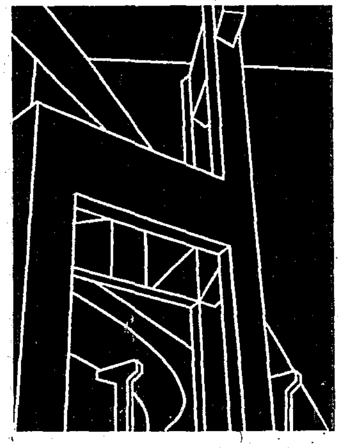
SPECIAL RESEARCH REPORT

MITIGATING THE ADVERSE IMPACTS OF THE DALLAS NORTH CENTRAL EXPRESSWAY CONSTRUCTION

Rob Harrison, Benjamin T. Waldman, Tamer El Diraby, and James T. O'Connor



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by

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EXECUTIVE SUMMARY

INTRODUCTION

The reconstruction of the Dallas North Central Expressway (NCE) is one of the largest, most complex, and expensive urban highway projects undertaken in Texas. And because work had to be carried out while the roadway remained in use and abutting businesses stayed open, it was recognized that the work could be highly disruptive to both highway users and those working, living, and transacting business in the catchment area. To mitigate the adverse impacts caused by the construction project, two decisions were made. First, a strong working relationship was forged between the contractors for the various segments of the project and Texas Department of Transportation (TxDOT) staff to address mitigation needs, both in the field and at the District office, to address mitigation needs. These were in part based on the quality control/assurance program promoted by TxDOT in recent years. Second, a North Central Mobility Task Force (NCMTF) was formed to address issues of mobility planning, traffic management, public information, and community outreach. The main goal of the NCMTF was to maintain the integrity of the residential community and the economic viability of the business community and to safely provide acceptable levels of mobility to those traveling through the corridor while under reconstruction.

Once the project was underway, it became clear that opportunities were available to improve the original design plans and to expedite the construction process. The plans for controlling traffic while the project was underway also offered opportunities for substantial improvements. The Center for Transportation Research (CTR) was contracted to provide services to the TxDOT field office to address issues in three critical related areas. These comprised traffic operations, construction sequencing, and measuring business and residential impacts. In order to form an effective link between the researchers and the field office, a resident research engineer was stationed in Dallas to provide effective communication and leadership in the various areas. This report addresses the major findings identified in the three research areas. A second report will be prepared detailing the specific results of construction sequencing research.

MAJOR FINDINGS

Business Impacts

The NCMTF has been instrumental in alleviating many of the adverse user and business impacts associated with project work. Surveys indicated that there was an effective link between those carrying out the work and those expected to be adversely affected from engineering activities. Dedication of a group similar to the NCMTF for large urban reconstruction projects should result in an improved mitigation process and a greater understanding in the business community about work undertaken and objectives sought in the work.

Results confirm that on large urban projects it is critical to expedite the construction of frontage roads. This is particularly true where the highway links to multi-occupancy buildings, large corporate offices, shopping malls, and areas where there is substantial business activity. Surveys indicated that there was generally little impact on driveway access and parking and most business respondents agreed that the completion of the frontage roads was perceived as helping all aspects of commercial activity.

Previous studies had suggested that the construction work would have substantial impacts on a wide range of businesses, but this did not happen. NCE surveys showed that some retail activities were adversely impacted, but that generally the retail activities showed the same trends to those in control groups and the overall metropolitan area. This suggests that sales for the majority of businesses are more dependent on the overall level in the economy rather than specific construction projects, subject to minimum levels of access being maintained. In addition, data on the business surveys showed more businesses actually opened than closed along the frontage areas. And the vacancy rate for office space on the NCE was less than half that for downtown Dallas, again indicating that access and mobility issues did not impact choice of location.

Results from the questionnaire show that the construction activities were highly selective in terms of negative impacts. More than half of business startups and failures were relatively small retail stores. It would seem that a rather small and narrowly defined number of retail categories are sensitive to construction activity and that the adverse impacts to these can be mitigated by improving traffic control, expediting frontage road construction, and other planning activities.

The research indicates that the communication process on the NCE has improved with each successive construction section. This suggests that the process is iterative and a multi-stage project benefits from the experience gained on earlier completed sections. The recommendation is that the issue of communication should be explicitly recognized in any large, urban project and it should be a dynamic process taking advantage of all possible media opportunities.

Traffic Impacts

A computer model used for analysis of traffic flow characteristics and routing, called TEMPO, was specifically used for evaluating the North Central corridor and interchange plans. Features include a routing utility which shows the shortest route in terms of distance and travel time, and a diversion utility which provides a view of the effects of closing a link or links in the network. This model can be used to evaluate proposed traffic control plans and allows TxDOT staff to understand the impact traffic plans have on the broader city network. It shows great promise, can be used in other cities, and is still in the research and development stage.

Construction Sequencing

The cooperative approach between TxDOT, the primary contractor, subcontractors, and research staff enhanced project performance and produced time savings of around 30% and cost savings of around 16% for each of the three bridges evaluated in this study. The procedure used for the Mockingbird Lane bridge (saw cutting and demolishing part of the bridge) was effective in maintaining cross-street traffic without the use of a temporary bridge and similar procedures were easily applied to other bridges on the later sections of the project.

The phase consolidation plan (PCP) provided safer detours (better curves, longer radii of curvature and smaller grade differences) and allowed traffic to be switched to permanent pavement approximately five months earlier for the north-bound main lanes and almost 13 months earlier for the south-bound main lanes, greatly improving safety because of the elimination of detours and temporary ramps. The PCP allowed the South 2 (S2) portion of the project to be completed up to six months ahead of schedule, reducing the impact to businesses and saving millions of dollars in indirect user costs and overhead costs to TxDOT. Finally, the PCP saved TxDOT about $680,000 in direct costs and the stage construction plan (SCP) will likely produce similar savings, demonstrating that the research efforts generated high benefit-cost ratios for those using the NCE in general and Dallas citizens in particular.

CHAPTER 1. INTRODUCTION

OVERVIEW

The North Central Expressway (NCE) has been a key link in Dallas' transportation network for over 45 years. While the central location makes it a vital north-south thoroughfare (Fig 1), value has not been limited to expediting travel between the central business district (CBD) and the suburbs at the northern county limits. Because of improved access, abutting property values have been directly influenced through the promotion of industrial, commercial, and residential growth throughout its length. This aspect was documented at least as early as 1961 (Ref 1). Its indispensability as a thoroughfare, though, has led to its obsolescence in terms of capacity, while improvements in automotive and roadway geometric design have led to its obsolescence from those perspectives. Reconstruction, a goal for nearly two decades, has now finally become a reality. This reality poses several interesting challenges for local businesses, residents, and the traveling public, and an opportunity to study the effects of urban freeway reconstruction and construction impact mitigation policies on these entities.

HISTORICAL BACKGROUND

Justification for improving the NCE has existed for over 25 years. Design traffic flow capacity was exceeded by 1971 and peak capacities during more recent times were twice the original design capacity (Ref 2). Expansion plans eventually focused on two major segments: a 20.8-km (12.9-mile) segment from the LBJ Freeway to the northern suburb of Allen, and a 15-km (9.3-mile) stretch from the LBJ Freeway south to the CBD. The northern stretch offered fewer constraints in terms of expanding capacity (four main lanes each direction) at grade; rights-of-way were more generous, and the abutting properties were less densely developed than those further south. The southern segment, particularly the 8 km (5 miles) closest to the CBD, have right-of-way limitations imposed by encroachment of commercial and residential structures directly adjacent to the existing frontage roads. Hence, the original proposal submitted by the (then) Texas Department of Highways and Public Transportation to the City Council involved a plan to double-deck the expressway from Park Lane to the downtown area (Ref 3). This proposal was approved by the City Council in 1980. However, by 1982, protests from adjacent neighborhoods regarding the elevated roadway forced the City Council to withdraw its support of the plan. Furthermore, then-Texas Governor Mark White supported the City Council and prevented additional work from being done on the elevated design.

For the next four years, city and highway officials and local residents attempted to reach a consensus on an acceptable design. This effort resulted in the current design, which calls for depressing the main lanes to about 7.5m (25 ft) below grade, and overhanging the frontage road (cantilever) in sections where right-of-way constrictions would not otherwise allow for sufficient roadway width. Significant expansion of subterranean drainage features would be required, including 5 km (3.1 miles) of 2.4 to 5.5 m (8- to 18-foot) tunnels bored 24.4 to 27.4 m (80-90 feet) below the current freeway and a 270,000 M^3 (71-million gallon) system of retention caverns (Refs 4, 5). In addition, the construction efforts were to be coordinated with the Dallas Area Rapid Transit's (DART) construction of a light rail system running in proximity and roughly parallel (below, at, and above grade) to the expressway.

The finished product is intended to be more than just utilitarian in nature; in fact, the many planned embellishments will make this segment of urban freeway one of the most attractive in the nation, one that is destined to enhance the surrounding land use. Special features include extensive landscaping with irrigation, extra-wide pedestrian-friendly bridges, decorative landmarks, paving bricks or tinted and stamped concrete roadway at intersections, decorative residential sound barrier walls, and more modern signage (Ref 3).

CONSTRUCTION PROJECT LAYOUT

The reconstruction effort of the 15-km (9.3-mile) segment of the NCE located south of the LBJ Freeway was administratively divided into five individual projects, each open to separate bid (Fig 2). The interchange between the NCE and the LBJ Freeway constitutes a separate project. The projected construction schedule and estimated costs for each project are shown in Table 1.

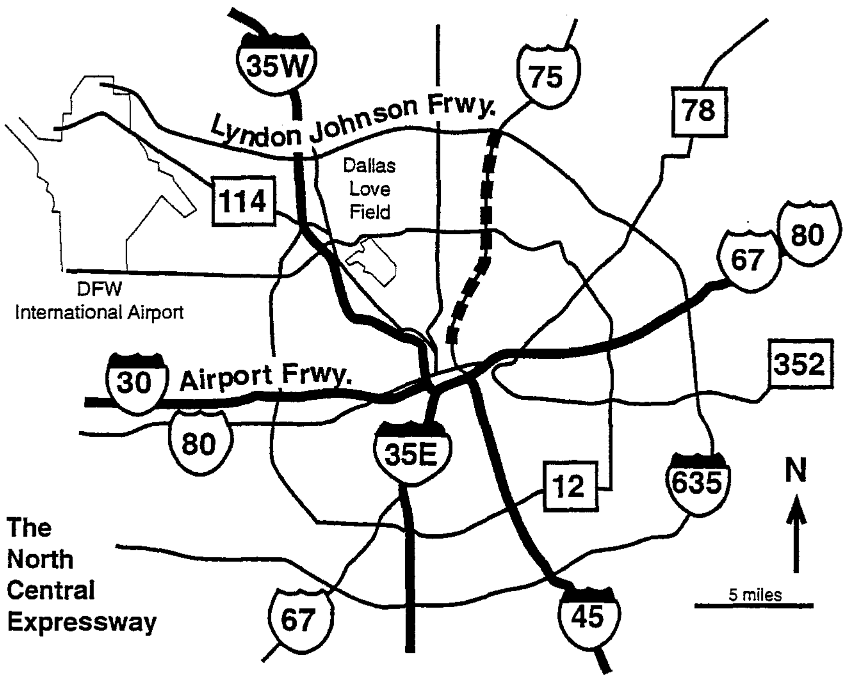


Figure 1. The North Central Expressway in Dallas

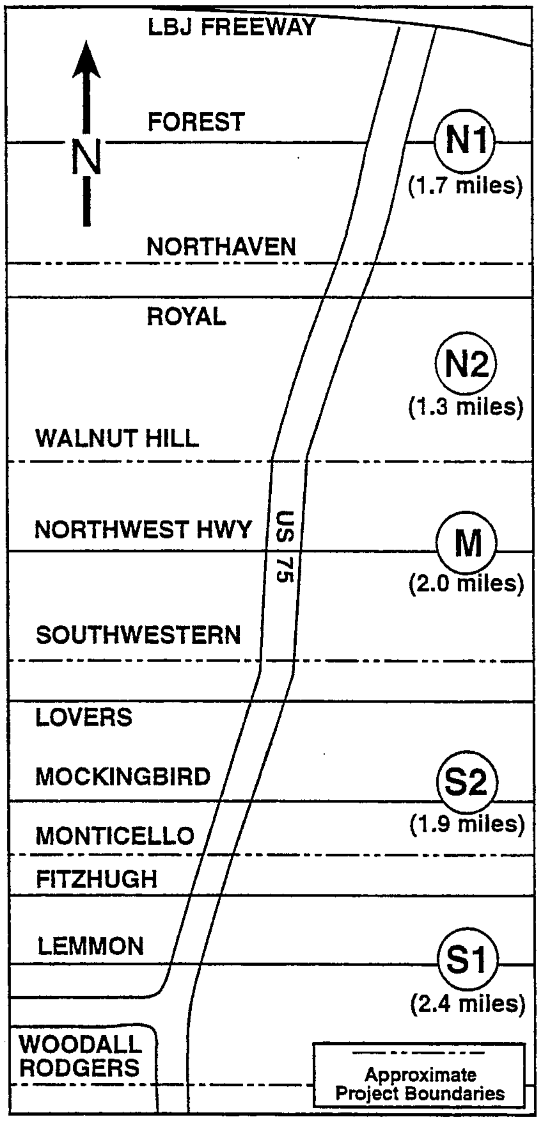


Figure 2. North Central Expressway project sections

Table 1. North Central Expressway construction schedule

Project Designation	Estimated Start Date	Estimated Finish Date	Estimated Cost ($ Millions)
N1–LBJ Freeway to Northaven Road	9/90	7/94	33.7
N2–Northaven Road to Walnut Hill Lane	6/90	4/94	30.1
M–Walnut Hill Lane to Southwestern Blvd.	4/94	6/99	114.0
S2–Southwestern Blvd. to Monticello Ave.	9/93	12/99	105.5
S1–Monticello Ave. to Woodall Rodgers Fwy.	4/95	12/99	108.2
LBJ/NCE Interchange	12/97	12/03	150.0

