table 5.13 Category 5 - East Texas

Business Trend Relative to Projected Trend	
Positive	
This is Consistent with:	
Variable	Characteristic Value of Variable
Nature of Access	Uncontrolled
Population Growth Rate	Positive
Income Growth Rate	Negative or low (2%)
Incoming Traffic Growth Rate	< ± 3%
Distance to a Larger City	< 35 Miles
Analysis Unaffected by:	
Population	
Income Per Capita	
Incoming Traffic Volume	
Inferred Trend May be Altered if:	
Variable	Characteristic Value of Variable
Nature of Access	Controlled
Distance to a Larger City	> 35 Miles

For each category (economic region), an average retail sales trend relative to the projected trend can be inferred. This is seen as a characteristic of the economic region. Thereafter, the interactions with other variables are taken into account for possible alteration of the trend first inferred. A summary of variables that exhibit consistent trends is listed. Also, variables that do not show any specific trend and probably will not affect the analysis are listed.

Category 6: The Border Region

One cannot explicitly infer characteristic trends for this region with confidence. We therefore regarded Edinburg as an outlier and not representative of the cluster it was grouped with. The values for its population and traffic volumes are much larger than those found in any other observation in the sample. Also, it is very close to a larger city. This all represents a somewhat contorted picture. Assessing trends for this region, one can do no better than to say that experience of local conditions and experience gained from the other regions should be used to predict trends for this region.

The categorization procedure that was followed emphasized the importance of the geographic location variable. Informally it was observed that there are other variables that may affect business trends dramatically. They are population size, population growth rate, distance to a larger city, and access control.

This categorizing procedure pointed out certain consistencies within economic regions. However, one should interpret the data cautiously. Interpretation should be linked to performance within a larger economic framework, whether local, regionwide, statewide, or nationwide. Urban and rural migration trends and their implication should also be considered. The timeframe within which a city is bypassed and the corresponding economic trends seem to play a significant role in the clustering procedure. This should be kept in mind when drawing inferences from these data. Characteristic retail sales trends were observed for each city, with dominant trends for clusters as a whole obtained. It cannot be inferred from this analysis whether deviations from projected trends can be attributed to the bypass. Also, it is not known whether the clustering structure obtained is unique to bypassed cities. The categorization of bypassed cities that was developed in this section may apply just as well to other cities in a rural setting in Texas. Cluster analysis will be applied to the control cities in the next section to explore some of these issues.

5.2 CLUSTER ANALYSIS APPLIED TO CONTROL CITIES

Cluster analysis is applied to the control cities to group cities with similar characteristics. The clustering procedure that was applied to the bypassed cities is now repeated for the control city group.

The choice set consists of the 23 control cities listed in Table 3.2 of Chapter 3.

The list of variables used for the cluster analysis is the same as that given in Table 5.3, the only exception being the variable for access control on the bypass. Since the control cities have no bypass, this variable is not defined. Descriptive statistics for all continuous explanatory variables are listed in Table 5.14. The number of observations for all binary variables is listed in Table 5.15.

Retail sales again serve as the dependent variable, acting as an indicator of overall economic and business activity. Control cities are characterized by trends for periods that cor-respond to the pre- and post-bypass trends of their matching bypassed cities. The pre-bypass trend is extrapolated to yield the post-bypass trend. As for the bypassed cities, this trend can have (a) a positive slope, (b) a negative slope, (c) a zero slope, or (d) an undetermined slope, indicated by +, –, ± and ~ respectively. Actual data for the post bypass period can be (1) higher, (2) as expected, (3) lower, or (4) undetermined.

As was the case for the bypassed cities, three data points were collected for the pre-bypass period and three data points for the period thereafter. These trends are reflected in the appendix, showing the data points and trends for each control city. Total retail sales trends and data for control cities are summarized in Table 5.16.

All variables are converted to the same scale in a manner similar to that followed for the bypassed cities. The complete linkage method is used for cluster analysis.

Table 5.14 Descriptive statistics for all continuous explanatory variables for the control cities

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value	Median
Population	6,836	3,990	2,772	2,020	5,467
Growth in Population	0.70	1.50	-1.68	5.52	0.4
Income	5,682	1,559	3,491	9,322	5,467
Growth in Income	2.40	2.01	-1.09	6.77	2.21
Distance to a Larger City	29.4	11.71	11	61	29
Total Incoming Traffic	12, 124	5,435	5,851	27,076	10,276
Growth in Traffic	2.98	2.00	0	6.97	2.17

Table 5.15 The number of observations for binary variables for control cities

Variable	Number of Observations
The Plains	9
East Texas	2
The Border	2
Metroplex	1
Central Texas	4
Gulf Coast	5

Three clear clusters emerged from the cluster procedure. They are characterized by retail sales trends. Table 5.17 lists the pre-bypass trend for each city as well as the trend of the actual data for the post-bypass period.

Each of the three clusters appear to be represented by distinct characteristics, as inferred from retail sales for each city.

Cluster #1 indicates positive trends for the pre-bypass period. Post-bypass trends relative to the projected trends are, on average, higher. Similar to the first cluster, cluster #2 also exhibits positive trends for the pre-bypass period. The difference between the two clusters lies in the post-bypass period. There appears to be more variation in the relative trends for this period, ranging from low to high. Cluster #3 is characterized by the fact that no clear trends for either of the time periods are exhibited. Trends range over the whole spectrum, with no trend clearly dominating.

By applying cluster analysis to the control cities, three clusters emerged. The next section will compare the results obtained in this section with the clusters that were obtained for the bypassed cities.

5.3 COMPARISON BETWEEN BYPASSED AND CONTROL CITIES

Cluster Analysis

The results of the cluster analysis for the control cities are now compared with the results for the bypassed cities. Initially, bypassed cities were clustered to determine whether they form any natural groups. Very significant characteristics were observed, especially with regard to their respective retail sales. Even more significant was the fact that the sales data were not included as a clustering variable, but, rather, were used as a way of characterizing the clusters after they had been defined.

Table 5.16 Total retail sales trends for control cities

City Number	City	Pre-Bypass and Projected Trend	Actual Data Points Relative to Projected Trend, Post Bypass
1	Clarksville	+	Higher
2	Comanche	+	Higher
4	Graham	−	Higher
5	Childress	±	Higher
6	Memphis	±	Lower
7	Nocona	~	As Expected
8	Post	+	Lower
9	Brownfield	+	Lower
10	Morton	−	As Expected
11	Stamford	±	Lower
12	Angleton	+	Higher
13	Bay City	+	Higher
14	Eagle Lake	~	Undetermined
15	Cuero	+	As Expected
16	Lockhart	+	Higher
17	Giddings	+	Higher
18	Alice	+	As Expected
19	Hearne	~	Undetermined
20	Cameron	+	Lower
21	Gilmer	+	Higher
22	Liberty	+	Lower
23	Rio Grande City	+	Higher
24	Brady	+	Higher

Table 5.17 Results of cluster analysis for control cities, indicating retail sales trends for the pre- and post-bypass periods

Cluster #1		
City	Pre-Bypass Trends	Actual Data Points Relative to Projected Trend, Post Bypass
Clarksville	+	Higher
Gimer	+	Higher
Lockhart	+	Higher
Giddings	+	Higher
Hearne	~	Indifferent
Cameron	+	Lower

Cluster #2		
City	Pre-Bypass Trends	Actual Data Points Relative to Projected Trend, Post Bypass
Angleton	+	Higher
Bay City	+	Higher
Liberty	+	Lower
Eagle Lake	~	Indifferent
Cuero	+	As Expected
Alice	+	As Expected
Rio Grande City	+	Higher

Cluster #3		
City	Pre-Bypass Trends	Actual Data Points Relative to Projected Trend, Post Bypass
Comanche	+	Higher
Memphis	±	Lower
Stamford	±	Lower
Childress	±	Higher
Brady	+	Higher
Graham	–	Higher
Post	+	Lower
Brownfield	+	Lower
Morton	–	As Expected
Nocona	~	As Expected

The next step was to determine whether the control cities exhibit the same characteristics. One should keep in mind that the control cities were chosen on the basic assumption that they had the same retail sales trend for the period before the bypass was opened. The other variables by which the cities are characterized should also be similar for both groups. Three distinct clusters were also obtained within the control cities. Again, these clusters seemed to track retail sales trends rather well.

Cluster results showing the matched pairs are featured in Table 5.18, which also indicates sales trends and the cluster to which each city belongs. The bypass and control cities appear to cluster in the same way.

Table 5.19 shows the number of cities found in each cluster. The number of control cities found within each cluster, corresponding to their matched pair, is also shown.

There are only three cities in the control group that did not cluster in the same way as their corresponding bypassed cities. Entries in bold in Table 5.18 indicate matching cities that did not fall within the same cluster. There are plausible reasons for this occurrence. These three control cities are Comanche, Nocona, and Cameron. Comanche is the control city for Bridgeport, the latter located just within the borders of the Metroplex region. Although Comanche is located close to Bridgeport, it falls just within the Plains region and is clustered with the other cities in the Plains region. Nocona, being the control city for Bowie, is located within the Metroplex region and is also clustered with cities of this region. Since Bowie's economic base was dominated by the oil industry (before the oil bust), it was clustered with the cities of the Gulf Coast region. Nocona's economic base did not share this dependence on oil-related industry with Bowie. Cameron and Navasota form another pair that did not cluster similarly. Although Navasota's economy is diversified and not dependent on the oil industry, it is situated in the Gulf Coast region and clustered as such. Cameron is situated close to Navasota, falling just within the borders of the Central Texas region. Its economic base is more similar to that of the Central region and is clustered with cities in the Central region. It is seen that the seeming discrepancies in the clustering procedure can be well explained: This "misclassification" is more a function of the way the control cities were chosen than it is a case of the clustering procedure being inaccurate.

It is evident that the bypassed cities and control cities cluster in the same way most of the time. As such, the cluster analysis does not allow us to draw direct inferences about the effect of a bypass on a small city. Bypassed cities do not seem to exhibit any special features that would cause them to form clusters different from those obtained by control cities. Cluster analysis does, however, confirm the relevance of the chosen variables in characterizing a small city. Also, cluster results appear to indicate that the control cities were well chosen.

Table 5.18 Results of cluster analysis for bypassed and control cities

B = Bypass C = Control	City	Pre-bypass Trend	Actual Data Relative to Projected Trend, Post Bypass	Cluster
B	Bonham	+	Higher	1
C	Clarksville	+	Higher	1
B	**Bridgeport**	+	**Higher**	1
C	**Comanche**	+	**Higher**	3
B	Atlanta	±	Higher	1
C	Gilmer	+	Higher	1
B	Taylor	±	Higher	1
C	Lockhart	+	Higher	1
B	Bastrop	±	Higher	1
C	Giddings	+	Higher	1
B	Teague	+	Undetermined	1
C	Hearne	~	Undetermined	1
B	**Bowie**	+	**Lower**	2
C	**Nocona**	~	**As Expected**	3
B	Alvin	+	Higher	2
C	Angleton	+	Higher	2
B	Wharton	+	Lower	2
C	Bay City	+	Higher	2
B	El Campo	+	Undetermined	2
C	Eagle Lake	~	Undetermined	2
B	Silsbee	+	Lower	2
C	Liberty	+	Lower	2
B	Edna	+	As Expected	2
C	Cuero	+	As Expected	2
B	Beeville	+	As Expected	2
C	Alice	+	As Expected	2
B	**Navasota**	+	**Lower**	2
C	**Cameron**	+	**Lower**	1
B	Edinburg	+	Higher	2
C	Rio Grande City	+	Higher	2
B	Vernon	±	Undetermined	3
C	Graham	−	Higher	3
B	Snyder	±	Higher	3
C	Stamford	±	Lower	3
B	Electra	−	As Expected	3
C	Childress	±	Higher	3
B	Tahoka	−	As Expected	3
C	Morton	−	As Expected	3
B	Henrietta	~	Lower	3
C	Memphis	±	Lower	3
B	Slaton	+	As Expected	3
C	Brownfield	+	Lower	3
B	Littlefield	±	Lower	3
C	Post	+	Lower	3
B	Coleman	+	Lower	3
C	Brady	+	Higher	3

Table 5.19 ***A comparison between the numbers of bypass and control cities found within clusters***

	Number of Cities in each Cluster		Number of Control Cities in a Cluster Corresponding to their Matched Pair
	Bypass Group	Control Group	
Cluster #1	6	6	5
Cluster #2	9	8	7
Cluster #3	8	10	8
Total	23	23	20

Retail Sales

Inferences can be drawn about the effect of the bypass on a small city by comparing retail sales trends of bypassed and control cities for the post-bypass period. Because there are only three data points for each city in the approximately 10-year period following bypass construction, these trends are not always very clear. One cannot have too much confidence in results from appropriate statistical tests for so few degrees of freedom. This problem is addressed through informal exploratory analysis.

Both bypassed cities and control cities can be characterized by a retail sales trend for the pre-bypass period. This trend is extended for the post-bypass period to yield the projected trend. The actual data points for the after period are then mapped onto the projected trend (see appendix for characteristic trends and data points for all cities). The difference between the projected trend and the actual data points is expressed as a percentage change in retail sales for a specific year, and is captured in several ways:

(a) the arithmetic mean of the percentage difference for each city,
(b) the root mean square (RMS) for each city, and
(c) an index is created for three categories of differences:
    if difference > 5%, then index = 1
    if difference < 5%, then index = –1
    if 5% ≤ difference ≤ 5%, then index = 0;
    an average index is then obtained for each city.