RESEARCH OBJECTIVES AND REPORT STRUCTURE

In December 1993, the Dallas District of the Texas Department of Transportation (TxDOT) contacted the Center for Transportation Research (CTR) of The University of Texas at Austin to elicit possible research services to be provided as the NCE was being reconstructed. The original proposal submitted by CTR in early January 1994 suggested research in the following three areas: 1) business impacts, 2) effects on traffic flows caused by work zone configuration, and 3) analysis of traffic accidents/incidents within the general construction area. Primary assistance would be to the S2 project staff, as construction on this section had just recently begun. By early February 1994, the TxDOT Northeast Area Engineer had requested assistance on developing an alternative to the planned reconstruction of the Mockingbird Lane overpass and the Lovers Lane overpass. This request then became the fourth major area of assistance (Fig 3). A contract was let effective March 1, 1994, for a support period of 18 months, with renewal options if further assistance was required. To maximize interactive capabilities, CTR positioned a research engineer in the S2 Dallas project office and provided supplemental assistance tailored to specific research requirements.

This report summarizes the research provided to date on this project. In Chapter 2, the impact of urban highway construction activities on abutting businesses is investigated. Previous research conducted in this area is cited and used to determine the survey design best suited to measure the impact experienced by businesses in the N1/N2 and M/S2 regions of the NCE project. The condition of the multi-tenant real estate market along the corridor is also examined. In Chapter 3, recommendations for placement of traffic control devices at a high incident ramp are presented, and a traffic flow simulation package originally developed to assist transportation officials in rerouting traffic after the 1989 San Francisco earthquake is explored. In Chapter 4, methods of streamlining the reconstruction project by changing the construction sequencing are examined. Conclusions and recommendations for each topic are given in the relevant chapters. Finally, recommendations for future work are made in Chapter 5. The Appendix contains a description of the N1/N2 survey (Appendix A), the M/S2 survey

(Appendix B), tables containing peak traffic volumes and plots of the distribution of the factors for various types of links (Appendix C), and detailed drawings of the Mockingbird BCP (Appendix D).

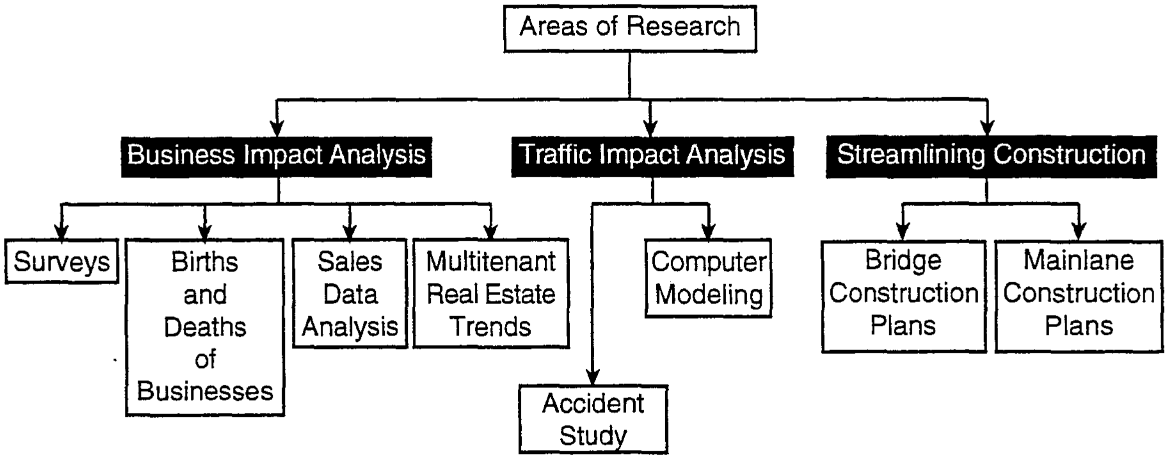


Figure 3. Major areas of research

CHAPTER 2. BUSINESS IMPACT STUDY

Urban reconstruction, particularly in or near city central business districts, impedes traffic flow and creates a variety of problems to those working, living, or passing through the areas affected by the project. Essentially, there are three major phases which produce different impacts. First, there is the initial construction, where disruption is highest owing to the need to create temporary detours, provide access to abutting businesses, and complete structural work (e.g., overpasses). The second phase is when the project passes into a mature period, where part of the work is complete (like frontage roads) and good progress is being made on main lane construction. In this stage, access to local businesses has been re-established and mobility improved for through traffic. Finally, as the project nears completion and the impacts become more positive, users and businesses benefit from improved mobility and access. Therefore, the goal of the planner is to help businesses overcome the short-term costs in order to take advantage of the long-term benefits.

Using this model, the critical business phase is the first, where disruption to access and impact on profitability is greatest. Planning and construction personnel now recognize that if minimum acceptable levels of business access can be maintained during the first phase, there is every likelihood that business survival will depend only on normal commercial risks, including competition. The NCE management team fully recognized the importance of access maintenance and every effort was made by both TxDOT and the contractor to work with the affected businesses and to maintain acceptable levels of access and mobility through the work zones, many of which were extensive. Because special efforts were committed to this activity, the CTR team was asked to monitor the progress — both successes and problems — in an attempt to improve future programs and transfer the results to other TxDOT districts.

The CTR effort focused on four issues: loss of customers (both short- and long-term), higher staff turnover, sales impacts, and occupancy rates for multi-tenant office space. Past work has emphasized loss of customers and sales during the first phase, although a previous CTR study (Ref 6) indicated that the response is more complex, with some businesses actually growing during the early phases of the project. This chapter, which describes the major steps taken in the CTR study, presents the following: the results of a literature search that sought to identify the best study methodology; the determination of a NCE mitigation and communication strategy; the measuring of business impacts, including openings and closings (termed births and deaths); an evaluation of the effectiveness of the NCE strategy; the impacts on commercial real estate in the area; and, finally, some conclusions to guide future work.

LITERATURE SEARCH

An extensive literature search revealed that little has been written regarding the impacts on businesses directly abutting urban highway reconstruction. However, three documents that proved relevant to this topic provided a base on which to build a study program for the NCE project.

Buffington (TTI) and Wisconsin DOT Studies

Staff at the Texas Transportation Institute (TTI) of the Texas A&M Univerisity System have conducted analyses of the economic impacts of highway reconstruction in urban areas for TxDOT. A "before and after" approach utilized in several of these studies (Refs 7, 8) summarized those general impacts present in most urban highway improvement operations. Impacts can be beneficial, adverse, or a combination of both, and quantification of these impacts is often difficult. TTI research suggests that it is almost impossible to totally isolate the effects of highway improvements on a community from other economic factors that may be at work within the general and local economies. Businesses may be particularly vulnerable to short-term negative impacts during the active highway improvement construction phase. Disrupted access, congestion, and loss of parking may temporarily dissuade customers from patronizing a business. On the other hand, some expenditures directly attributed to the construction and construction workers may offset these losses (Ref 7).

In a 1987 study, the Wisconsin DOT (Ref 9) attempted to assess the economic impact of detours abutting highways undergoing improvements. It was shown that there was a decline in overall levels of sales activity from between 2% to 17%, with the degree of this decline dependent on the type of business. While the long-term outlook following reconstruction was generally positive, the degree of impact on abutting businesses showed a direct relationship to the construction project duration. The study also showed that businesses that aggressively sought to mitigate detrimental construction effects were generally successful in reducing lost sales while roadwork was in progress, and that sales improved more rapidly following the construction.

Houston Study

In research conducted for his dissertation, de Solminihac (Ref 10) sought to expand on the methodology used by Buffington, using the reconstruction of a section of the Southwest Freeway (U.S. 59) in Houston as a case study using a dual methodology. The first approach relied on an analysis of gross sales data collected by the Texas State Comptroller's Office, while the second relied on analysis of survey data related to the degree of impact the construction had on various aspects of the commercial activities of individual businesses abutting the route.

In the first approach, earnings data for each of 10 different business categories (Standardized Industrial Classification codes) were obtained over a period immediately preceding reconstruction for zip codes adjacent to the study area, adjacent to a similar "control area" where no construction had taken place, and for the metropolitan area as a whole. Regression analysis was conducted on the earnings data for each business category in each area (study, control, and greater metropolitan) to predict what the level of sales would have been during the first full year of construction. In comparing actual sales levels with the predicted values for each area and using a set of decision rules for comparing results from the different areas, it was possible to isolate construction effects on each type of business and to determine whether the construction had a significant impact on the overall metropolitan area economy.

In the second approach, random business owners/managers of establishments directly abutting the route were interviewed via a questionnaire. Questions included the effectiveness of communication between businesses and TxDOT, the effectiveness of mitigation strategies, and the effects that active construction and the finished product had on sales. Summaries were then prepared for each question and for each type of business.

A set of five hypotheses were developed (Ref 6) and tested using the results of the analyses cited above. These hypotheses were:

a. road construction activities significantly impact the sales of abutting businesses,
b. road construction activities along a major corridor significantly impact the economy of the entire city where it is located,
c. road construction activities affect some businesses more than others,
d. an officer or group dedicated to mitigation for a major construction job can be instrumental in alleviating user and business impacts, and finally
e. considerate and intelligent construction phasing can minimize impact on abutting businesses.

De Solminihac surprisingly concluded that the first hypothesis was not accurate and that construction impact on businesses was not highly significant, since only 12% of the responding (abutting) businesses indicated a drop in sales over 40%. The second hypothesis also proved invalid: data supplied by the State Comptroller showed that Houston appeared to suffer no business loss from the construction. The third hypothesis proved to be true, and this finding was particularly interesting because if certain business activities are vulnerable during construction, actions to specifically address their needs can be taken by the contractor. Assessment of the fourth hypothesis was based on a driver's (user's) survey and the business survey cited earlier. In each survey, respondents indicated that the TxDOT Public Relations department had largely communicated effectively, thereby alerting owners to potential inconveniences. The hypothesis, therefore, was determined to be valid. Finally, de Solminihac concluded that the fifth hypothesis was also valid because the policy of completing the frontage roads early in the project reduced disruption and improved access problems to the abutting businesses, with many businesses indicating that the sales had improved following completion of the frontage roads.

The five hypotheses supported the benefit of having a dedicated individual, or group, focused specifically on developing mitigation policies. In Houston, an individual was chosen to work out of the site office to develop an active mitigation policy, while for the NCE project a different approach was chosen and is now described.