These measures are obtained to indicate the deviation of actual data points from the projected trend. The average for each of these measures are reported for each cluster and each full sample. Results of this procedure are presented in Table 5.20.

The arithmetic mean in cluster #1 is slightly lower for the bypassed cities than for the control cities. A slightly higher RMS for the bypassed cities indicates more variation in the bypassed cities. The average index for the bypassed cities is also slightly lower than that of the control cities. If anything, one could infer that the bypass had a small negative effect on sales volumes. The trends are still higher than projected, but might have been higher without the bypass.

Cluster #2 exhibits similar trends. The arithmetic mean is negative and lower for the bypassed cities. Again, the RMS is higher for the bypassed cities and the average index is also lower than that of the control cities. For the bypassed cities, the average trend is more or less what was projected. However, trends for the control cities are higher than projected.

The average trends for the third cluster are in both cases lower than projected, with the bypassed cities having a lower average than the control cities. The RMS is once again higher for the bypassed cities, while the average indices are negative and nearly equal. Once again one might conclude that the bypass had a slight negative effect on sales volumes.

The statistics for the full sample provide a sense of the overall effect of a bypass on sales volumes. The arithmetic mean is slightly negative for the bypassed cities, as opposed to a slightly positive value for the control cities. The RMS is higher for bypassed cities overall. The average index for bypassed cities indicates more or less no change from the projected values. The index for control cities is slightly higher. On average, it appears

Table 5.20 ***Exploratory measures for the deviation of actual data points from projected trends for the post-bypass period, both for control and bypassed cities***

	Arithmetic Mean		Arithmetic RMS		Average Index	
	Bypass	Control	Bypass	Control	Bypass	Control
Cluster #1	6.6	10.09	32.74	28.33	0.20	0.27
Cluster #2	-0.84	7.57	24.10	20.77	0.00	0.37
Cluster #3	-14.69	-1.71	27.50	21.76	-0.17	-0.13
Total	-4.65	4.38	27.62	23.06	-0.03	0.16

that sales volumes for bypassed cities are slightly below projected values and also lower than the small positive value for the control cities.

The exploratory analysis indicates slightly different trends among clusters. However, the trends for the bypassed cities are at all times lower than those of the control cities. Although this difference seems very small, one can conclude that the bypass has a small but negative effect on the sales volumes of a small city.

5.4 CLOSURE

In this chapter cluster analysis was used to group both bypassed cities and control cities. The complete linkage method was used as a clustering procedure. Retail sales was chosen as an indicator of overall business activity, without including it as a clustering variable. It was used as a benchmark against which the cluster groupings were judged.

Three clear clusters emerged for the bypass cities. Each cluster could be characterized by specific trends in retail sales for both the pre- and post-bypass period. The geographic location variable seemed to be the most important clustering variable. This variable is consistent with regional trends in retail sales. The geographic location of a city in a rural setting can be a starting point for predicting future retail sales trends. Other variables observed that may have a dramatic effect on retail sales trends were population size, population growth rate, distance to a larger city, and access control. A categorization of bypassed cities in Texas was developed, showing the variables that affect retail sales trends within each category.

Cluster analysis was also applied to the control cities, also resulting in three clusters. These clusters exhibited retail sales trends.

The bypass cities and control cities clustered in the same way, with corresponding paired cities almost always clustering in the same group. It appears that, with the introduction of the bypass, no new phenomenon is added that will change the characteristics of a city drastically. Cluster analysis was an informal way of testing the validity of the control cities. However, cluster analysis did not allow one to draw any inferences regarding the effect of a bypass on a small city.

Several descriptive statistics were used to explore the effect of the bypass on sales volumes. The results suggest that the bypass had a slightly negative effect on sales volumes.

CHAPTER 6. STUDY FINDINGS

This chapter summarizes the study findings and makes some recommendations for future research in the area of bypass effects. The first section contains a brief discussion of each of the key aspects analyzed (database development, traffic impacts, spatial impacts, and categorization by means of cluster analysis) and provides some concluding remarks regarding this study. The second section presents recommendations and suggestions for future research.

6.1 SUMMARY AND CONCLUSIONS

This report presented an exploration and analysis of traffic and spatial changes brought about by bypass construction in small cities in essentially rural areas. A highway bypass is defined as that segment of a new highway intended to reroute through traffic around a central business district, leaving the remainder of the intercity route unchanged. A sample of bypassed cities in Texas was then classified according to relevant characteristics by means of cluster analysis (a multivariate procedure). The population of the bypassed cities in the sample ranged from 2,500 to 25,000.

A database of pertinent variables from secondary sources was established. These variables represent characteristics of a city that are believed to reflect different behavior among cities when bypassed. The pertinence of these variables was confirmed by observations made during site visits to several bypassed cities in Texas. In addition, traffic data were assembled for cities to present a clear picture of the traffic pattern in each city. The location and relocation history of highway-related businesses for both the pre- and post-bypass periods were assembled for selected cities.

Analysis of the traffic impacts indicated a shift away from the bypassed route, with more traffic using the shortest connector from the city center to the bypass. The consistent increase in the ratio of traffic on the shortest connector from the bypass to traffic on the bypassed route confirmed this shift. On average, a reduction of 25 percent in traffic along the bypassed route in proximity to the city center was observed. There did not appear to be a significant change in traffic on the shortest connector to the traffic on the bypassed route.

Six bypassed cities in Texas were chosen for detailed analysis of spatial changes for highway-related businesses. This analysis indicated a general decline in highway-related business activity along the bypassed route, relative to the other main arterial. A time lag of a few years was observed before these spatial changes became evident.

Cluster analysis was used to group bypassed cities. Three clear clusters emerged, characterized by specific trends in retail sales. Retail sales was not a variable in the clustering procedure, but merely used as a benchmark against which the cluster groupings were judged. The clustering of a group of control cities yielded similar results. Throughout, the geographic location variable seemed to be the most important clustering variable.

An informal exploratory analysis of post-bypass retail sales trends for the bypassed and control cities was performed. The analysis indicated some differences in typical trends among clusters. In all cases, the bypass seemed to impose a very small but slightly negative impact on retail sales volumes.

From the previous analysis, the following concluding remarks can be made:

(1) The construction of a bypass is one of many factors contributing to the overall economic performance of a city in a rural setting. However, bypass construction appears to be of lesser importance than overall economic conditions within this context.
(2) A bypass changes activity patterns within a city. Traffic shifts away from the bypassed route. Increased traffic activity is found on the shortest connector from the bypass to the city center, resulting in increased development along this route.

(3) Cities in a rural context in Texas can be clustered according to certain characteristics. This clustering for bypassed cities is no different from that obtained for control cities.
(4) The geographic location of a city emerged as the prime clustering variable. Business trends seem to vary by geographical region. Other factors that appear to have a dramatic effect on business trends are population, population growth, the distance to a larger city, and access control.
(5) A bypass may have a small but negative effect on the overall business activity of a small city.

6.2 RECOMMENDATIONS AND FUTURE RESEARCH

Shifts in the activity pattern of a small city appear to be predictable. The local community can use this knowledge to adjust to the anticipated effects of a bypass. Where the effects are anticipated or perceived to be negative, they can be counteracted by, for example, timely relocation of some highway-oriented businesses, the addition of road signs on the highway advertising the amenities the city has to offer, or even by improving downtown facilities (parking, etc.) to lure local people back to the downtown area.

It was concluded that the bypass has a slight negative effect on the economic activity of a small city. However, there seemed to be distinct trends among clusters. This knowledge can be used in future research to improve current econometric models dealing with highway bypass effects.

Another aspect that should be covered in future research is the effect of highway bypasses on cities that were outside the scope of this analysis, namely, cities having a population less than 2,500, and cities having a highway configuration not conforming to this study's definition of a bypass.

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[83] Hereafter, any reference to "city" implies a city in a rural setting.

[84] This arterial is in most cases a numbered highway and the minor crossing arterial in the city. This most "major" arterial was found to be a Farm-to-Market road in some of the bypassed cities that were visited.

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[86] See Table 3.1 for a list of these bypassed cities.

[87] See Chapter 3, Table 3.6.

[88] These regions are described in Chapter 3 and graphically depicted in Figure 3.7.

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[94] This operation can be performed by defining categories within the range of the continuous variable.

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[97] The variables are listed in Table 5.3.

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APPENDIX A. LIST OF BYPASSED CITIES IN TEXAS AND INTERVIEW GUIDELINES FOR SURVEY OF BYPASSED CITIES

LIST OF BYPASSED CITIES IN TEXAS

City	Population in the Year Bypass was Opened	Highway	County	Year Bypass was Opened
District 1				
Whitesboro	2,839	US 377, US 82	Grayson	1968, 1973
Randolph	70 (-87 population)	State 121	Fannin	1967
Cooper	2,249	State 24	Delta	1968
Emory	613	US 69	Rains	1964
Sulphur Springs	10,049	IH-30, State 19	Hopkins	1956, 1966
Greenville	22,047	IH-30, US 69	Hunt	1959, 1970
Commerce	5,809	State 24	Hunt	1958
Quinlan	614	State 34	Hunt	1957
Bonham	7,698	State 121	Fannin	1970
District 2				
Antelope	65 (-87)	US 281	Jack	1959
Alvord	942	US 287	Wise	1982
Decatur	3,531	US 287, US 380	Wise	1961
Rhome	410	US 287	Wise	1972
Bridgeport	3,376	US 380	Wise	1964
Granbury	2,375	US 377	Hood	1966
Stephenville	7,743	US 377, US 281	Erath	1962
District 3				
Vernon	11,798	US 287	Wilbarger	1965
Oklaunion	138 (-87)	US 287	Wilbarger	1959
Electra	3,981	US 287	Wichita	1969
Henrietta	2,947	US 287	Clay	1972
Jolly	183 (-87)	US 287	Clay	1964
Bowie	5,627	US 287	Montague	1978
District 4				
Lefors	835	State 273	Gray	1966

City	Population in the Year Bypass was Opened	Highway	County	Year Bypass was Opened
District 5				
Littlefield	6,937	US 84	Lamb	1966
Shallowater	1,102	US 84	Lubbock	1963
Slaton	6,574	US 84	Lubbock	1964
Wolfforth	597	US 82	Lubbock	1960
Tahoka	2,967	US 87	Lynn	1968
District 6				
–				
District 7				
Christoval	216 (-87)	US 277	Tom Green	1987
District 8				
Weinert	254	US 277	Haskell	1976
Snyder	12,778	US 84	Scurry	1964
Hermleigh	200 (-87)	US 84	Scurry	1962
Stamford	4,496	US 277	Jones	1987
Abilene	85,888	IH-20,US 83	Taylor	1959
District 9				
Covington	230	State 171	Hill	1975
Gatesville	6,727	State 36	Coryell	1986
Killeen	40,899	US 190	Bell	1975
Marlin	7,099	State 6	Falls	1980
Temple	29,429 IH-35	State 36, US 190	Bell 1959	1958
District 10				
Canton	3,518 (-87)	State 64	Van Zandt	1988
Larue	160 (-87)	US 175	Henderson	before 1945
Palestine	14,194	US 79	Anderson	1964
Neches	114 (-87)	US 79	Anderson	1959
District 11				
Nacogdoches	18,596	US 59	Nacogdoches	1966
Grapeland	1,465	US 287	Houston	1976
Shephard	1,165	US 59	San Jacinto	1965
Livingstone	5,074	US 59	Polk	1981
Goodrich	350 (-87)	US 59	Polk	1963

City	Population in the Year Bypass was Opened	Highway	County	Year Bypass was Opened
District 12				
Splendora	190	US 59	Montgomery	1968
Beasly	434	US 59	Fort Bend	1981
Kendleton	653	US 59	Fort Bend	1981
Alvin	7,654	State 35	Brazoria	1964
District 13				
La Grange	4,155 (-87)	State 71	Fayette	1990
Wharton	8,342	US 59	Wharton	1974
Pierce	49 (-87)	US 59	Wharton	1973
El Campo	9,133	US 59	Wharton	1973
Hungerford	179 (-87)	US 59	Wharton	1969
Louise	310 (-87)	US 59	Wharton	1978
Hillje	51 (-87)	US 59	Wharton	1978
Edna	5,459	US 59	Jackson	1974
Ganado	1,692	US 59	Jackson	1974
District 14				
Johnson City	642	US 281	Blanco	1962
Briggs	92 (-87)	US 183	Burnet	1957
Liberty Hill	300 (-87)	State 29	Williamson	1958
Taylor	10,017	US 79	Williamson	1974
Lexington	603 (-50)	US 77	Lee	before 1950
Elgin	3,168 (-50)	US 290	Bastrop	before 1950
Bastrop	3,001	State 71	Bastrop	1960
Smithville	4,399	State 71	Bastrop	1984
District 15				
Floresville	1,949 (-50)	US 181	Wilson	before 1950
Stockdale	1,122	US 87	Wilson	1965
New Braunfels	16,745	IH-35, State46	Comal	1960, 1965
Seguin	16,318	IH-10, State 123	Guadalupe	1969, 1972
District 16				
Kenedy	4,254	US181	Karnes	1953
Karnes City	2,620	US 181	Karnes	1953
Beeville	13,826	US 181	Bee	1973
Gregory	1,354	US 181, State 35	San Patricio	1952, 1952
Sinton	6,037	US 77	San Patricio	1981
Robstown	9,071	US 77	Nueces	1956

City	Population in the Year Bypass was Opened	Highway	County	Year Bypass was Opened
District 17				
Brenham	7,660	US 290, State 36	Washington	1959, 1964
Teague	2,728	US84	Freestone	1960
Navasota	5,283	State 6	Grimes	1972
District 18				
Celina	1,263	State 289	Collin	1969
Prosper	436	State 289	Collin	1966
Blue Ridge	462	State 78	Collin	1981
Pilot Point	1,581	US 377	Denton	1968
Aubrey	573	US 377	Denton	1962
Midlothian	2,162	US 67	Ellis	1968
Kaufman	2,775	US 175	Kaufman	1957
Kemp	1,214	US 175	Kaufman	1984
Waxahachie	14,155	IH-35E, US 287	Ellis	1961, 1976
District 19				
De Kalb	2,104	US 259	Bowie	1964
Pittsburg	3,207	US 271	Camp	1951
Atlanta	4,355	US 59	Cass	1963
Beckville	558	State 149	Panola	1951
District 20				
Newton	1,529	State 87	Newton	1970
Silsbee	7,643	US 96	Hardin	1979
Cleveland	6,339	US 59	Liberty	1988
Jasper	4,792	US 190	Jasper	1958
District 21				
Edinburg	22,001	US 281	Hidalgo	1977
District 23				
Goldthwaite	1,548	US 84	Mills	1951
Coleman	5,761	US 84	Coleman	1968
District 24				
–				
District 25				
Spur	2,183 (-50)	State 70	Dickens	before 1950

GENERAL GUIDE FOR INTERVIEWS - SURVEY OF BYPASSED CITIES

General questions - to be directed primarily to Chamber of Commerce

Comment on:

Current economic viability of the town
- changes in last decade (or two)/growth or decline in economy/population etc.
- external/internal reasons for changes (related to bypass?)

Effect of bypass
- on city growth
- on highway-related businesses (business breakdowns, stimulation?)
- non-highway-related businesses (ditto)
- tourist industry
- impact at time of construction
- increase in local customers (same market area?)

Adjustment to bypass
- relocation of businesses
- increase/reduction in number of businesses/floorspace (expansion of businesses)
- reorienting of businesses towards local customers?

Opinions of businesses/local residents regarding desirability of bypass
- did they change, before vs after?
- involvement of community re bypass issue

Programs to improve downtown/lure people back into downtown
- beautification
- whose initiative?
- advertisements, road signs, tourist information

Outreach activities

Changes in land use
- increased industrial activity closer to bypass?
- less residential closer to bypass?

City limits
- changes since bypass

Position in county
- same basic industries as county?

Position in economic region
- industries comparable to larger region?

Additional data sources
- number of businesses
- sales data?
- property values
- number of employees
- other city information
- industrial directory for different time periods

Reason for building bypass

Business/Industry settlement
- reason for settling (heavy marketing?)

Local/County Government

Interview with local businesses

Name of firm

Highway-oriented sales or not

Location - bypass/bypassed route /other

Before vs after
- change of customer (more local residents/other)
- change of opinion re desirability of bypass
- adjustments to cope with changes (relocation/expanding, etc.)
- at what time were adjustments made (if any)?

Firm located on bypassed route (other than bypass)
- Opinion on downtown activities (parking, accessibility, etc.)

Firm located on bypass
- satisfactory/prefer another site/unsatisfactory/how soon did they respond?

Sales figures/employment or other applicable data

Traffic-related questions

Percentage using bypass

Breakdown of traffic
- on bypass
- on bypassed route

Changes before vs after
- breakdown of traffic on BR
- congestion on BR
- parking downtown
- more local people using downtown streets

Time savings because of bypass

Local people using bypass

Accident rates - B and BR

Type of access

APPENDIX B. DERIVATION OF TRAVEL TIME BOUNDARIES

DERIVATION OF TRAVEL TIME BOUNDARIES

Refer to Figure 4.2 for the layout of the hypothetical city.

The main arterial runs from east to west, crossing a north-south arterial in the center of the city. A bypass is constructed south of the city, connecting the east-west arterial. The total bypass length is 4 miles. The distance from the city center to the bypass is 1 mile via the north-south arterial. The distance from the city center via the bypassed route to the bypass is 2 miles. The city limits are 1.5 miles from the city center along the bypassed route, i.e., the bypass and bypassed route meet one-half mile outside the city limits. The running speed on the bypass is 55 mph, with 25 mph allowed on all other roads in the city.

As an example, we tested whether a travel time boundary exists between the city center and the eastern split between the bypass and bypassed route. To determine this, the travel time from the split along the bypass and via the other main arterial is compared with the travel time along the bypassed route. The unknown distance, x, is measured from the split toward the city center along the bypassed route.

Travel time via bypass: $\frac{2}{55}\times 60+\frac{1}{25}\times 60+\frac{(2-X)}{25}\times 60$ (min) .....(1)

Travel time along bypassed route: $\frac{X}{25}\times 60$ (min) .....(2)

Setting (1) = (2), yields X=1.95.

This means that the travel time boundary is nearly at the crossing of the highway at the city center. All road users east of the city center will be inclined to use the bypassed route to get to a destination east of the city. Assuming that the local streets form a dense grid network, travel time can be calculated for all possible routes. The same reasoning can be used to determine the boundary for the western side of the city, as depicted in Figure 4.4.

APPENDIX C. CORRELATION MATRIX FOR ALL EXPLANATORY VARIABLES AND CHARACTERISTIC RETAIL SALES TRENDS FOR BYPASSED AND CONTROL CITIES

Correlation Matrix For All Explanatory Variables

VARIABLES	Population	Growth in Population	Employment	Growth in Employment	Income	Growth in Income	Distance to a Larger City	Total Incoming Traffic	Growth in Traffic
Population	1								
Growth in Population	-0.02	1							
Employment	0.86	0.06	1						
Growth in Employment	0.24	0.38	0.56	1					
Income	-0.14	0.02	0.06	0.35	1				
Growth in Income	-0.19	0.04	-0.01	0.31	0.09	1			
Distance to a Larger City	0.35	-0.13	0.43	0.03	0.22	-0.06	1		
Total Incoming Traffic	0.59	0.15	0.74	0.53	0.21	0.34	0.22	1	
Growth in Traffic	-0.05	0.40	0.05	0.38	-0.19	0.66	-0.31	0.31	1

Correlation Matrix(continued)

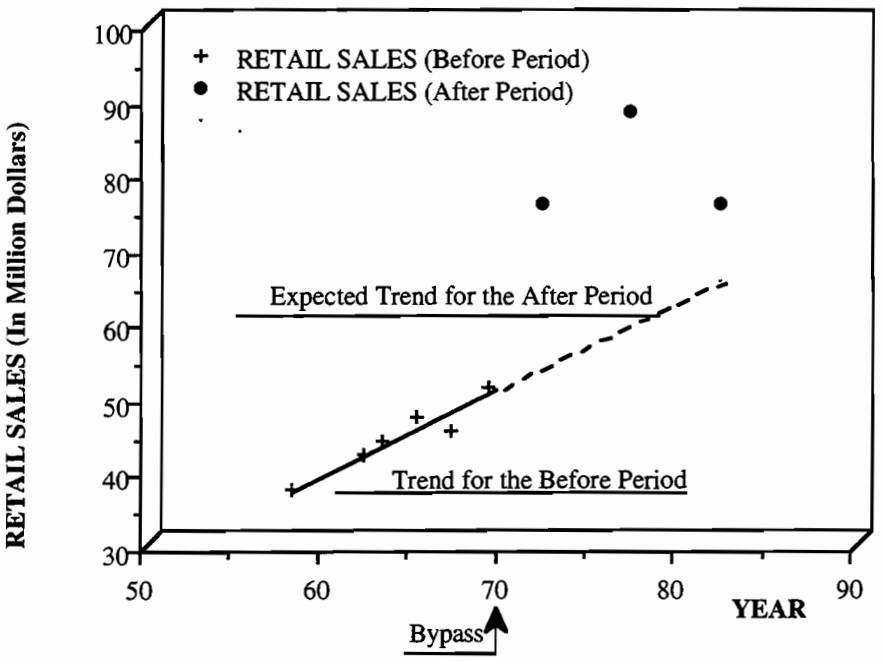
VARIABLES	Population	Growth in Population	Employment	Growth in Employment	Income	Growth in Income	Distance to a larger city	Total Incomimg TRaffic	Growth in Traffic
Distance between Bypass and Bypassed route	0.21	-0.02	0.24	0.28	-0.03	0.14	-0.10	0.34	0.32
The Plains	-0.20	-0.17	-0.24	-0.11	-0.31	0.26	-0.14	-0.35	0.13
East Texas	-0.07	-0.42	-0.21	-0.46	0.32	-0.58	0.03	-0.43	-0.63
Border Region	-0.16	0.09	-0.15	-0.15	-0.34	-0.03	-0.06	-0.02	0.36
Metroplex	0.62	-0.07	0.41	0.11	-0.30	0.09	-0.33	0.54	0.28
Central Texas	-0.17	0.22	-0.16	0.18	0.13	0.16	0.05	0.03	0.25
Gulf Coast	0.14	0.39	0.40	0.45	0.08	0.27	0.21	0.45	0.10
Access	0.10	-0.36	-0.02	-0.03	0.31	0.01	0.12	0.26	-0.24

Correlation Matrix(continued)

VARIABLES	Distance between bypass and bypassed route	The Plains	East Texas	Border Region	Metroplex	Central Texas	Gulf Coast	Access Control
Distance between Bypass and Bypassed route	1							
The Plains	-0.05	1						
East Texas	-0.37	-0.28	1					
Border Region	-0.20	-0.08	-0.16	1				
Metroplex	0.10	-0.08	-0.16	-0.05	1			
Central Texas	0.25	-0.15	-0.28	-0.08	-0.08	1		
Gulf Coast	0.28	-0.26	-0.48	-0.14	-0.14	-0.25	1	
Access	-0.11	-0.34	0.28	-0.19	0.24	-0.08	-0.01	1

CHARACTERISTIC RETAIL SALES TRENDS FOR BYPASSED CITIES

BONHAM



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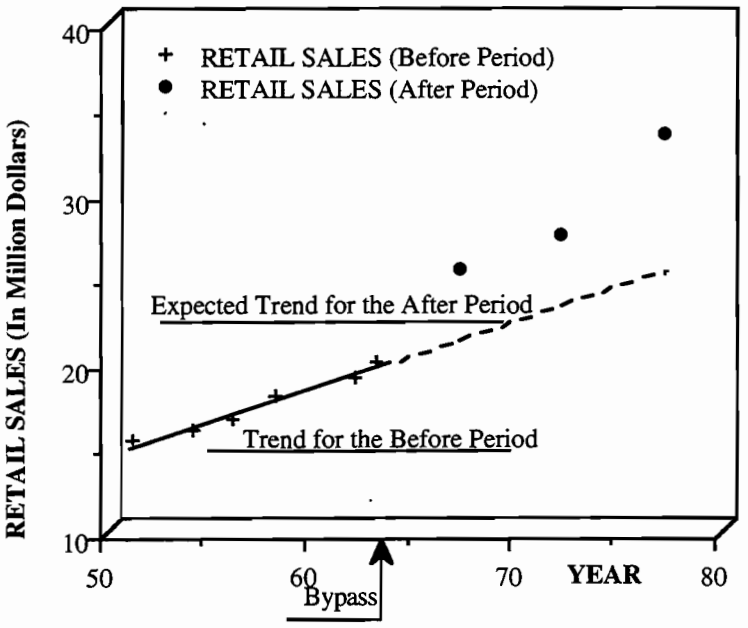

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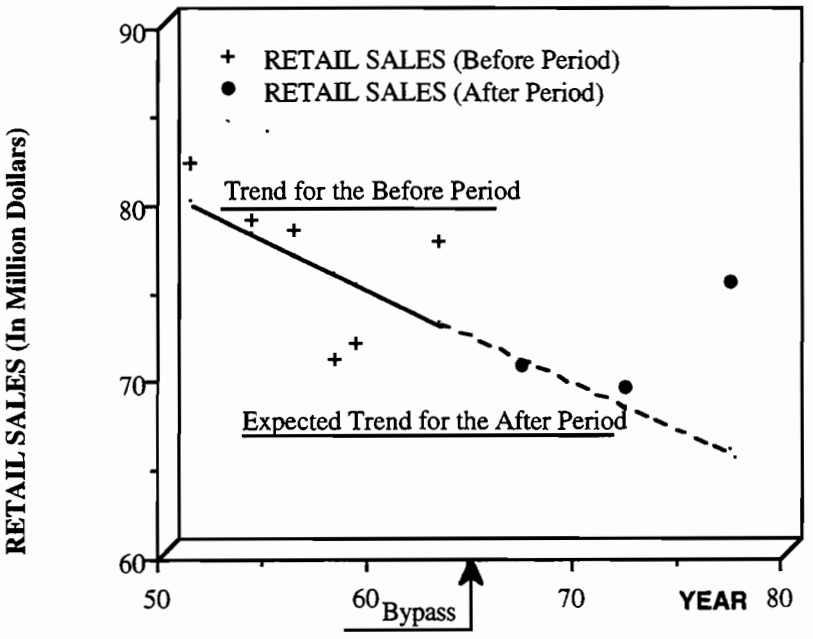