MITIGATION POLICIES

The North Central Mobility Task Force

Realizing that the reconstruction of NCE would be a major undertaking, TxDOT, DART, and City of Dallas staff decided to jointly establish the North Central Mobility Task Force (NCMTF), coordinated through personnel provided by TTI. The NCMTF, as shown in Figure 4, has four thrust areas comprising mobility planning, traffic management, public information, and community outreach.

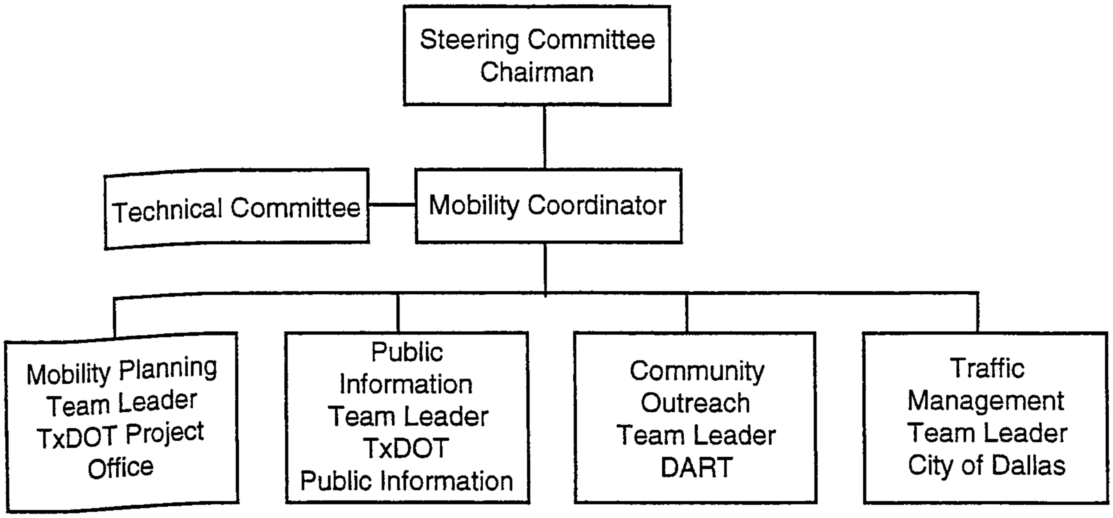


Figure 4. North Central Mobility Task Force

The task force has the responsibility, but not the authority, of maintaining mobility through these four areas. The central goal of the task force is to maintain the integrity of the residential community and the economic viability of the business community, and to safely provide an acceptable level of mobility for persons traveling through the corridor during the reconstruction of the North Central Expressway and the construction of the adjacent DART light rail line. With this goal, the objectives of the task force are to facilitate all issues related to project amenities, right of way (ROW), and mobility.

The North Central project team, shown in Figure 5, is responsible for coordinating these efforts through TxDOT, the contractors, businesses, and all other North Central project team members, and seeing that the project runs smoothly.

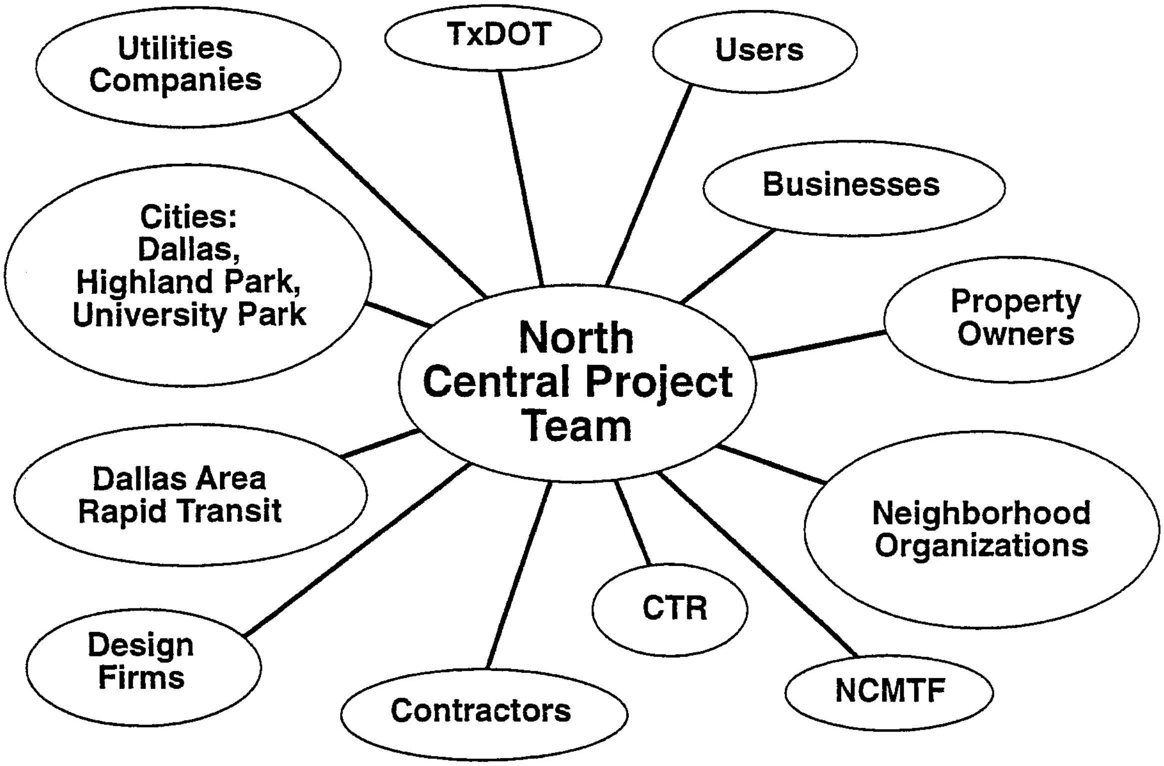


Figure 5. North Central Project Team

Figure 6 shows the communication links between team members in order to meet the objectives of the taskforce. Mitigation efforts managed by the NCMTF take place on several fronts and includes a phone number (WIDEN-75) giving callers various information about construction activities. A quarterly newsletter, *North Central Expressions*, is also produced, containing valuable information on both the highway reconstruction and DART light rail construction projects, such as lane closures and detours, costs of varying tasks within the project, and general information such as phone numbers to call for specific information. Flyers are also distributed to affected businesses and neighborhoods detailing construction information, and contributions are made to local neighborhood publications.

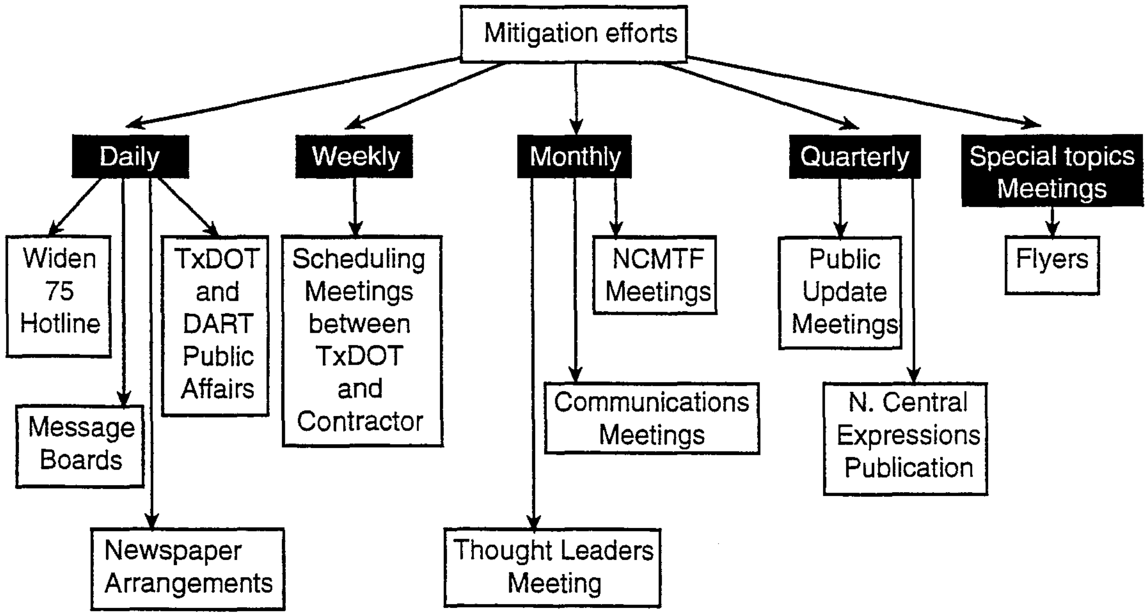


Figure 6. Mitigation efforts

Weekly meetings are held between TxDOT and the Contractor to discuss scheduling and construction activities, monthly meetings are held to discuss mobility policies among various team members, and quarterly meetings are also held to address public and business group needs. At the quarterly meetings, the general public is allowed to voice concerns and, if necessary, request small group meetings to address special issues. If no group meetings are requested, communication is accomplished through the WIDEN-75 hotline and/or the quarterly newsletter. If there is a special construction event scheduled to occur where there might be substantial delays, information is disseminated by mail, door postings, or flyers and, if necessary, a representative from an involved party, typically TxDOT or DART, makes public visits. For cases that cause extreme delays, such as bridge demolition, electronic message boards and press releases are also used.

It can therefore be seen that considerable effort was expended by all parties involved in the NCE project to mitigate the adverse impact of construction. The next section addresses the work undertaken by the CTR team to evaluate how successful this policy was, based on the responses of those most critically affected by the project.

BUSINESS IMPACT ANALYSIS

The methodology to analyze the impact of construction on businesses (Fig 7) is an enhanced version of one developed in an earlier CTR study (Ref 10). A survey of the businesses abutting the construction was first administered, and the relative revenue statistics supplied by the State Comptroller's Office were then analyzed. The survey measures business owners' perceptions, while the earning statistics provide a more objective picture of how businesses fared economically. In addition, births and deaths of businesses and trends in the multi-tenant real estate market were also examined to gauge the effects of the construction on the business community.

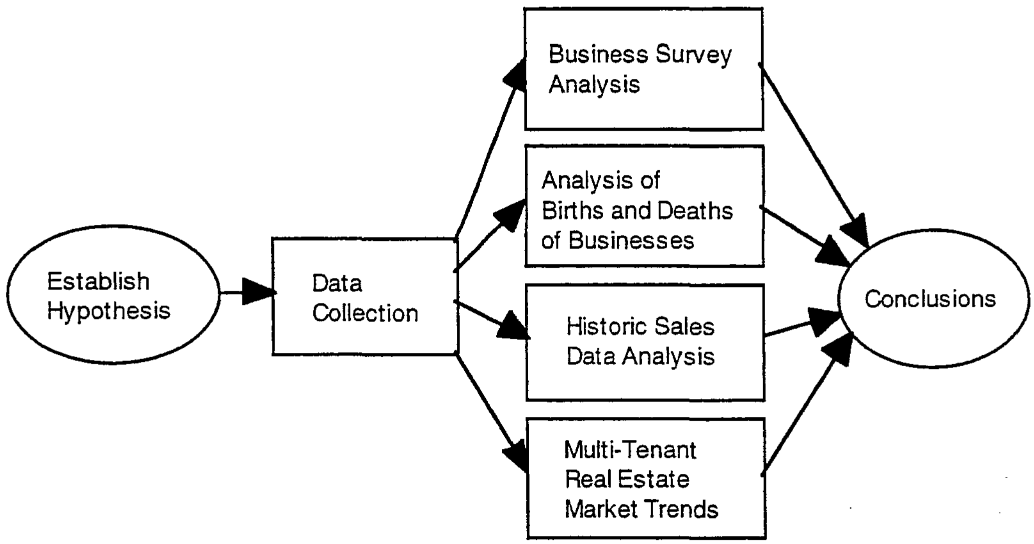


Figure 7. Business impact methodology

The survey administered by the CTR team in Houston worked well, therefore it was decided to design a similar survey for use in Dallas and also to adopt for the Dallas NCE the five hypotheses tested in Houston. Results of the Dallas survey could then be compared to those in Houston, to determine if any general trends existed. The five hypotheses were:

a. road construction activities significantly affect the sales of abutting businesses,
b. road construction activities along a major corridor significantly impact the economy of the city where it is located,
c. road construction activities affect some businesses more than others,
d. an officer or group dedicated to mitigation for a major construction job can be instrumental in alleviating user and business impacts, and
e. considerate and intelligent construction phasing can minimize impact on abutting businesses.