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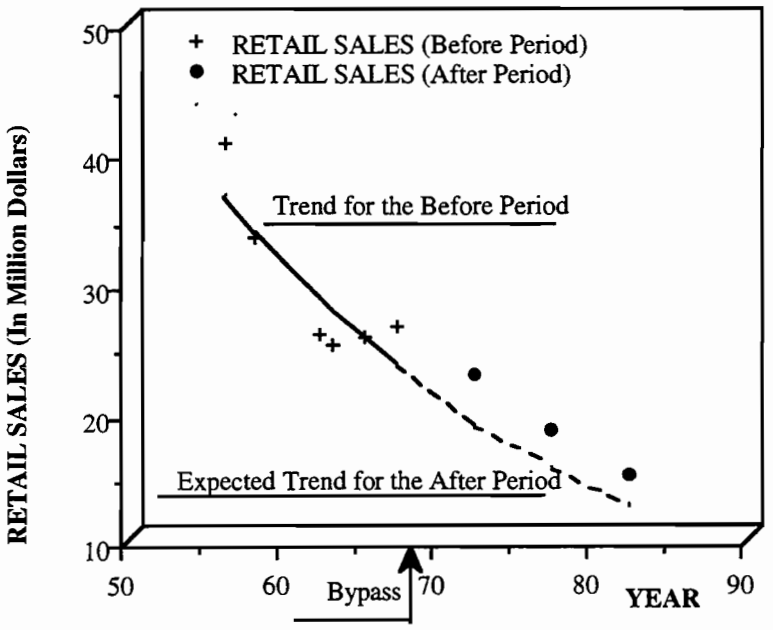

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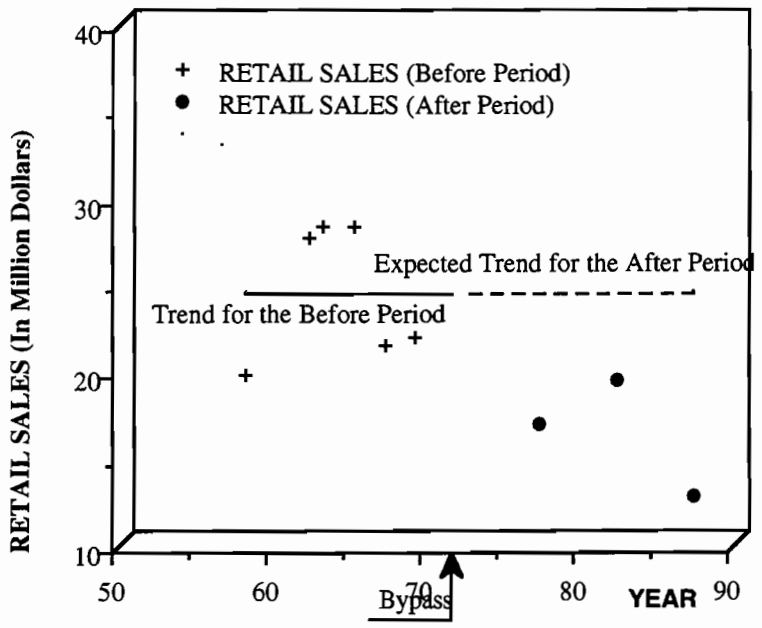

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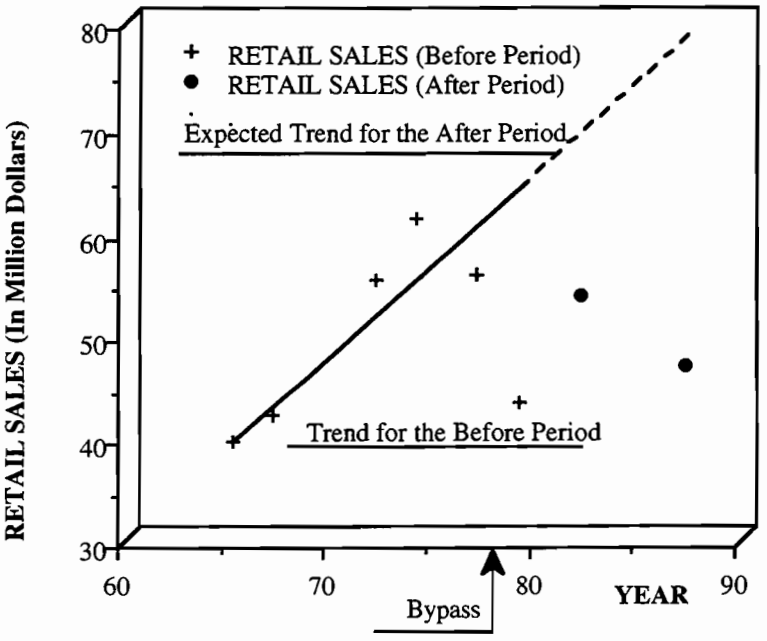

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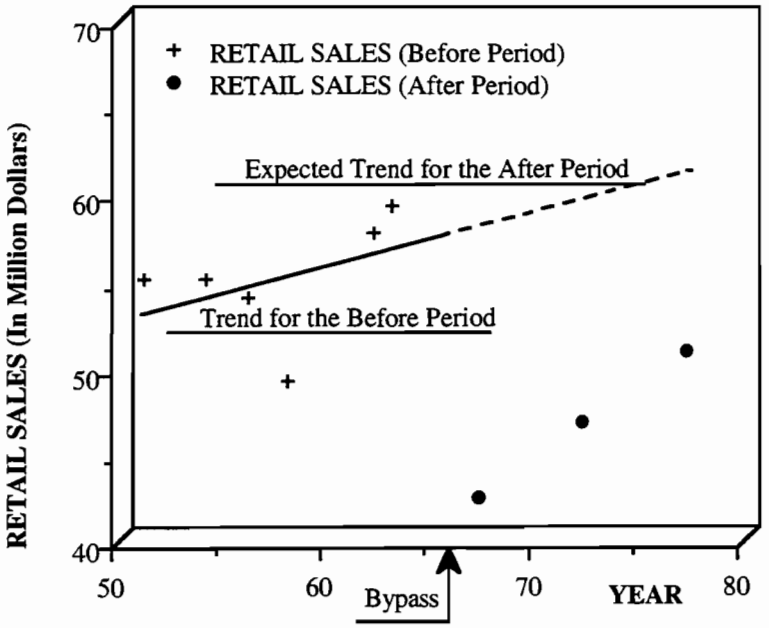

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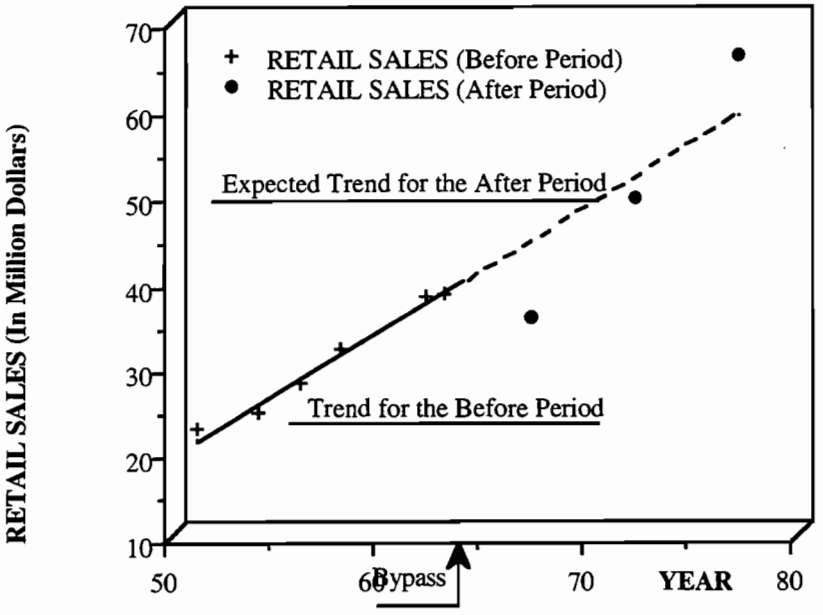

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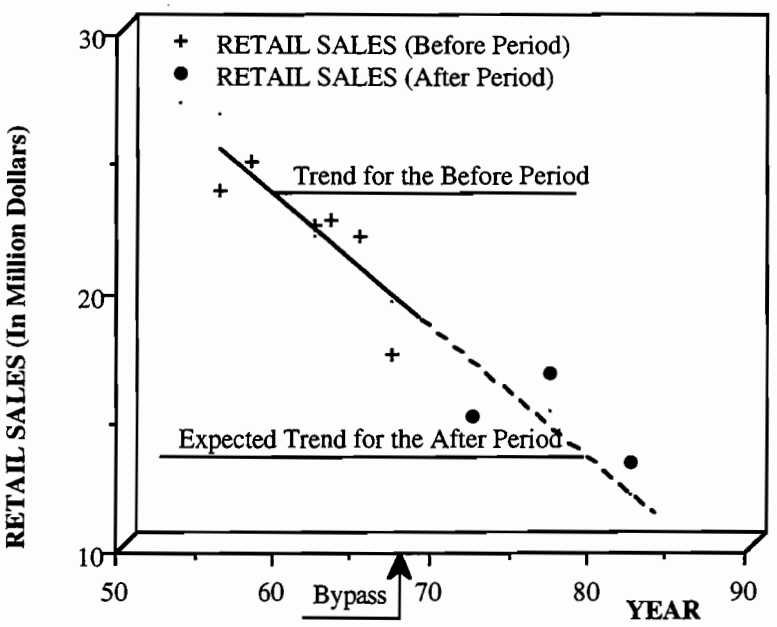

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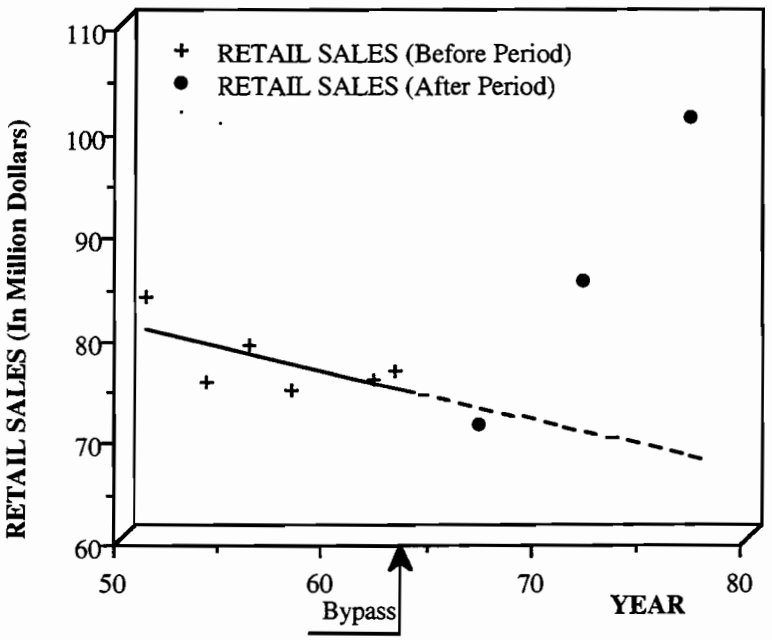

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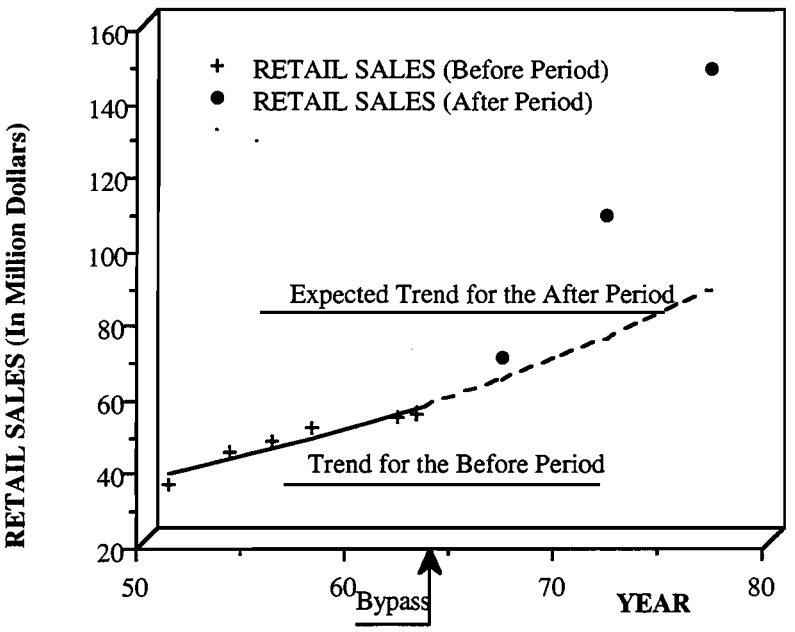

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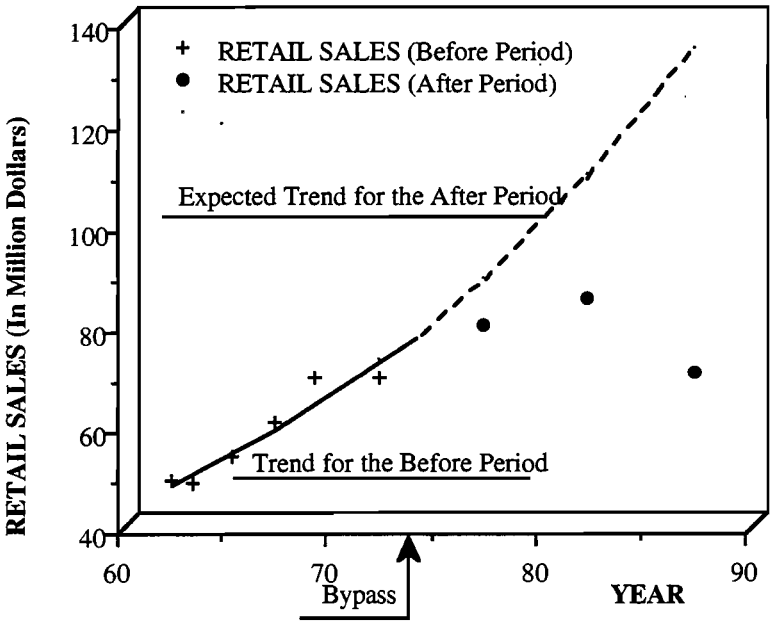