Furthermore, the following three hypotheses were added:

f. communication is an integral part of traffic mitigation strategies,
g. major reconstruction projects may produce business opportunities, and

h. to effectively reduce negative construction effects, mitigation must include action by businesses, as well as the highway department and contractor.

Data collection was accomplished by a windshield survey of businesses within each project section (taking an inventory of existing businesses), and then interviewing businesses with the purpose of completing a survey. The survey includes questions on business startups and failures and this, combined with an ongoing effort to monitor the births and deaths of businesses abutting the south projects, enables some interesting conclusions to be drawn. Related to this, earning statistics by zip code in the Dallas metropolitan area were obtained from the Texas State Comptroller and regression analysis was used to determine the effects on sales in the areas affected by the reconstruction project. Finally, the trends for the multi-tenant real estate market for the major economic regions in Dallas were compared to those in the North Central Corridor. Following the analysis of these topics, conclusions are presented relating to the hypotheses previously described.

Initial Survey of Sections N1 and N2

In order to measure the economic effects of the reconstruction activities, surveys were administered to businesses abutting reconstruction following completion of the first two sections (N1 and N2), and then later during reconstruction of the proceeding two sections (M and S2). In both cases, a windshield survey was conducted to create a working list of all businesses within the analysis zone. There were 149 businesses categorized within N1/N2, while 107 were categorized for M/S2. Research staff visited businesses, conducting questionnaire interviews and setting up future contacts. If the appropriate person was not available for interview, then the questionnaire was left to be completed at their discretion and they were given self-addressed envelopes in which to return the survey. In some cases, return visits were made to serve as reminders to complete the survey. In both sections, response rates to the questionnaire were slightly greater than 50%, with 76 and 56 questionnaires returned, respectively.

During the summer of 1994, a survey (shown in Appendix A) was administered to businesses abutting reconstruction of U.S. 75 in the N1/N2 sections. It is important to note that this survey was administered while construction activities were continuing but after frontage road reconstruction was complete.

Appendix A depicts the responses from the survey questions and draws conclusions. It is important to note that the questions were structured to reveal respondent perceptions in a subjective manner. This creates a broad range of responses caused by respondent bias, and one must be careful drawing conclusions from the survey. Due to the survey length, and the limited time some businesses were able to give, questions at the end of the questionnaire were not filled out as well as earlier questions.

In examining the first survey, some observations can be made. First, there were some clearly perceived impacts felt by businesses in N1/N2 where sales and driving patterns were most affected. Also, there were significant improvements in most businesses after the frontage road construction was complete. Secondly, there were responses that indicated a lack of communication between TxDOT, contractors and businesses. This conflicts with the deliberate creation of the NCMTF and the numerous contacts, meetings, and personal communication activities which characterized the communication activities at the N1/N2 sections. It was thought that staff turnover in the various businesses (many of which are retail with high natural turnovers) meant that those staff originally contacted were no longer employed at the business and the staff interviewed were not in a position to accurately comment on the early communication process. However, most of those replying believed the finished expressway would promote economic growth and be good for business.

Follow-Up Survey of Sections M and S2

Building on the experience gained in the first survey, a second survey, altered to afford ease of completion (shown in Appendix B), was administered to two other sections on the project. The primary change was to allow the person being surveyed to check an appropriate box instead of expressing a subjective opinion, an improvement both for those administering and completing the survey. Total time to complete the second survey was therefore reduced and analysis was simplified by eliminating the painstaking task of subjectively determining the answers. Comments were also encouraged.

It is important to note this survey was administered during the frontage road reconstruction process, whereas the N1/N2 questionnaire was administered after frontage road construction. Surveying during construction has traditionally been avoided because it was believed that responses would tend to be negative and biased. The reason for surveying during construction was both to test this theory and to more accurately measure communication effectiveness. Because of this, the survey did not include questions concerning the finished project and included certain questions pertaining specifically to the two sections (M and S2) under construction. Appendix B contains responses from the second survey and again, conclusions are drawn.

Survey Comparisons

In comparing the two Dallas surveys, many results are similar although the second can be held in higher confidence for two reasons: there is less subjectivity and more consistency, and response rates were higher on almost all questions, especially toward the end of the questionnaire.

There was an initial concern that the second survey would contain more negative responses because it was administered during construction, but this seems unfounded. Staff at most businesses, when approached, showed no increased negativity towards the project. Further, there was no significant difference in the percent of questionnaires returned and both had response rates slightly above 50%.

Through further analysis of both surveys, it is evident a learning curve exists for TxDOT, the contractor, and businesses. Results of a question addressing the effects felt by customers showed an improvement in sections M/S2 when compared to N1/N2 results. The same can be said for the questions which dealt with handling of the construction process and project safety. Therefore, throughout a construction project, both sides apparently can learn from initial experiences which then helps to improve later stages of the project.

One goal of adjusting the first survey was to increase the response rate by altering the format of certain questions. Figure 8 shows the response rates for the two surveys. The average response rate for the second survey was 93%, which is a significant improvement compared to the first questionnaire's average response rate of 63%. It is concluded that redesigning the questionnaire to improve ease of response is highly desirable and should be followed in any future attempts to interview business staff and measure communication effectiveness.

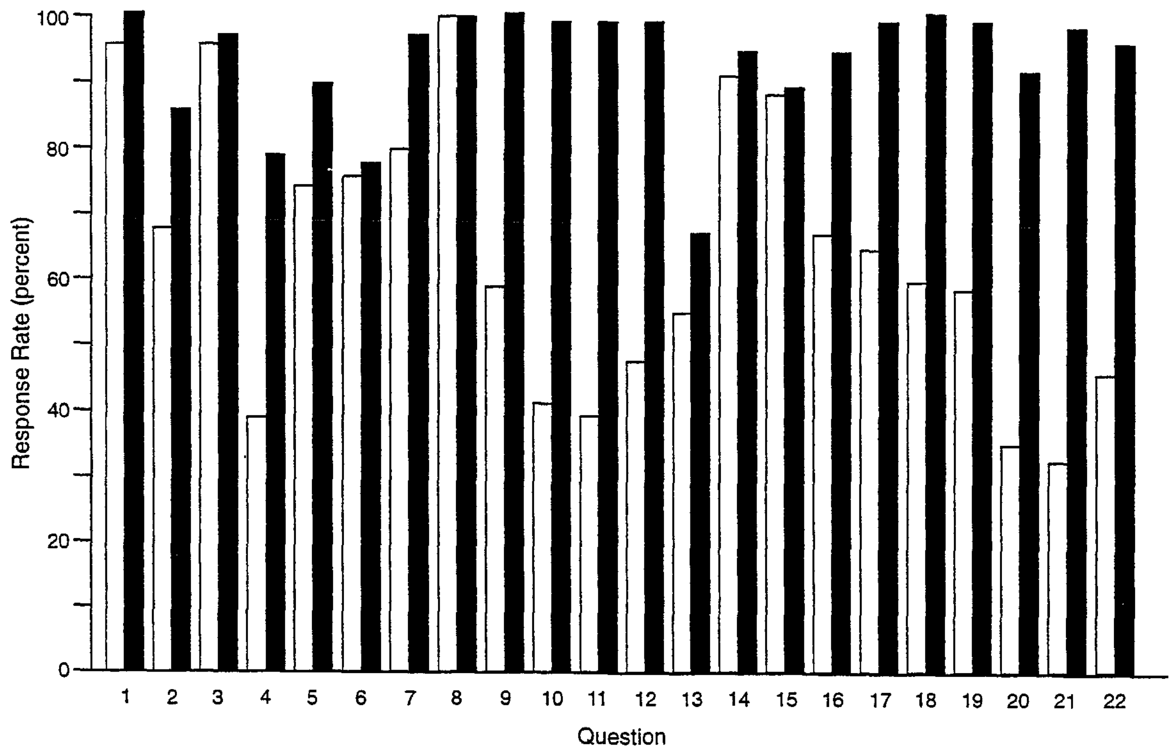


Figure 8. Response rates

Births and Deaths of Businesses During Construction

Previous work has tended to focus on the problems that urban construction creates for abutting businesses and companies, with the recognition that once the construction is completed, the business environment and opportunities show an improvement. However, it became clear in the Houston study that many business opportunities present themselves during construction, either from different patterns of demand arising from the construction work or from companies moving to the area to take advantage of enhanced opportunities available once the work is complete. Since it was believed that the NCE would provide many such opportunities, CTR researchers decided to record those businesses that closed ("deaths") and those that opened ("births") during the construction. The surveys were done for the N1/N2 and S2/M sections of the NCE project and are summarized by business category in Table 1 below.

Table 1. Births and deaths of businesses

Business Births and Deaths During Construction		
Category	Births	Deaths
Agricultural/Construction/Manufacturing	0	0
Retail - Food	13	10
Retail - Automotive	6	3
Retail - Other	34	18
Utilities	0	0
Services	2	2
Finance/Real-Estate/Insurance	5	3
Total	**60**	**36**

There were 96 responses from the two surveys. High activity within the retail category is evident, as expected. This category entails all forms of retail other than food or automotive needs; examples of which are hair/nail salons and music stores.

Currently, the births and deaths of businesses abutting the S1 and S2 projects are being monitored. Table 2 shows the births and deaths that were recorded from January 1996 to August 1997 for the S1 and S2 sections.

Table 2. Births and deaths of businesses adjacent to NCE construction

Name	Type of Business	Date of Birth or Death
Gaspars Restaurant	Retail, Food	Opened 5/20/94, Closed 1/16/96
Tuscanas Restaurant	Retail, Food	Opened 6/20/96
Area 51 Night Club	Retail, Food	Opened 6/96, Closed 8/96
Target	Retail, Other	Opened 1/94
Office Max	Retail, Other	Opened 1/95
Stuarts	Retail, Other	Opened 11/95
Payless Shoe Store	Retail, Other	Opened 11/95
Radio Shack	Retail, Other	Opened 11/95
MacFrugal's	Retail, O ther	Opened 4/26/96
Pace Cleaners	Services	Opened 2/96
Dr. Brad Pennington Chiropractor	Services	Opened 3/96
Mobile Gas Station	Retail, Auto	Opened 12/18/95
Ralph Global and Associates	Financial, Real estate, Insurance	Moved to location on North Central Expressway in 5/95
Mark Brown Auto Sales	Retail, Auto	Moved to location on North Central Expressway in 4/96
Roscoe Endel Realtor	Financial, Real estate, Insurance	Moved to location on North Central Expressway in 4/96
Dante Detail Shop	Retail, Auto	Closed in Late 1993
Hasty Liquor Store	Retail, Food	Closed in Late 1993
Ross Clothes Store	Retail, Other	Opened 10/96
Corvette City	Retail, Austo	Closed 11/96
TGF Hair Cutters	Services	Closed 10/96
Mustang Cellular	Retail, Other	Opened 11/96
Run on Clothing	Retail, Other	Opened 4/96
Revente Clothing	Retail, Other	Opened 12/96
Personal Wealth	Financial, Real estate, Insurance	Opened 2/96
Mohawk Music	Retail, Other	Closed 9/96
Block Buster Music	Retail, Other	Closed May 1996
Horchow Finale Furniture	Retail, Other	Opened May, 1997
Not Just Soccer	Retail, Other	Closed February 1997
Rucus Cards and Gifts	Retail, Other	Closed April 1997
Flower Market	Retail, Other	Moved south to NCE SBFR at McCommas Blvd.
Mr. J's Paint and Picture Frames	Retail, Other	Opened July 1997
Book Stop	Retail, Other	Closed February 1997
The Futon Company	Retail, Other	Closed June 1997
The Mattress Company	Retail, Other	Opened July 1997
Accent French Antiques	Retail, Other	Closed March 1997

Other Evaluation Measures of NCE Mitigation Strategies

Previously, measuring the effectiveness of mitigation strategies has focused on questioning the staff at businesses abutting the various NCE project section perimeters. To cross-check responses and gain insight into the overall effectiveness of the mitigation policies, two further studies were undertaken. The first relates to the reported business sales data, and the second to the occupancy rates for business properties along the project. The Houston study had shown that reported sales data combines well with the more subjective data derived from staff questionnaires. In one sense, occupancy rates are the acid test of disruption. If construction heavily disrupts business activities in the area, a substantial drop in occupancy rates for commercial properties along the route might be expected to occur, together with a reluctance for new businesses to move into the area. Therefore, combining business opinions with reported sales data to the Texas State Comptroller's Office and then relating both of these to occupancy rates should give a broad evaluation of the effectiveness of the strategy specifically designed in the NCE project to mitigate adverse construction impacts.