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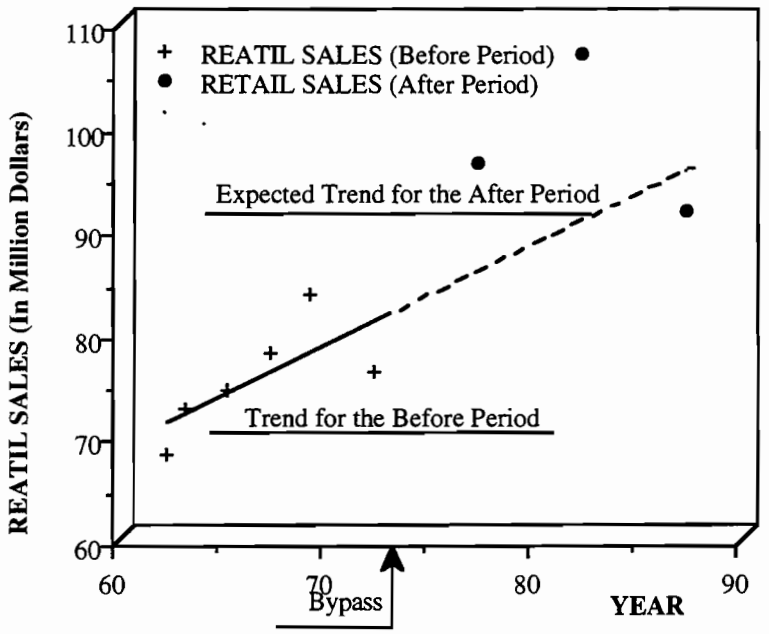

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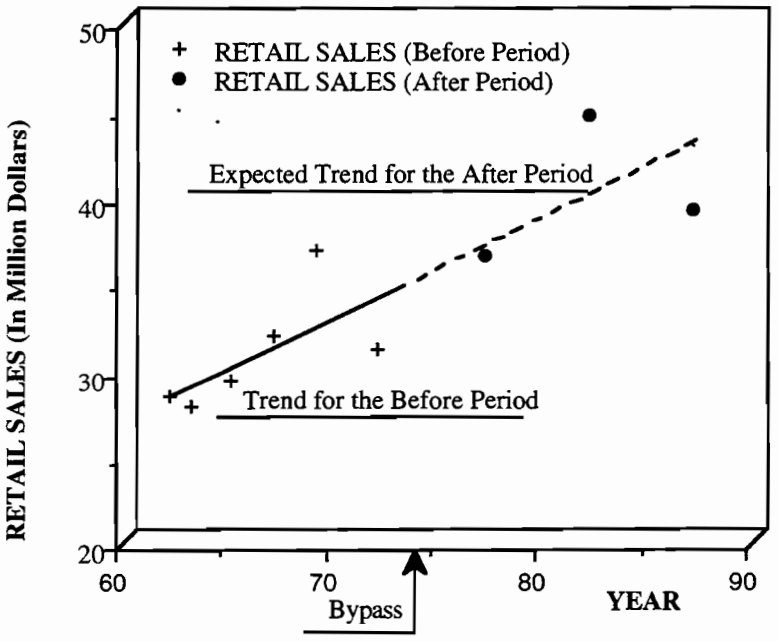

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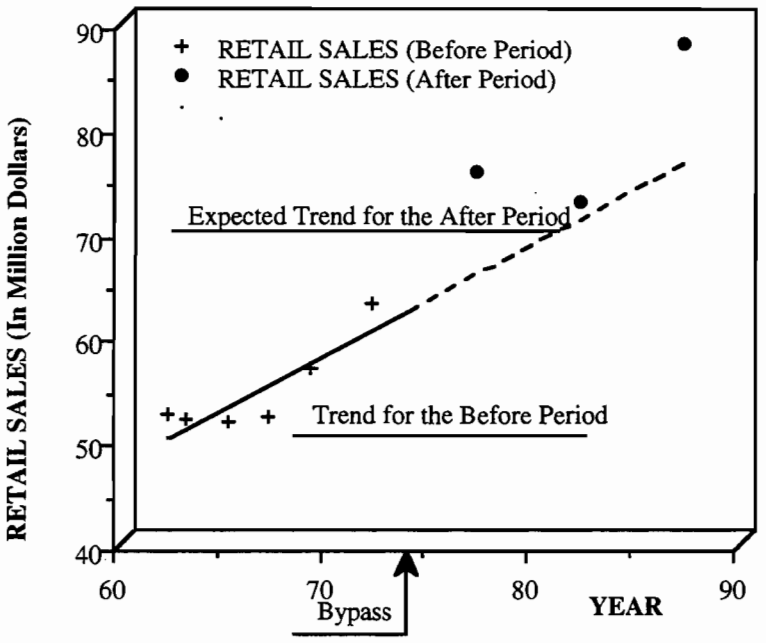

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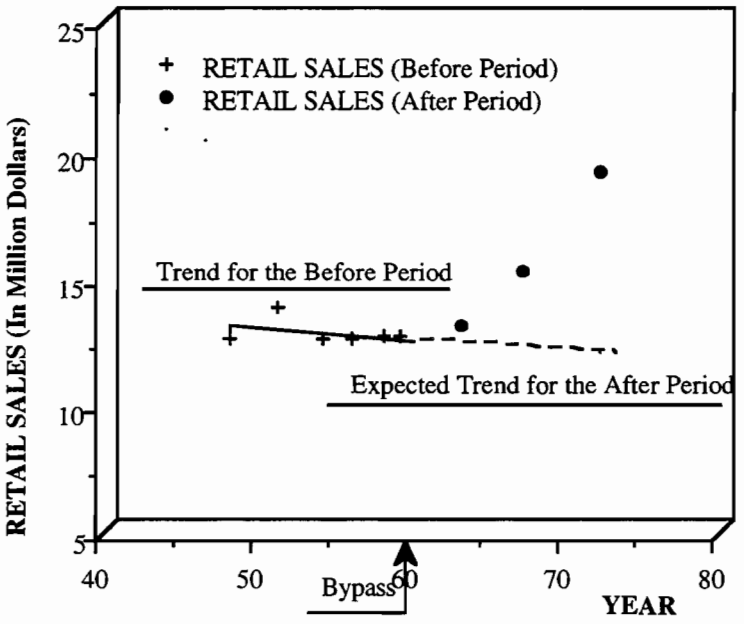
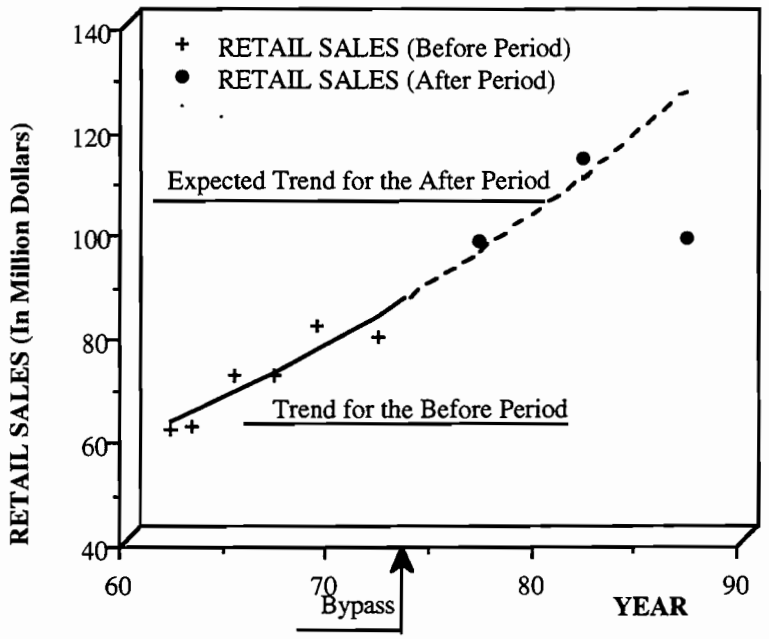
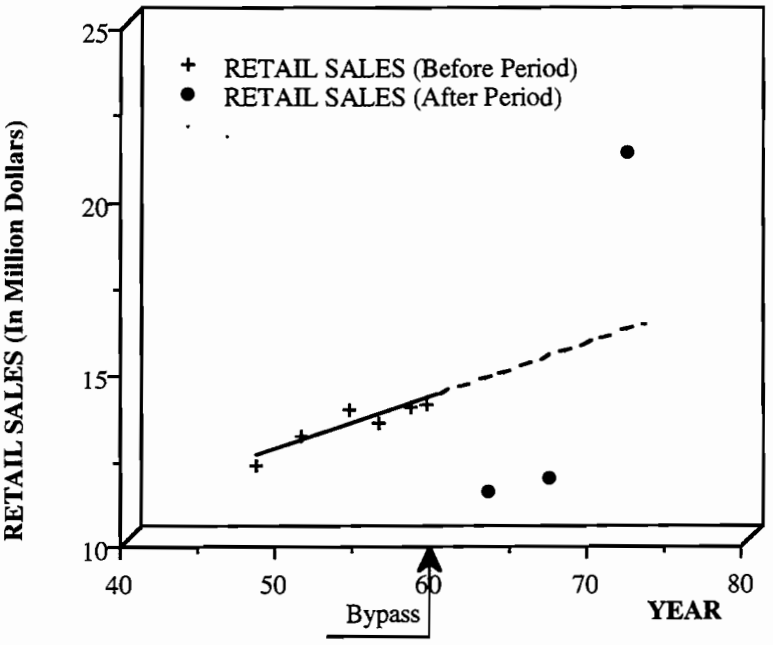