Evaluation of Sales Data. The NCE analysis is derived from that conducted successfully in Houston, and the methodology is shown in Figure 9. In this approach, three areas are chosen for comparative purposes. The first area bordered (as closely as possible) the construction activities. Then a control area was selected where the business and socio-economic characteristics were closely matched, with the major difference being that no construction activities were being undertaken. It was hoped that by controlling for most critical areas except construction, impacts of construction on the various economic indicators would be seen and appropriate conclusions drawn. Finally, from the metropolitan area of Dallas, data were collected to compare overall city aggregate data to both the construction area and the control group with respect to retail performance and sales trends. Table 3 gives the definitions of the three areas together with the zip codes used to collect the sales data. Source for the sales data was the Texas State Comptroller's Office, who provided information on diskette from 1984 through 1993. First, all sales data were aggregated by quarter and year, as shown in Figure 9, and then were adjusted to represent constant dollars. In this case, Bureau of Labor Statistics data were used to give values in terms of constant 1984 dollars.

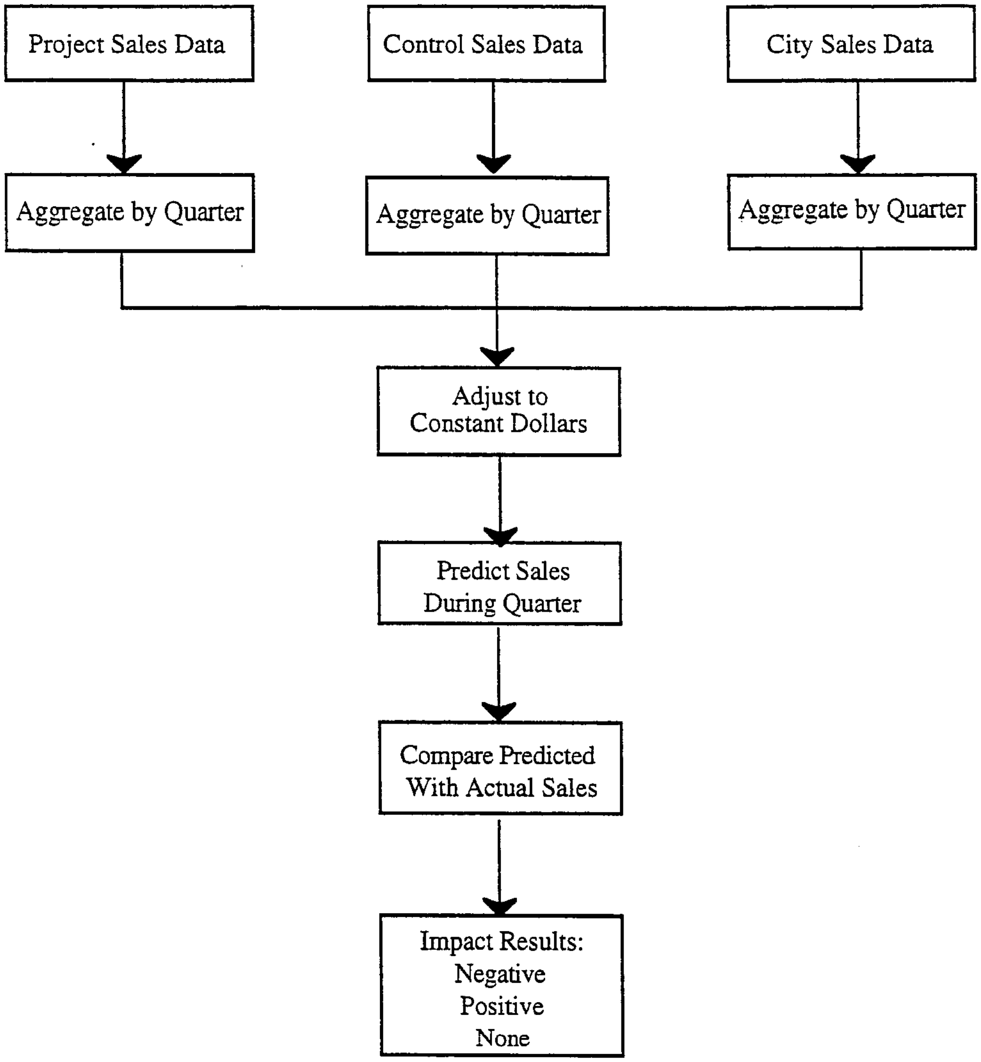


Figure 9. Comptroller sales data analysis (de Solminihac, 93)

Table 3. Zip codes

Project	Control Section	City
North Central Expressway, U.S. 75	Airport Freeway, Rt. 183	Dallas Metropolitan area
75205, 75206, 75255, 75230, 75231, 75243, 75251	75061, 75062	All zip codes within Metropolitan area

In addition to the data being aggregated by quarter, they were also broken into the various retail categories of interest for each of the three analysis groups. These data were then plotted to see if there were any unusual movements in the data and are reported in Figures 10 through 13. Previous work had indicated that professional and specialized businesses (like banks and physician offices) were less sensitive to construction activities. Accordingly, the sales analysis concentrated on those businesses known to be more sensitive to customer access, and seven groups were determined:

- agriculture/construction/manufacturing
- retail-food
- retail-automotive
- retail-other
- utilities
- finance/insurance/real estate, and
- services, such as gas stations.

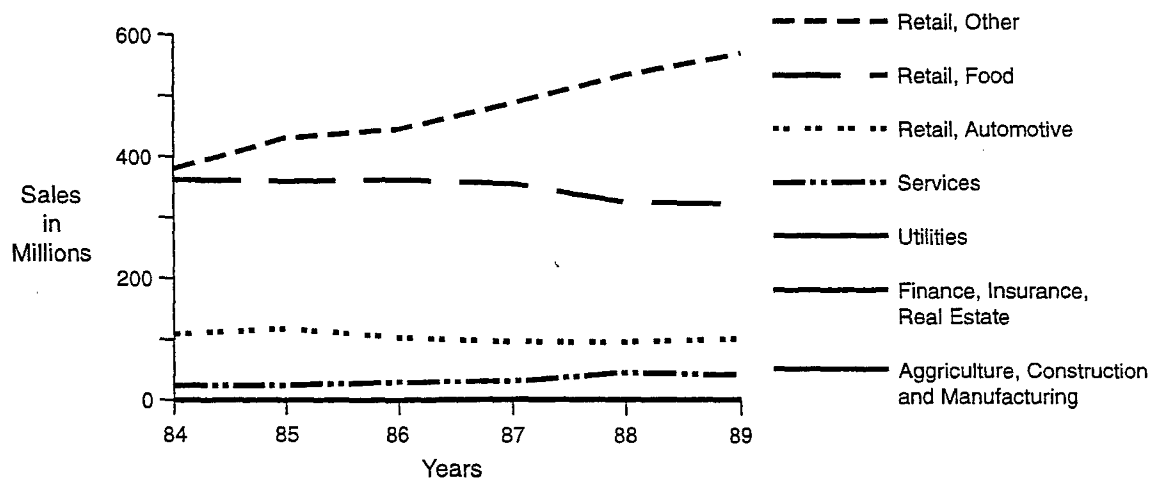


Figure 10. Sales trends before construction—NCE

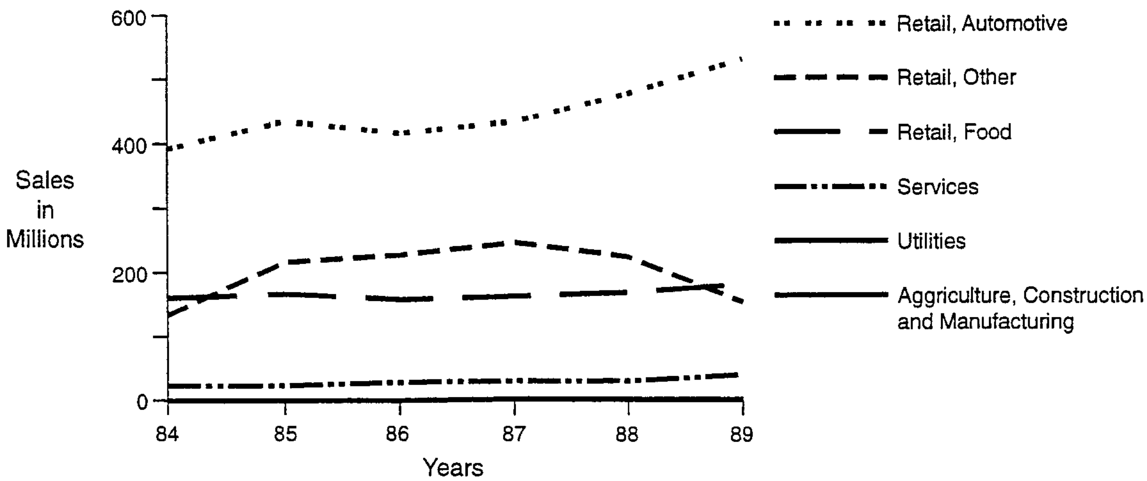


Figure 11. Sales trends before construction—Control Group

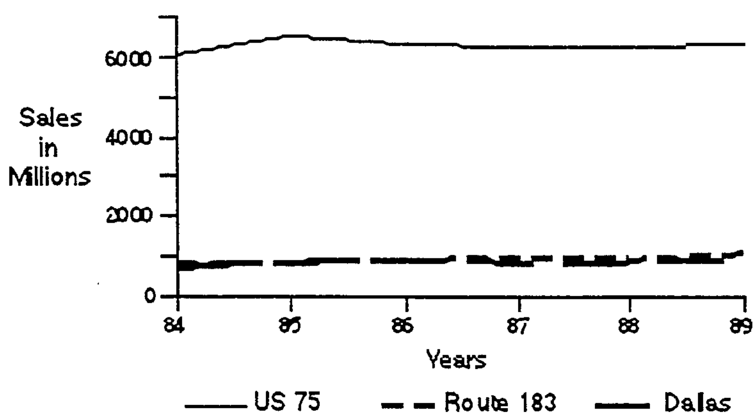


Figure 12. Total sales before construction—Dallas

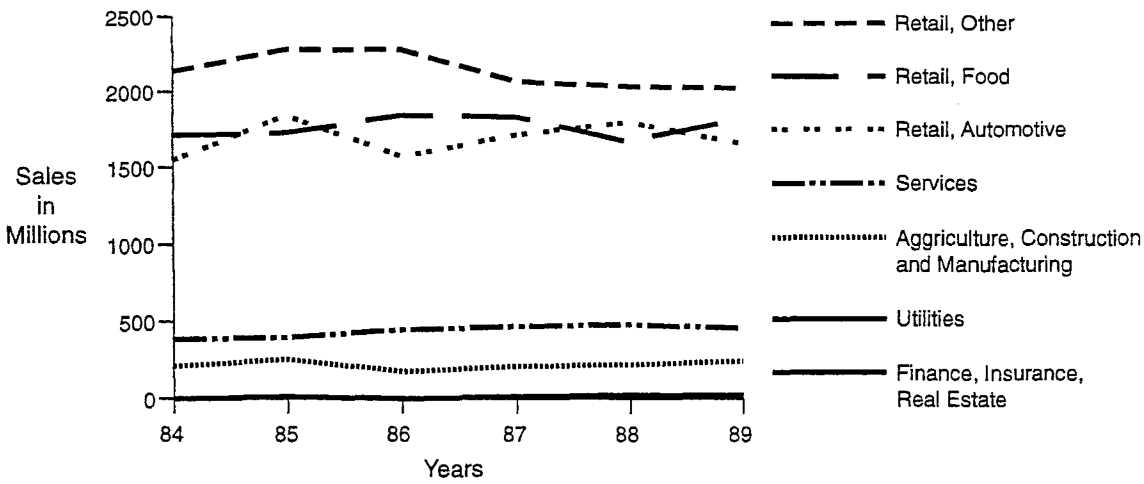


Figure 13. Sales trends before construction—Dallas

Some comments can be drawn from these analyses. First, in the City of Dallas, it can be seen that all three areas had relatively constant sales over the period 1984 to 1989, reflecting the mild but persistent recession that the city encountered during that period. (Again, remember that these data are in constant dollars and actual yearly values are higher.) On U.S. 75, sales held relatively constant apart from the general retail group, which showed strong upward growth during the period. Of the control group, a different retailing sector (food) showed this type of trend but, in general, two things can be stated. First, sales in real terms remained relatively constant during the pre-construction period, and second, that retailing was the key business activity in all three areas.