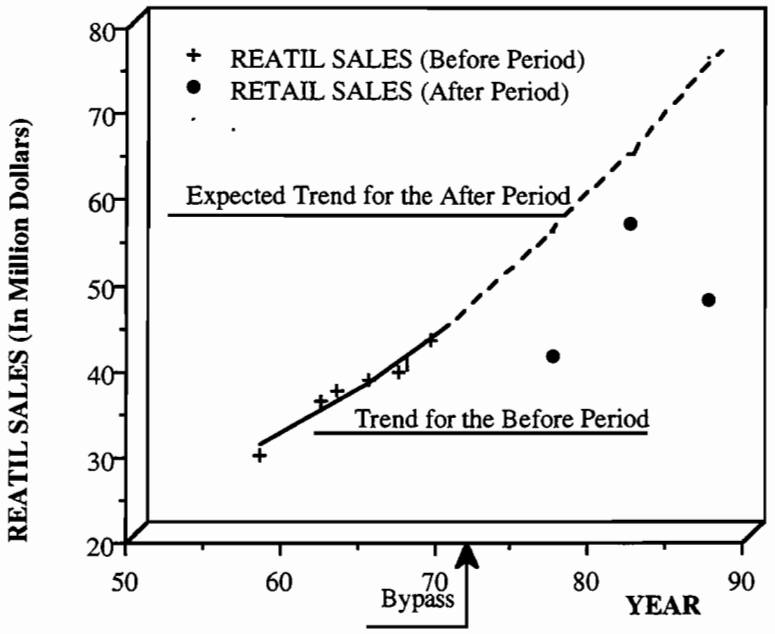
BEEVILLE



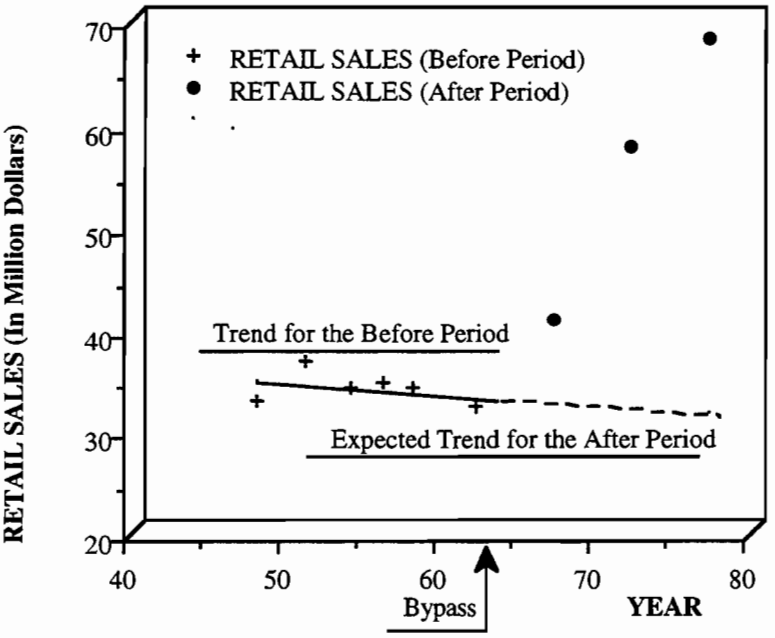
TEAGUE



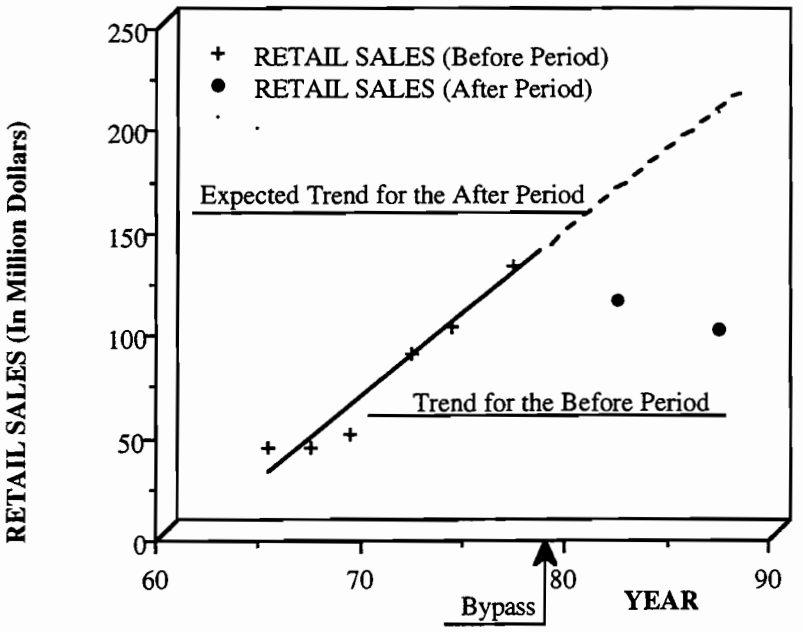
NAVASOTA



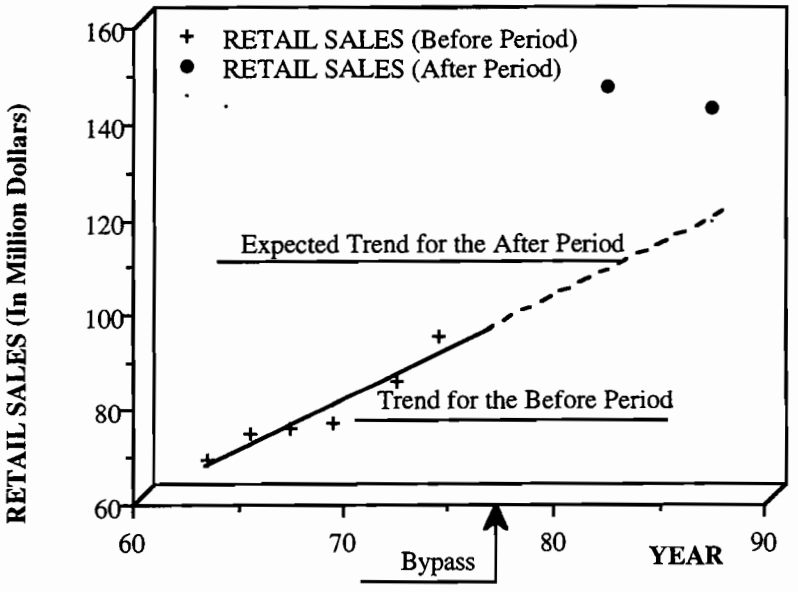
ATLANTA

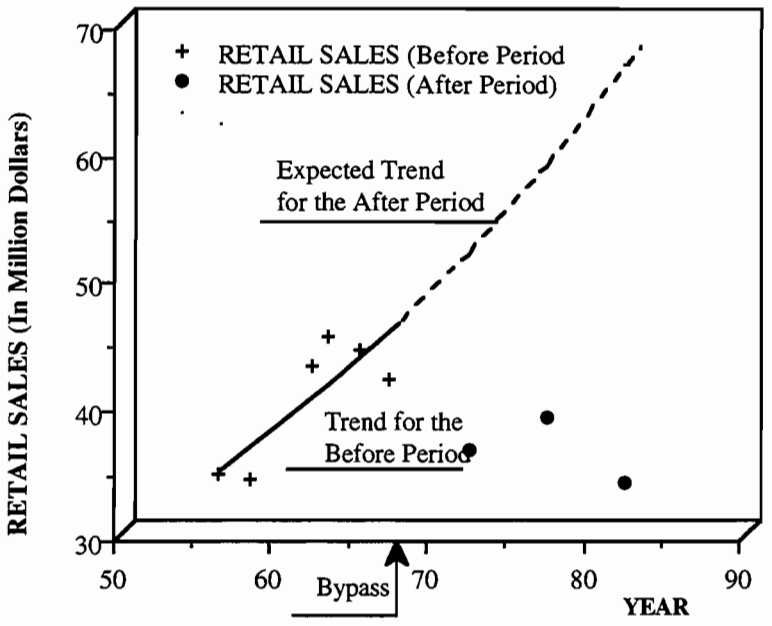


SILSBEE

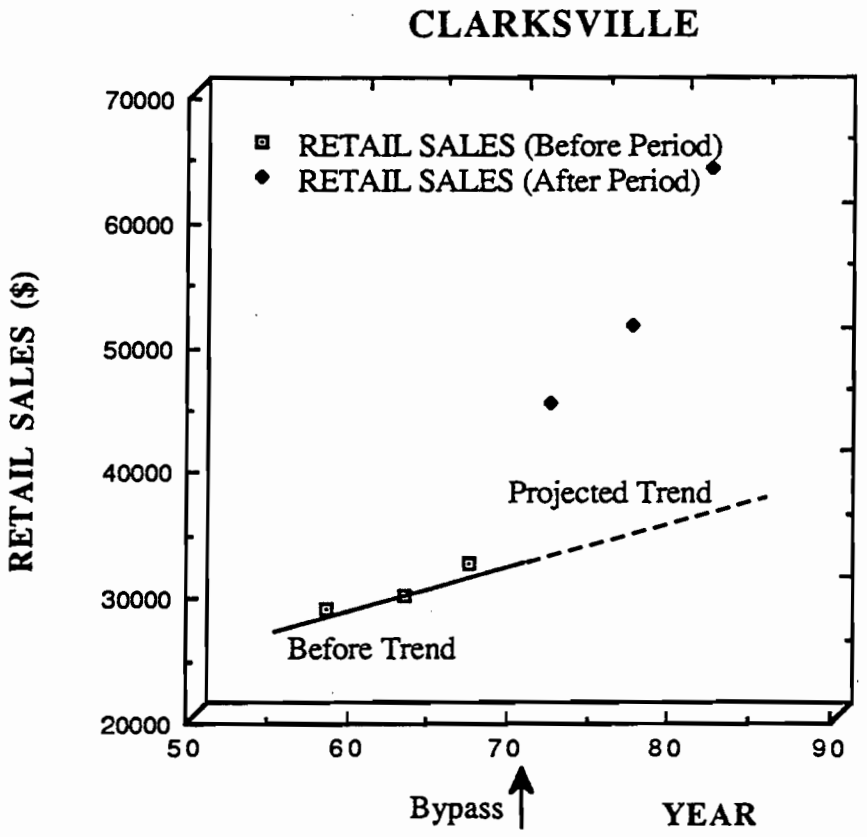


EDINBURG

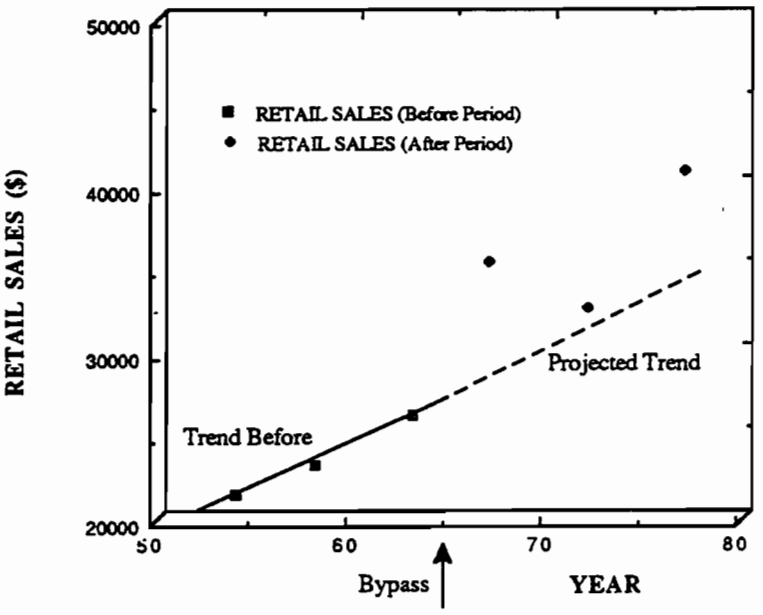



RETAIL SALES (In Million Dollars)
70
60
50
40
30
+ RETAIL SALES (Before Period
● RETAIL SALES (After Period)
Expected Trend
for the After Period
Trend for the
Before Period
50
60
Bypass
70
80
90
YEAR