Statistical Analysis. The methodology comprises two basic stages. First, areas within the city are identified, data collected through zip code analysis of State Comptroller data, and trends are then observed in these data. Second, these data are subject to statistical analysis to identify more clearly the impacts of construction on business activities being conducted in those business sectors selected for analysis. This involved predicting sales during construction using historic information supplied by the Comptroller's Office. Then, the predicted data are compared with actual information provided from the same source. Comparing actual to predicted, impacts can be identified as negative, positive, or neutral.

To conduct the analysis, a regression equation was developed for each category in each of the three geographic areas using information collected from the pre-construction period. Sales for the next years were then predicted using the regression equation so developed with confidence intervals given around that prediction, using a confidence level of 90%. This is shown in Figure 14. Then, predicted values were compared with the actual values for each specific year. If the actual values lay between the limits of the confidence interval, the expected value was regarded as statistically similar to the actual value. Additionally, if the actual value was greater than the upper limit, the actual value was statistically greater than the expected value. On the other hand, if the value lay below the lower limit, then it was regarded as statistically less than the expected value. As shown in Figure 14, the predicted value is compared with a value that is similar (A), greater (B), and lower (C). Regression analysis was developed using Microsoft Excel and 18 out of 21 possible equations were produced, deriving predictions that could be used to compare predicted with actual data after the NCE construction began. The three equations that could not be produced were attributable to the Comptroller's rule of not releasing data if there are less than three businesses per zip code report.

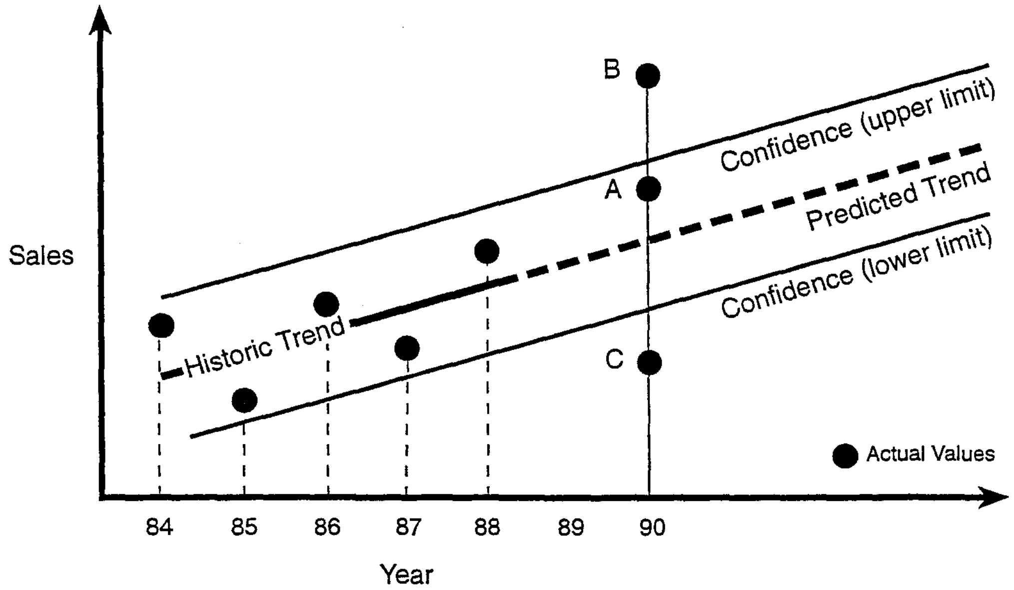


Figure 14. Statistical Methodology

The regression equations were used to create predicted values for the years 1991 to 1993. Construction on the NCE began in mid-1990, so this year was excluded because of the impact this would have on the Comptroller's data. Some businesses did not always report information per quarter and total their earnings in the fourth quarter. This introduces biases into the analysis and it was decided to concentrate on those full years for which data could be collected after the construction began.

Tables 4, 5, and 6 give results of the analysis for the years 1991 through 1993. It can be seen that there is no clear evidence that the construction had an adverse impact on sales. Overall sales in the Dallas metropolitan area generally grew in each of the three years, and the comparisons between the project area and the control group show roughly similar performances. Therefore, even in the early stages of construction when the disruption is at its peak, it would seem that the work was undertaken in a way which did not catastrophically affect overall sales in the major sensitive retailing areas.

Table 4. 1991 Results

Division	Year	t = 10%	Dallas Actual vs. Predicted	U.S. 75 Actual vs. Predicted	U.S. 183 Actual vs. Predicted
Agriculture, Construction, Manufacturing	1991	2.015	Greater	Greater	Greater
Utilities	1991	2.015	Similar	N/A	N/A
Retail, Other	1991	2.015	Greater	Similar	Lower
Retail, Food	1991	2.015	Similar	Similar	Similar
Retail, Auto	1991	2.015	Greater	Lower	Similar
Financial, Insurance, Real Estate	1991	2.015	Similar	N/A	N/A
Services	1991	2.015	Greater	Similar	Lower

Table 5. 1992 Results

Division	Year	t = 10%	Dallas Actual vs. Predicted	U.S. 75 Actual vs. Predicted	U.S. 183 Actual vs. Predicted
Agriculture, Construction, Manufacturing	1992	2.015	Greater	Greater	Greater
Utilities	1992	2.015	Similar	N/A	N/A
Retail, Other	1992	2.015	Greater	Similar	Lower
Retail, Food	1992	2.015	Greater	Similar	Similar
Retail, Auto	1992	2.015	Greater	Similar	Similar
Financial, Insurance, Real Estate	1992	2.015	Lower	N/A	N/A
Services	1992	2.015	Similar	Similar	Lower

Table 6. 1993 Results

Division	Year	t = 10%	Dallas Actual vs. Predicted	U.S. 75 Actual vs. Predicted	U.S. 183 Actual vs. Predicted
Agriculture, Construction, Manufacturing	1993	2.015	Greater	Greater	Greater
Utilities	1993	2.015	Lower	N/A	N/A
Retail, Other	1993	2.015	Greater	Similar	Similar
Retail, Food	1993	2.015	Greater	Similar	Similar
Retail, Auto	1993	2.015	Greater	Greater	Similar
Financial, Insurance, Real Estate	1993	2.015	Lower	N/A	N/A
Services	1993	2.015	Similar	Similar	Lower

Table 7 shows a business activity comparison between the project and the control group for the period 1991 through 1993. Again, there is little statistical evidence to pinpoint a general negative impact on sales related to the construction period.

Table 7. NCE control area comparison

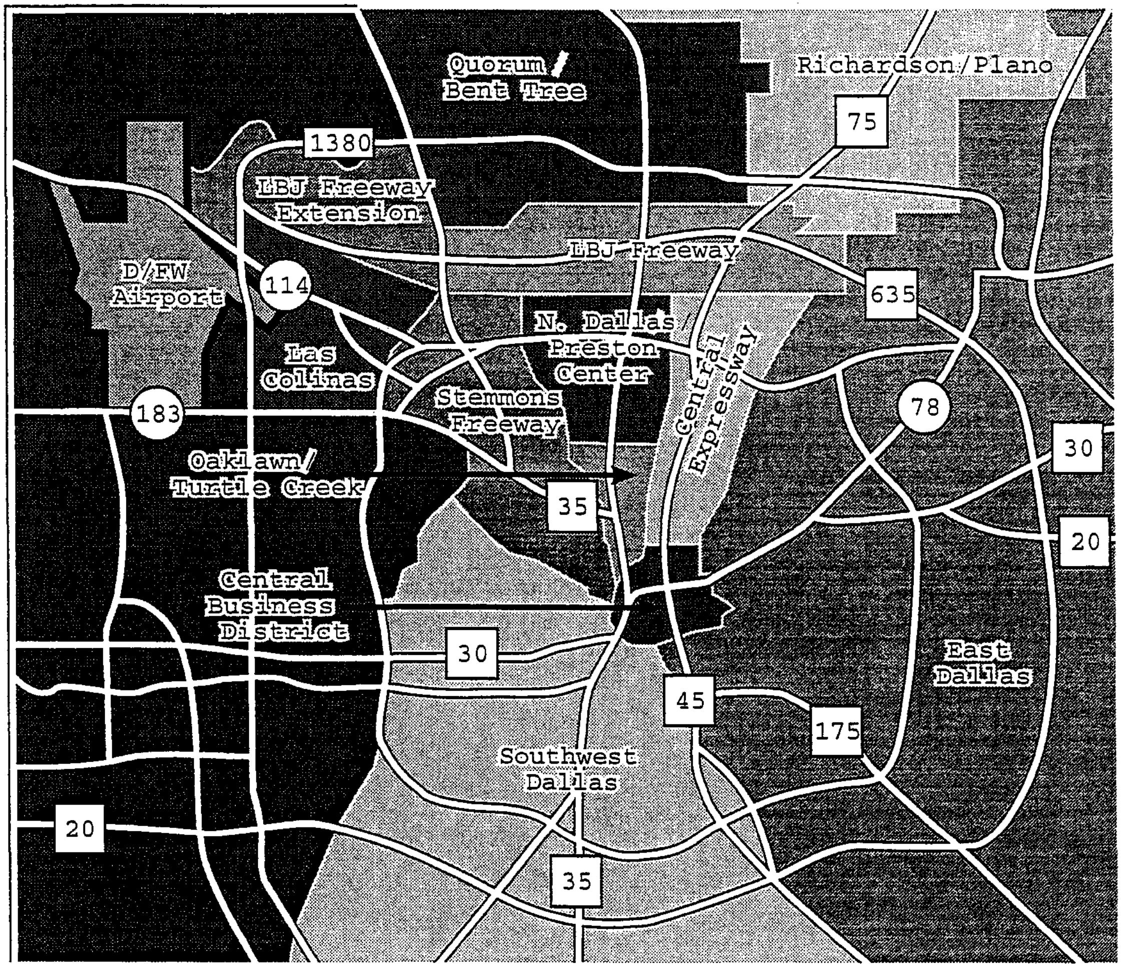
Sector	Year		
	1991	1992	1993
Agriculture, Construction, Manufacturing	No effect	No effect	No effect
Utilities	N/A	N/A	N/A
Retail, Other	Positive	Positive	No Effect
Retail, Food	No Effect	No Effect	No Effect
Retail, Auto	Negative	No Effect	Positive
Financial, Insurance, Real Estate	N/A	N/A	N/A
Services	Positive	Positive	Positive

These results should be regarded as preliminary and require further investigation which will be part of future study activities. It is hoped that they will be strengthened specifically by collecting more data which will allow greater statistical validity. However, the preliminary results indicate that, in general, there is little evidence for a catastrophic decline in sales in any of the major retail and business activities known to be sensitive to construction activities along the NCE project during the years 1991 through 1993. It is almost certain that some businesses were affected and either moved or closed. It is also known that new businesses opened in the hope of capitalizing on the enhanced economic environment that would be created once the project was complete. It would appear that the economic success of a business is more dependent on the general economic health of the metropolitan area than on the negative impacts of temporary actions such as construction activities. It is noted that sales were relatively flat in the pre-construction period due to the mild recession that Dallas was experiencing. In the early 1990's, the economy grew and this is reflected in the positive growth of most indicators. This does not mean that construction is beneficial to businesses, but that overall economic health is more important than construction activity. If the city economy is strong, people will continue to purchase services and this is reflected in the three sets of data analyzed in this preliminary exercise. Further work will be undertaken to collect those data not available during the preliminary phase, and results will be given in a later report.

The North Central Expressway Commercial Real Estate Market

The health of the commercial real estate market paralleling any urban highway project is another indicator of how the reconstruction is impacting the community. As with other business activities, the general consensus is that the greater the duration and complexity of construction, the worse the impact on commercial letting. An active construction zone is generally considered an unattractive place to work near, and represents an access encumbrance for employees and customers alike. However, as noted previously, the economy in the immediate area generally quickly improves once the construction is complete. The issue then focuses on timing, on the decision to move into the area, and on whether to purchase or lease commercial space. Taking into consideration all influences, at some point businesses will determine whether improvements made to the highway will result in improved potential for commercial success within a reasonable time and begin moving into the area. The perceived potential dictates the quantity and timing of the level of investment within the affected area.

Figure 15 shows the various office building sectors within the greater Dallas area. Statistics on absorption, occupancy, and rental rates for multi-tenant office buildings are updated by commercial property realtors on a quarterly basis. Since 1988, the total inventory of multi-office floor space has remained relatively constant in the Dallas market area (Table 8).



Source (Ref 11)

Figure 15. Business sectors for Dallas, Texas

Table 8. Dallas multi-tenant office market inventory comparison (sq. ft x 10^6)

Sector	1988	1989	1990	1991	1992	1993	1994	1995	1996
CBD	29.81	29.73	29.93	29.87	29.93	29.33	29.34	29.40	29.37
Central Expressway	10.75	10.75	10.80	10.80	10.76	10.75	10.75	10.74	10.74
N Dallas/Preston Ctr.	2.78	2.78	2.79	2.80	2.81	2.81	2.81	2.81	2.82
Oak Lawn/Turtle Crk.	6.93	7.10	7.19	7.10	7.05	7.01	6.98	7.05	7.35
Stemmons Freeway	9.54	9.56	9.60	9.63	9.56	9.57	9.57	9.58	9.45
Southwest Dallas	0.88	0.88	0.84	0.87	0.87	0.87	0.89	0.89	0.83
LBJ Freeway	19.85	19.68	19.93	19.92	19.88	19.88	19.89	19.69	19.87
East Dallas	2.42	2.42	2.44	2.42	2.38	2.27	2.26	2.27	2.26
Las Colinas	11.17	11.18	11.18	11.18	11.19	11.21	11.26	11.24	11.32
Quorum/Bent Tree	12.83	12.85	12.91	12.74	12.70	12.71	12.71	12.85	12.85
Richardson/Plano	7.80	7.74	7.71	7.75	7.73	7.73	7.73	7.78	7.67
LBJ ext./DFW Freprt	1.70	2.21	2.11	2.12	2.11	2.11	2.11	2.11	2.11
Total	116.46	116.88	117.43	117.20	116.97	116.25	116.30	116.41	116.64

The Dallas metropolitan area began experiencing an economic slow-down in the mid-1980's. One indicator of this was the decreasing absorption rate in every sector of the metropolitan area. Absorption is a term used to describe the reduction of unused floor space through the leasing process. The low point for the NCE appears to be in the 1991-1992 time frame (Fig 16) and construction activities, which began in mid-1990, may have exacerbated the downward trend in occupancy and rental rates.

Since 1991, the NCE market has seen a sustained resurgence in absorption, occupancy, and rental rates. The NCE market has had positive absorption rates for the last four years and in 1996 it was the second highest of all sectors in the city. Occupancy , which was 10% below the city average in 1991, was 4% above the average of 83% in 1996 (Fig 17). Finally, rental rates which were about $1.20 per square foot below the average in 1991 were just $0.55 per square foot below the average in 1996 (Fig 18). It should be noted that the rates provided are not indexed to any one year and are the average of rates quoted within the designated annual period.

These statistics reflect renewed investor confidence. Indications are that investors are realizing that once completed, the expressway will be the premiere major arterial in the region, and are willing to suffer some loss in revenue now in exchange for choice procurements along what will be a revitalized and critical link. Because the corridor adjoins every other major market region in greater Dallas, businesses which desire to improve their location and visibility are vying for select acquisition while choices can still be made.

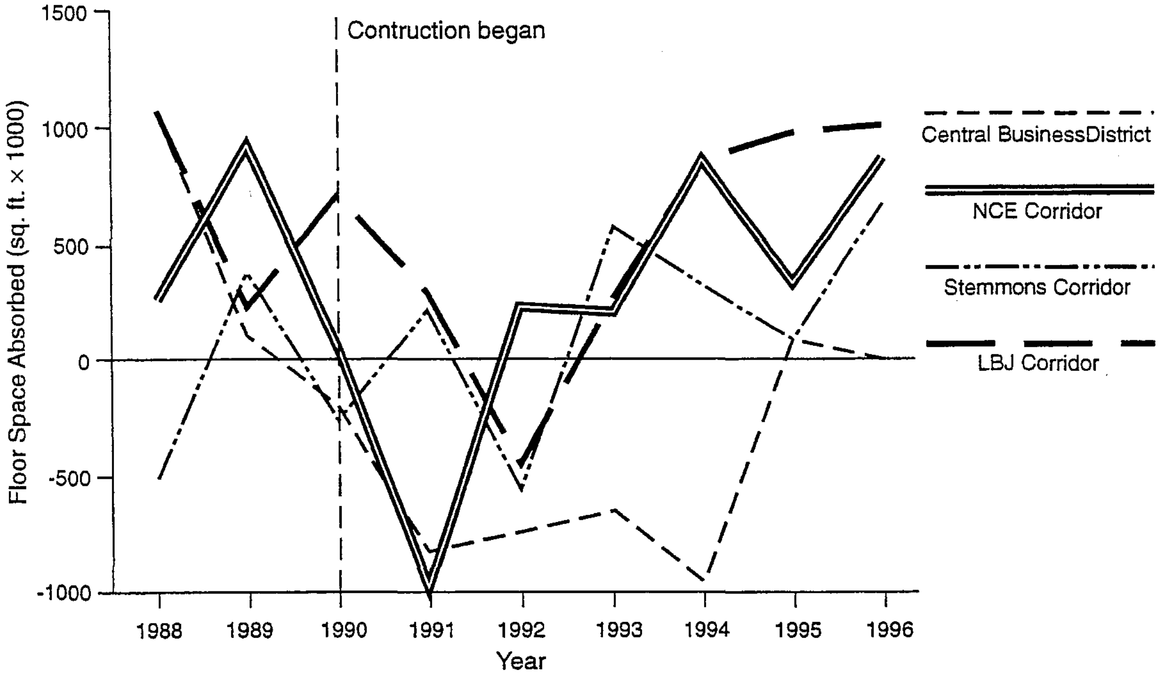


Figure 16. Absorption rates (Ref 11)

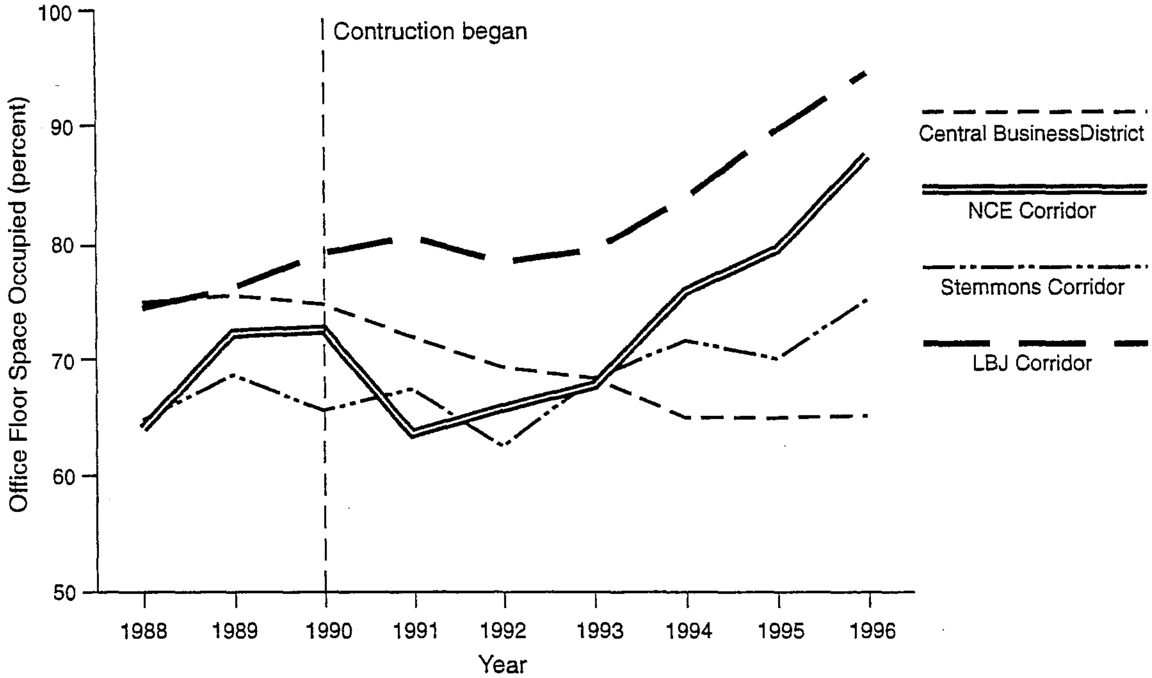


Figure 17. Occupation rates (Ref 11)

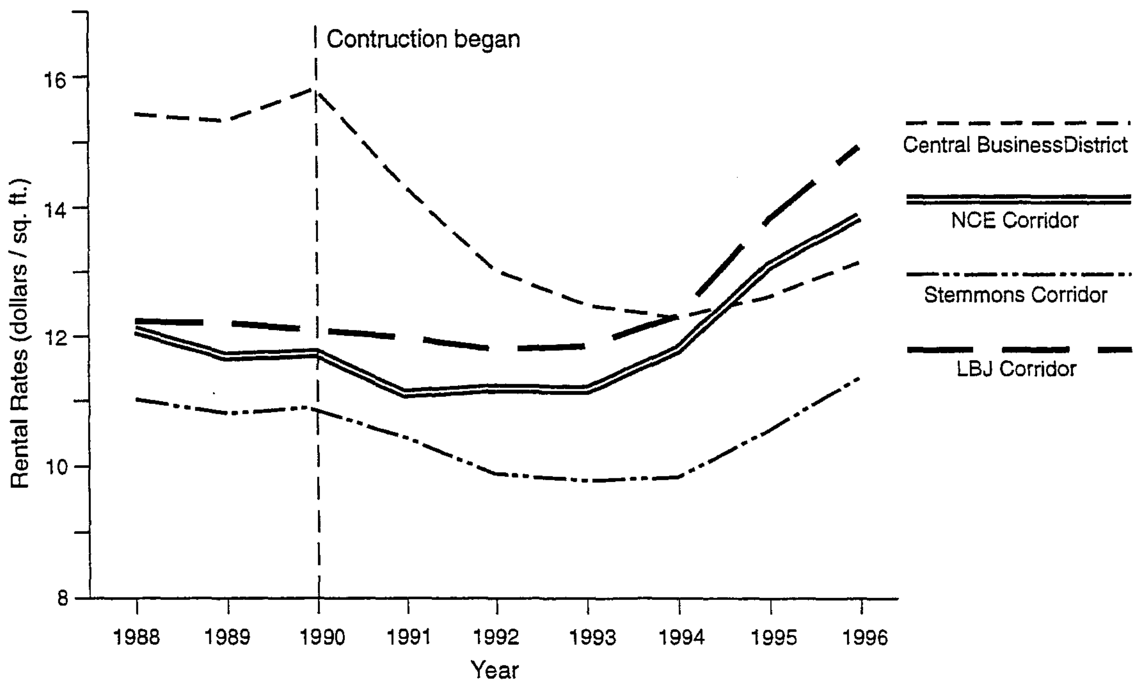


Figure 18. Rental rates (Ref 11)

CONCLUSIONS AND RECOMMENDATIONS

The reconstruction of the Dallas North Central Expressway is one of the largest, most complex, and expensive urban highway projects undertaken in Texas. And because work had to be undertaken while the arterial remained in use and abutting businesses stayed open, it was recognized that the work could be highly disruptive to both users and those working, living, and transacting business in the catchment area. However, this study has shown that the business impacts were not as great as might have been expected. In part, this is due to the special nature of the project which, when complete, will be a highly desirable urban area in the Dallas metropolitan region. This has tended to induce businesses to stay in or move to the area and wait for the significant improvements that the project will yield. However, the study shows that the most important action was the deliberate decision of TxDOT to bring all stakeholders together; businesses, communities, city authorities, transit, resident groups, contractor, and TxDOT, to develop special programs to mitigate the adverse construction impacts. In short, planning has reduced the impacts to tolerable levels for the majority of businesses.