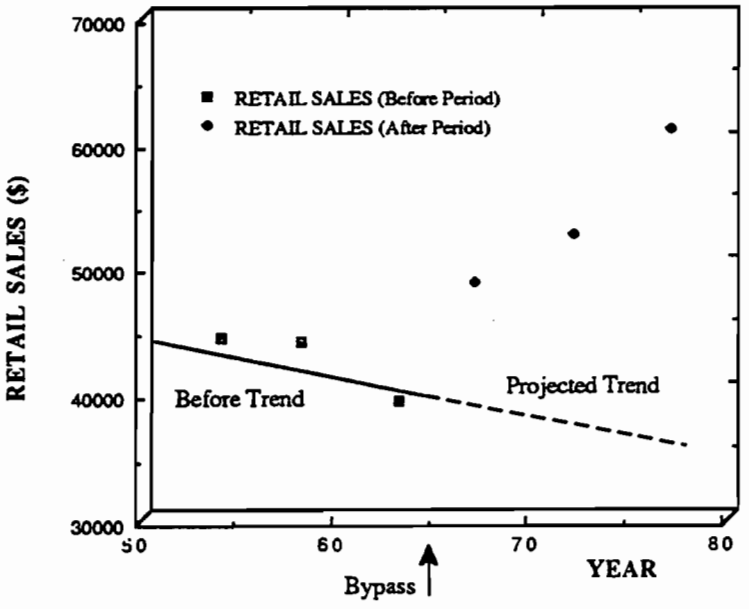
CHARACTERISTIC RETAIL SALES TRENDS FOR CONTROL CITIES

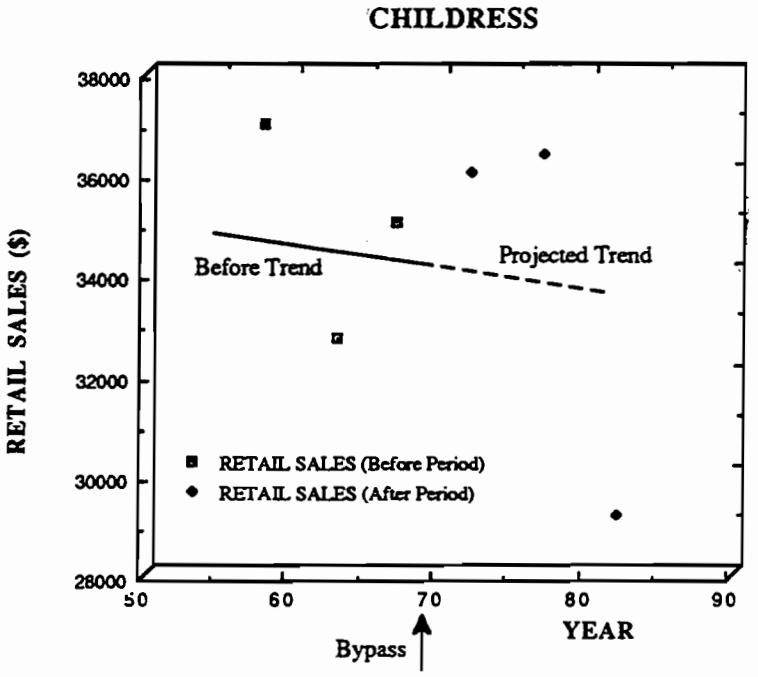


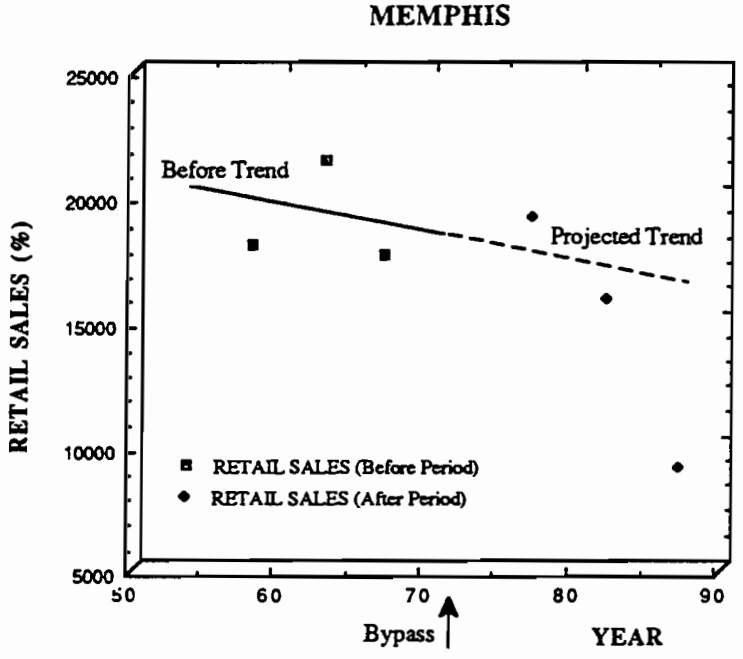
COMANCHE



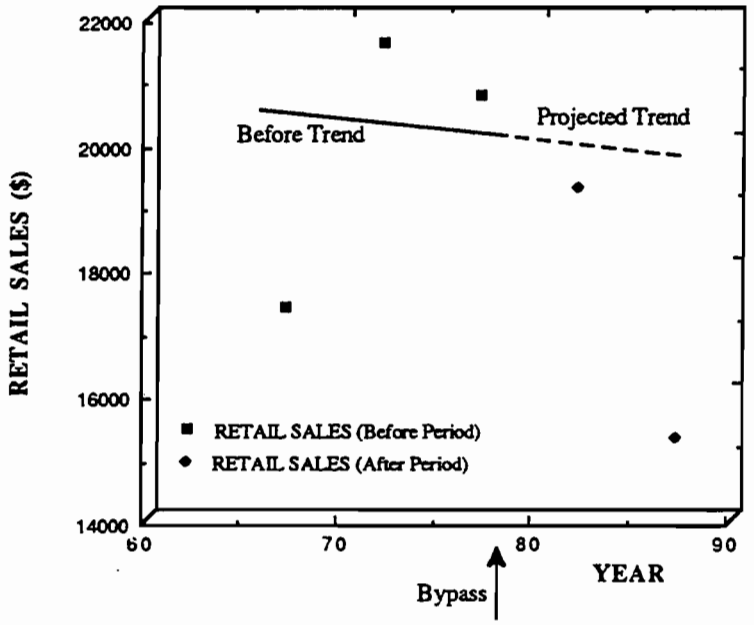
GRAHAM



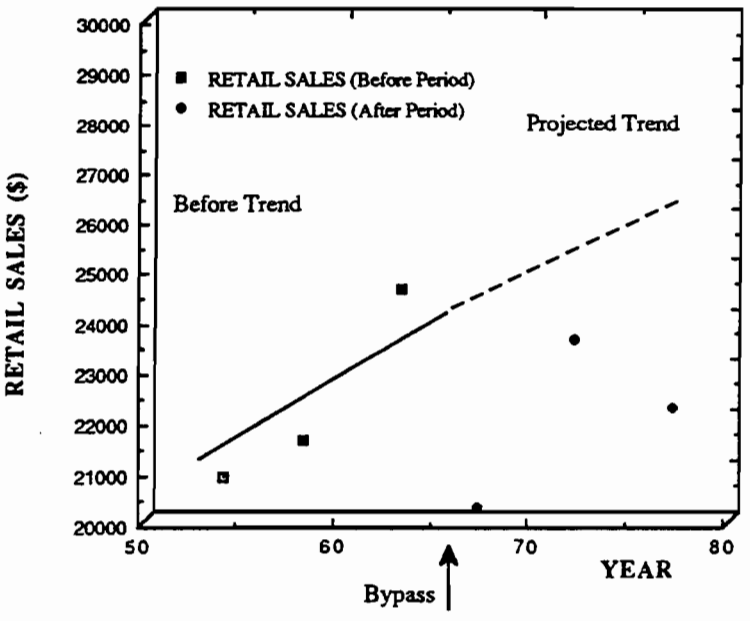

CHILDRESS
RETAIL SALES ($)
38000
36000
34000
32000
30000
28000
Before Trend
Projected Trend
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
50
60
70
80
90
YEAR
Bypass


MEMPHIS
RETAIL SALES (%)
25000
20000
15000
10000
5000
Before Trend
Projected Trend
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
50
60
70
80
90
YEAR
Bypass

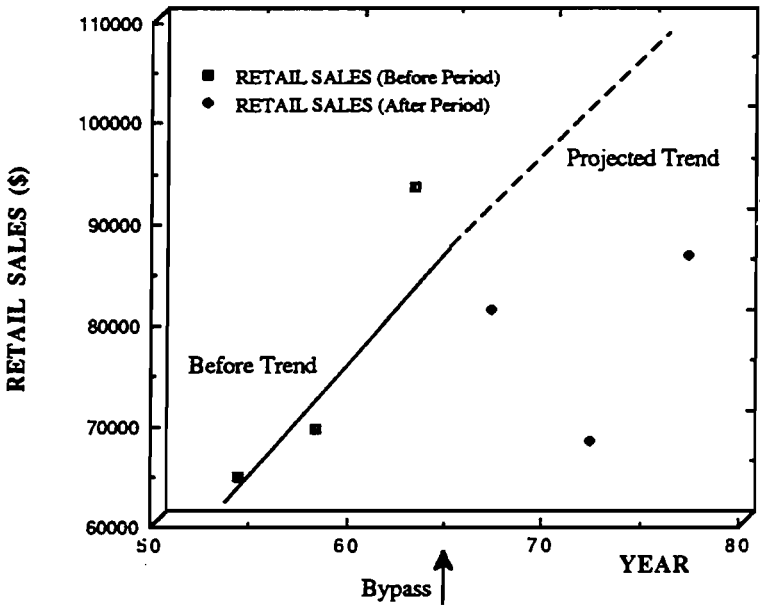
NOCONA


22000
20000
18000
16000
14000
RETAIL SALES ($)
Before Trend
Projected Trend
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
60
70
80
90
YEAR
Bypass

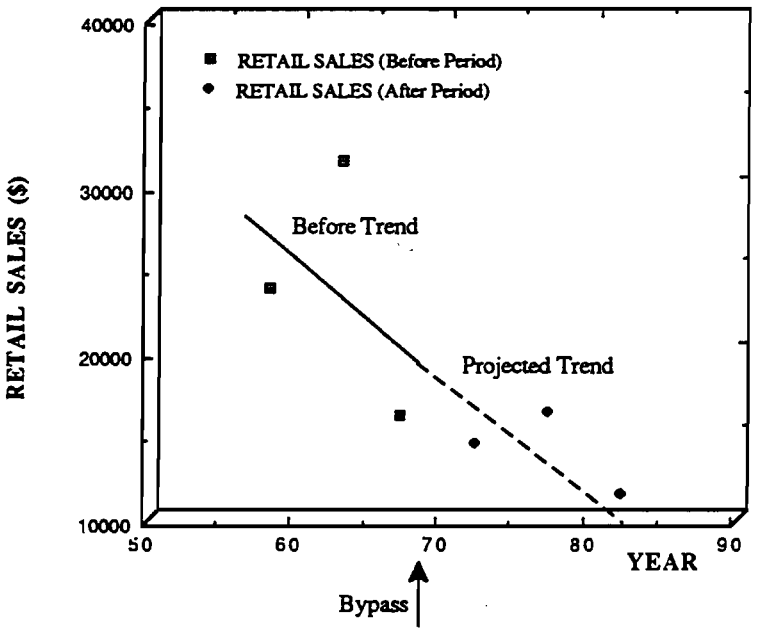
POST


30000
29000
28000
27000
26000
25000
24000
23000
22000
21000
20000
RETAIL SALES ($)
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
Projected Trend
Before Trend
50
60
70
80
YEAR
Bypass

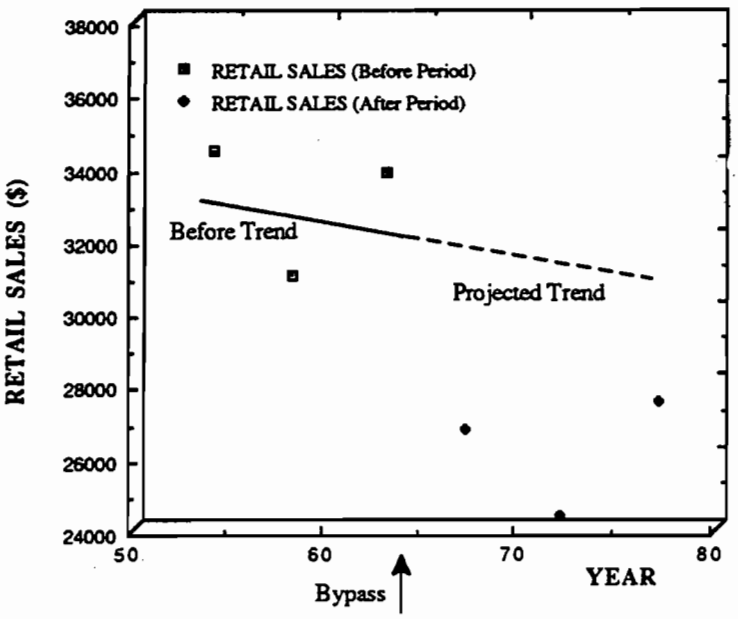
BROWNFIELD



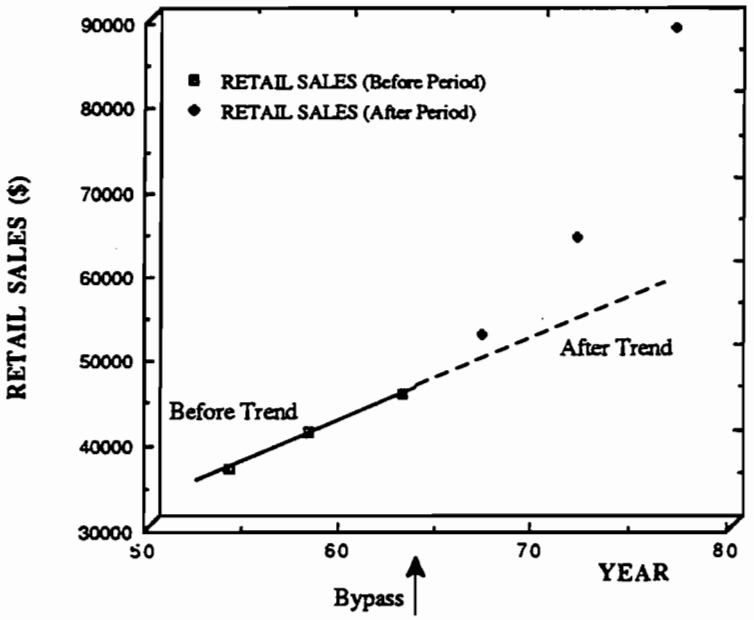
MORTON

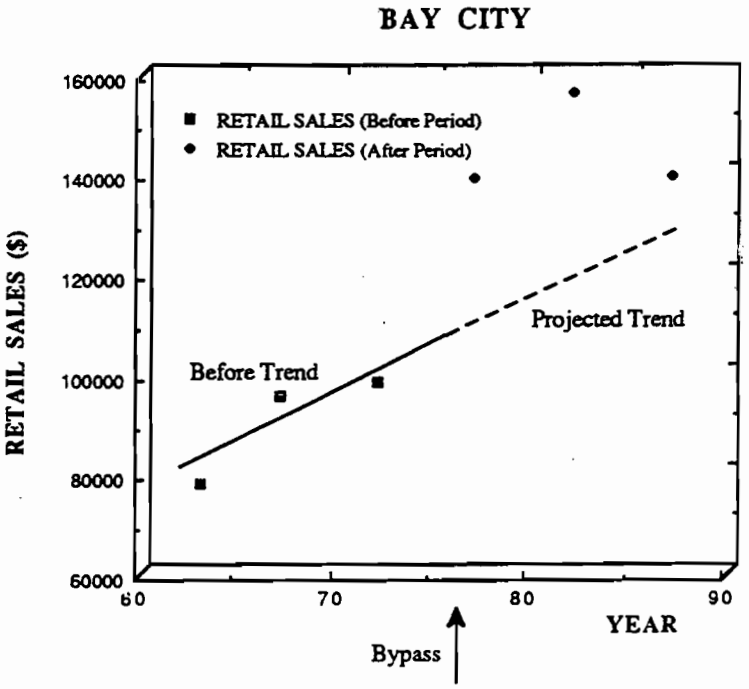


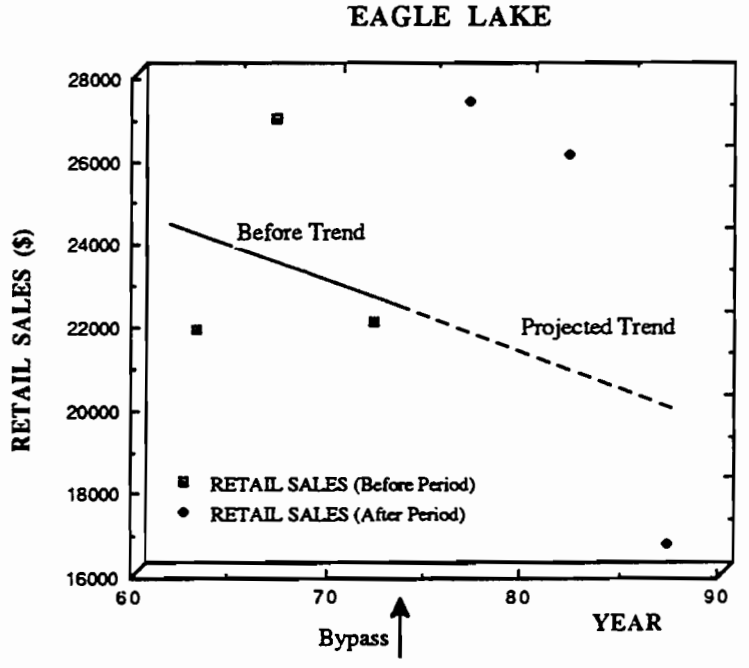
STAMFORD



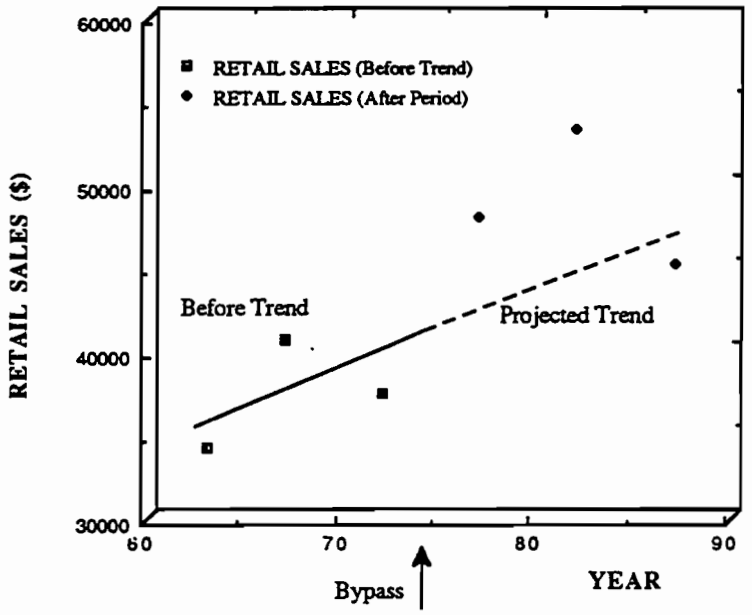
ANGELTON



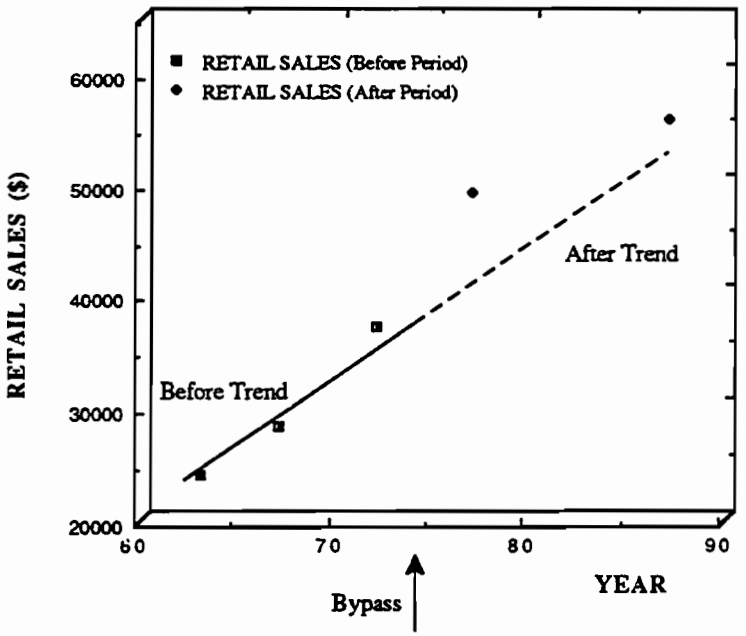

BAY CITY
RETAIL SALES ($)
160000
140000
120000
100000
80000
60000
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
Projected Trend
Before Trend
60
70
80
90
YEAR
Bypass


EAGLE LAKE
RETAIL SALES ($)
28000
26000
24000
22000
20000
18000
16000
Before Trend
Projected Trend
RETAIL SALES (Before Period)
RETAIL SALES (After Period)
60
70
80
90
YEAR
Bypass

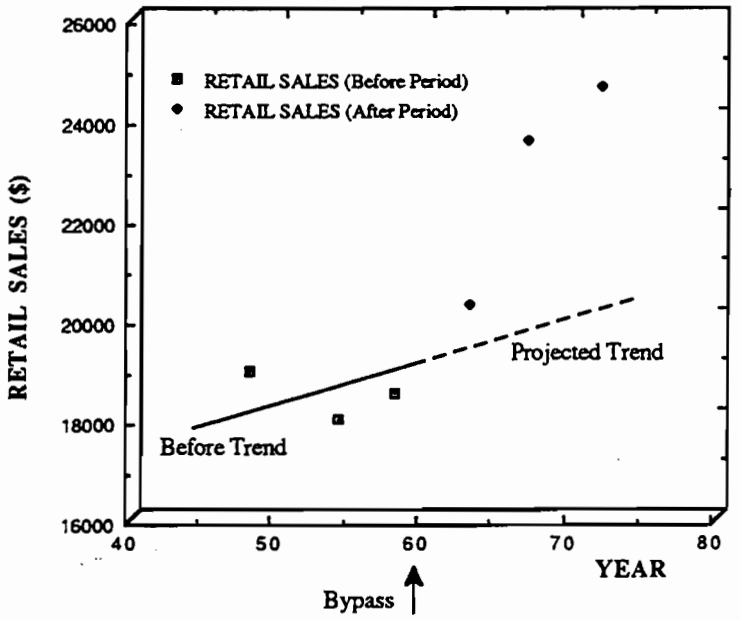
CUERO



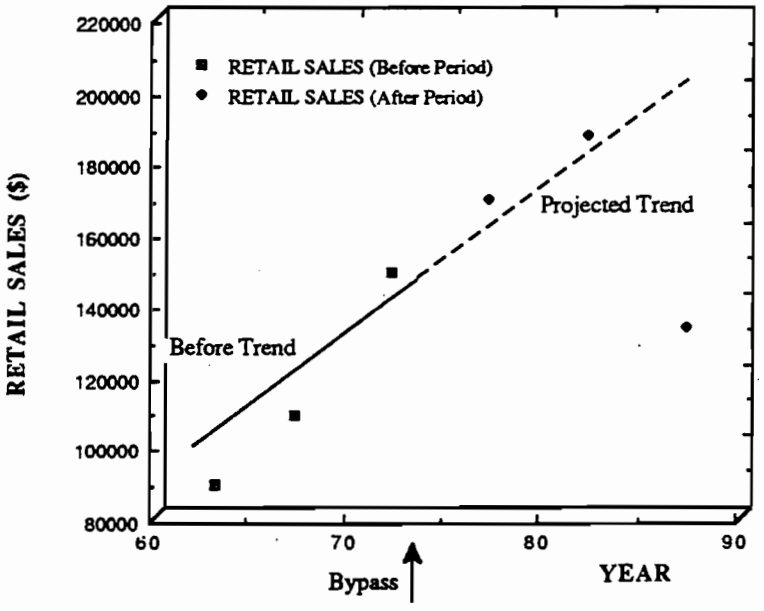
LOCKHART



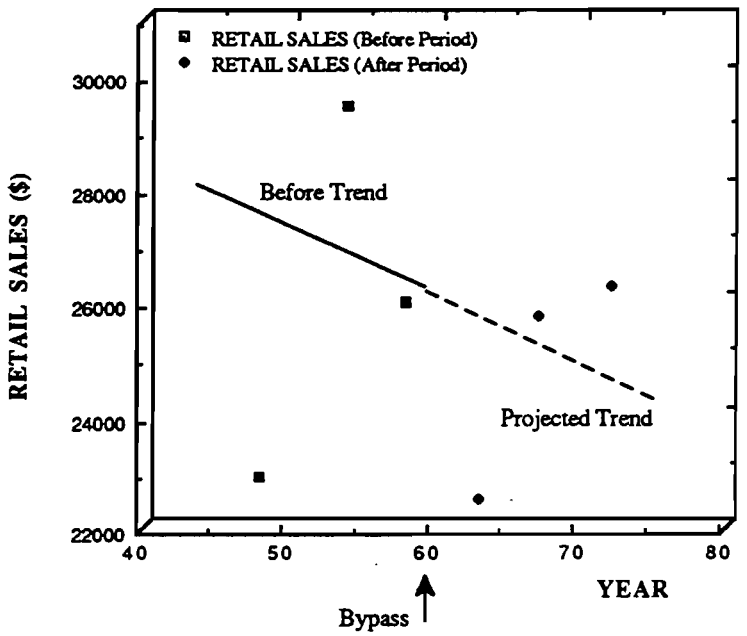
GIDDINGS



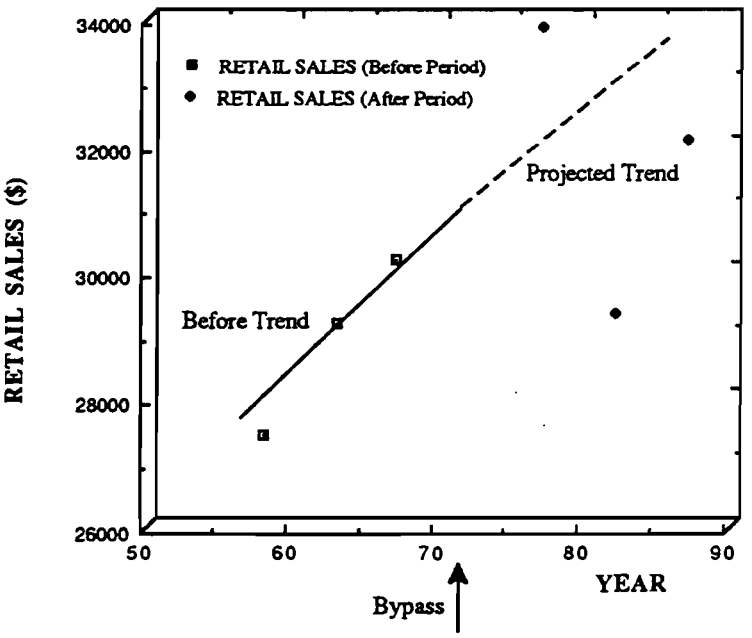
ALICE



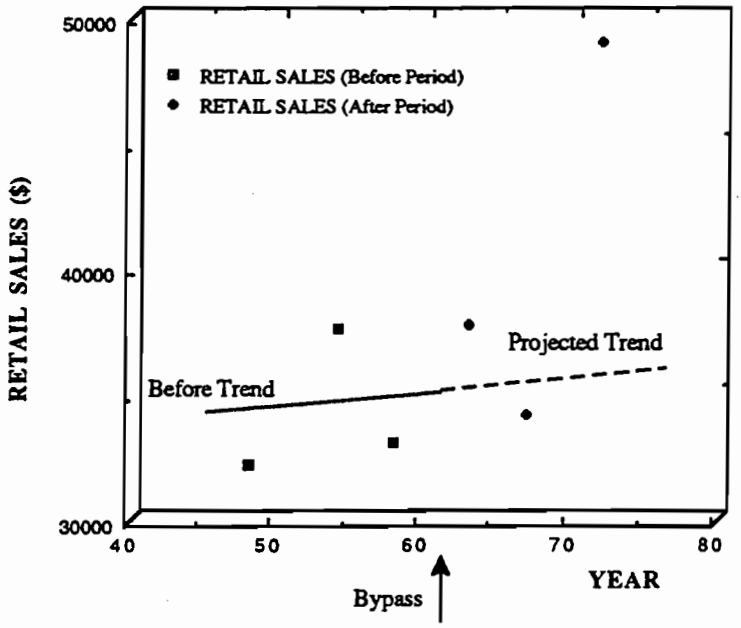
HEARNE



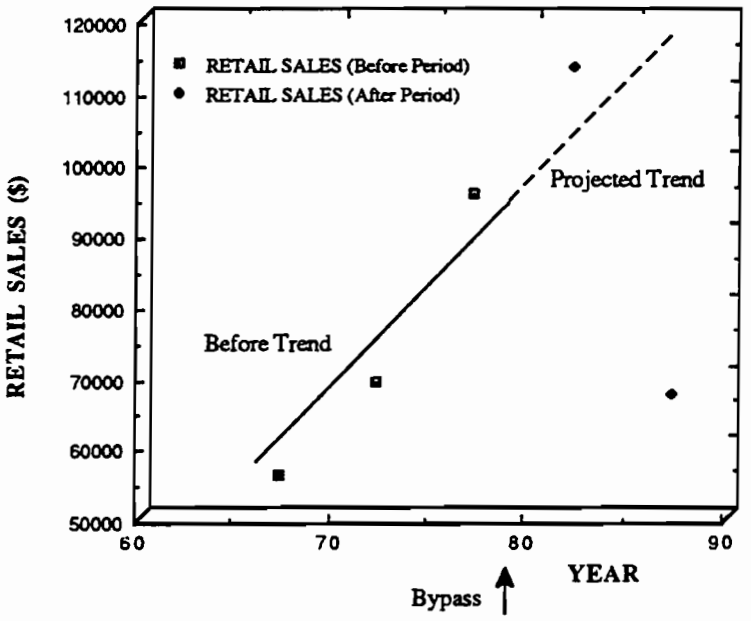
CAMERON



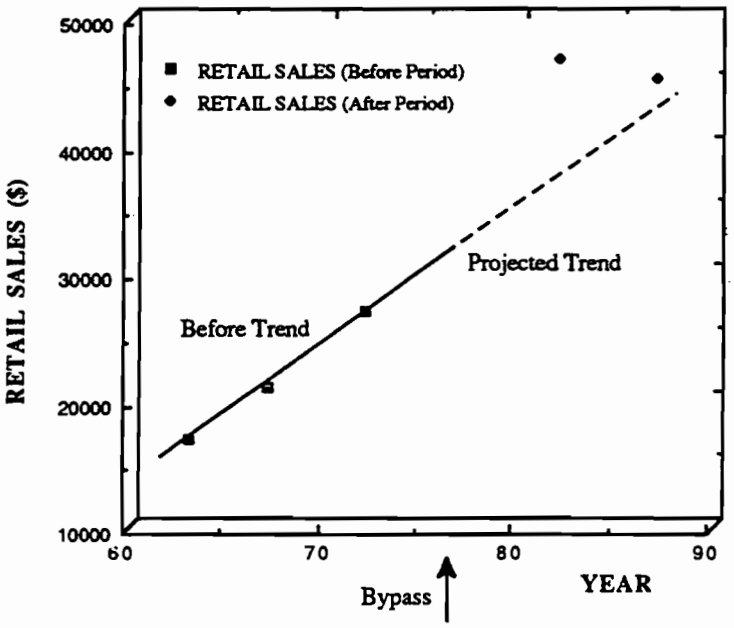
GILMER



LIBERTY



RIO GRANDE CITY



BRADY