The research study undertaken to measure the business impacts comprised four elements:

a. a questionnaire administered to business personnel along the construction site perimeters,
b. a survey of businesses that had closed and opened in the catchment area,
c. an analysis of business sales data reported to the Texas State Comptroller, and
d. an examination of multi-tenant occupancy rates for office space in the catchment area.

The main conclusions and recommendations to be drawn from these four evaluations are now presented.

a. Critical role of the North Central Mobility Task Force (NCMTF). The NCMTF has been instrumental in alleviating many of the adverse user and business impacts that might have been associated with project work. Surveys indicated an effective link between those carrying out the work and those expected to be adversely affected from engineering activities. Communication has been conducted through a variety of sources including flyers, television and radio material, newspaper articles, visits to businesses by contractor and TxDOT staff, and regular meetings within the different construction sectors where TxDOT engineers describe planned construction and answer questions from business people in the audience. The recommendation drawn from this conclusion is similar to that made in Houston; that the dedication of an officer or group similar to the NCMTF for large urban reconstruction projects will definitely result in an improved mitigation process and a greater understanding in the business community about work undertaken and objectives sought in the work.

b. Frontage road construction. In terms of design, the Dallas results confirm those first identified in Houston, which is that on large urban projects, it is critical to develop a program which expedites the construction of frontage roads. This is particularly true where the highway links to multi-occupancy buildings, large corporate offices, shopping malls, and areas where there is substantial business activity. Expediting the frontage road construction allows less interference with business activities, and also allows the development of alternative traffic plans on main lane and overpass construction. Surveys indicated that there was generally little impact on driveway access and parking, and most business respondents agreed that the completion of the frontage roads was perceived as helping all aspects of commercial activity. The recommendation to be made from this conclusion is that frontage roads should be constructed first, and that the construction should be expedited with close communication maintained with those most affected by the work.

c. Sales impacts less than predicted. Previous studies had suggested that construction work would have substantial impact on a wide range of businesses, but this did not happen. Surveys showed that some retail activities were adversely impacted, but that generally the retail activities showed the same trends to those in control groups and the overall metropolitan area. This suggests that sales for the majority of businesses are more dependent on the overall level in the economy rather than specific construction projects. In addition, data on the business surveys showed more businesses actually opened than closed along the frontage areas. The recommendation from this conclusion is that, first, a survey of businesses be undertaken in the area of a major urban project. Those most likely to be affected by construction can then be identified and specific actions developed with the management of these businesses. At the time of initial construction, when interest in the project is highest, the research results should be stated in order to calm fears of the individuals living and working near the work area. And second, the ability of those affected by construction to report to a task force or communications officer, should the problems persist, is a benefit that also needs to be emphasized.

d. Business impacts were localized. Results from the questionnaire show that the construction activities were highly selective in terms of negative impacts. More than half of business startups and failures were relatively small retail stores. This is shown in the statistical analysis of the work collected from the State Comptroller's Office and in the results of the previous Houston study. It would seem that a rather small and narrowly defined number of retail categories are sensitive to construction activity and that the adverse impacts to these can be mitigated by planning, traffic control, expedited frontage roads, and other activities. The recommendation is to clearly identify the more sensitive business activities in the construction zone and ensure that mitigation activities are undertaken for these businesses.

e. Communication is a learning experience. Research indicates that the communication process on the North Central Expressway has improved with each successive construction section. This suggests that the process is iterative and benefits from the experience gained on previous sections. The second survey suggested an improved communication level on the project and cooperation between DART, TxDOT, and all the businesses. The recommendation is that the issue of communication should be explicitly recognized in any large, urban project and should be a dynamic process taking advantage of all possible improvements in media. In this spirit, we suggest that a Web site detailing many of the salient characteristics of the project, together with major changes in traffic handling, bridge demolition, and other key matters be put on the Internet for access by businesses along the route.

As noted in the introduction, the CTR team provided assistance to TxDOT on both traffic and construction related issues. The next chapter focuses on traffic analyses undertaken to expedite mobility through the construction zones for all highway users.

CHAPTER 3.

CONSTRUCTION IMPACT ON TRAFFIC FLOWS

Reconstructing a major urban highway is potentially disruptive to normal traffic flow. Traffic on the NCE has exceeded the original design capacity since 1971 and accommodating heavy main lane and cross street traffic volumes throughout reconstruction is a vital concern. Figure 19 shows average hourly volume trends for selected S1 and S-2 routes using data collected by the TTI (Ref 12). All data were collected in October 1994 as part of a study in which data were collected every six months. At the time of collection, all locations were two traffic lanes wide in each direction. Diversion of traffic for construction purposes in high volume environments such as the NCE projects require special planning to prevent total gridlock. The plethora of activity, detours, and special barricades and signs within the construction area tend to make traffic flow less uniform and increase the level of driver confusion, contributing to an increase in overall potential for accidents. Identification and rapid correction of potentially hazardous conditions are in the interest of both the construction authority and the public.

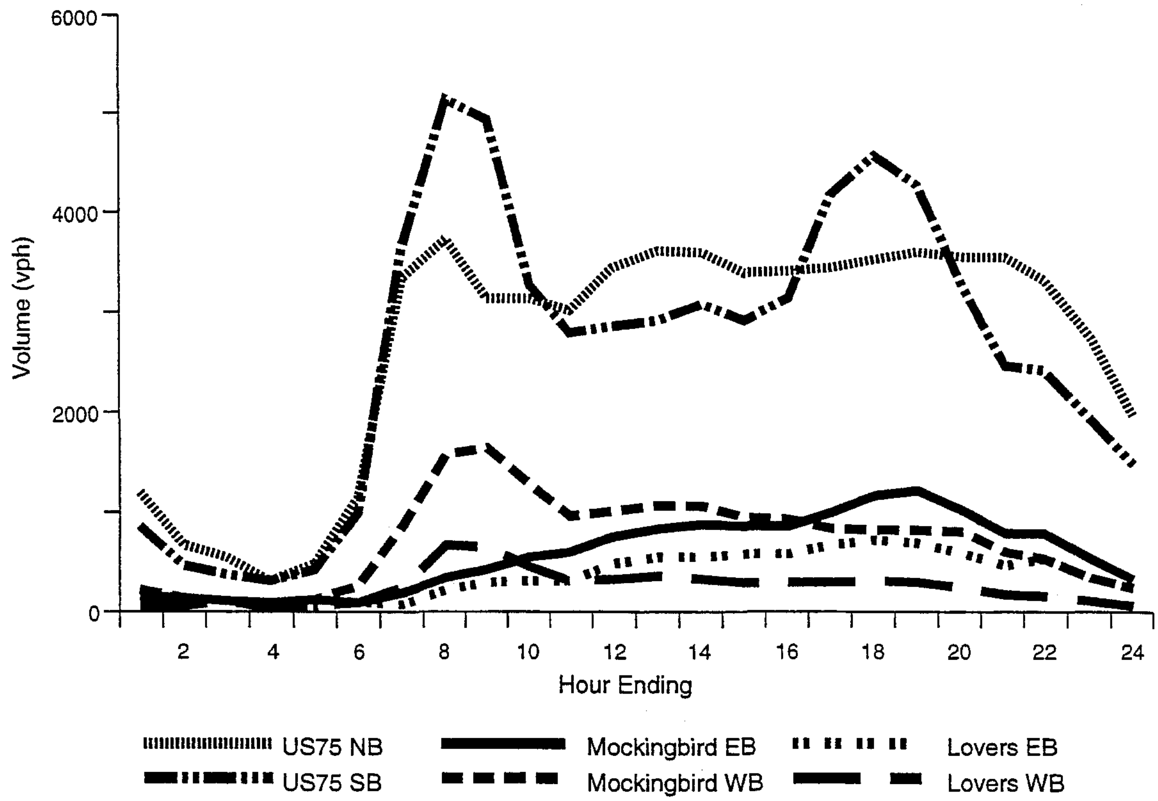


Figure 19. Traffic volumes for NCE and some important cross-streets

CASE STUDY OF LOVERS LANE NORTH-BOUND EXIT RAMP

This study having been documented extensively (Ref 13), TxDOT requested assistance in improving the safety of the north-bound Lovers Lane exit ramp in the summer of 1994. Because of on-going construction of the frontage road, the single-lane ramp was very short (about 61 m [200 ft]), and merged immediately into a single lane with the detour pavement (temporary) frontage road (Fig 20). The ramp was slightly depressed with respect to the frontage road; in addition, low profile concrete traffic barriers lined the left side of the frontage road making it difficult for frontage road motorists to spot ramp traffic. Unsafe driver behavior was also practiced occasionally when some motorists would drive across the non-curbed north gore to enter the expressway, essentially using the off-ramp as an on-ramp. A "stop" sign had already been placed about 26 feet from the merge point; related caution signs were in place upstream.

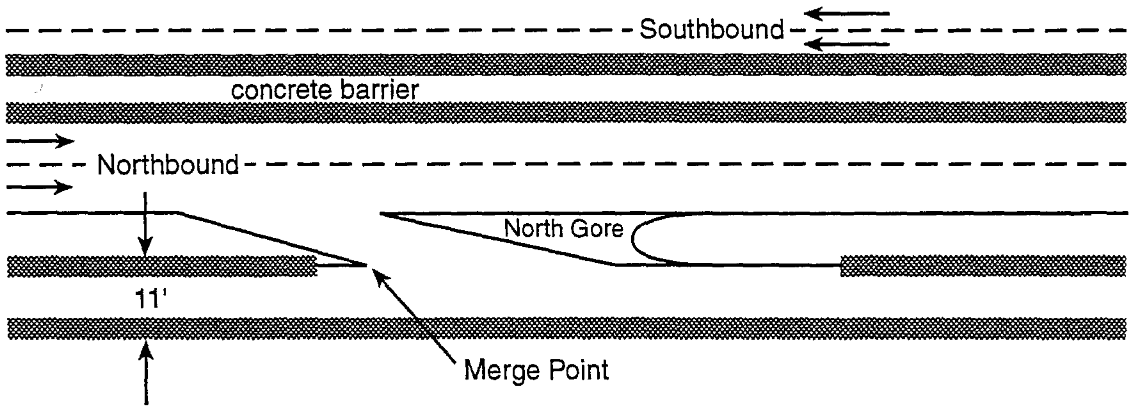


Fig. 20. Lovers Lane exit ramp study area

A CTR researcher video-taped driver behavior from an 11th floor office window overlooking the site. He noted that less than 50% of all frontage road traffic actually stopped at the sign, or slightly downstream from the sign at a better vantage point for spotting exit ramp traffic. The five leading contributors to conflict situations were: 1) the speed difference between ramp and frontage road traffic, 2) violations involving failure to stop or yield to ramp traffic, 3) ramp traffic exceeding the posted ramp speed limit, 4) frontage road traffic stopping too close to the merge point, causing a perceived lateral clearance problem for ramp traffic, and 5) violations involving use of the exit ramp as an entrance ramp. Recommendations by the researcher which were enacted were limited to placing flexible delineator posts in the gore area to prevent illegal use of the gore as an on-ramp, and repositioning the "stop" sign slightly more forward in conjunction with applying a pavement "stop bar," which better defined the stop point and allowed improved observation of ramp traffic. Following implementation of the first recommendation, a follow-up video session was conducted. It was noted that wrongful entry onto the NCE appeared to have been eliminated. Also, improved heeding of the "stop" sign was noted, a probable consequence of greater caution resulting from frontage road motorists seeing the delineators. The second recommendation was executed at a later date; no further observations of the ramp were made. Following completion of the permanent outside (two) frontage road lanes in April 1995, this dangerous merge point has been made considerably safer by allowing the ramp traffic a dedicated lane. Frontage road traffic is still required to yield to the ramp traffic.

RESEARCH TOOLS

Instrumented Vehicle

In order to assess the impacts of construction on traffic flow, CTR utilized an instrumented vehicle. The instrumentation for the vehicle is produced by JAMAR Technologies, Inc., and the software used to analyze the data collected by the vehicle is called PC Travel. The hardware attaches directly to the odometer of the vehicle. The data are collected and then dumped into a PC for analysis. The following data are available:

a. Length of each link,
b. Travel time of each link,
c. Number of stops on each link,
d. Average speed on each link,
e. Time below three different speeds,
r. Fuel use for each link,
g. Speed-vs-Distance plots,
h. Time-vs-Distance plots,
i. Speed-vs-Time plots.

The vehicle is useful for quickly determining troubled spots in the construction zone by viewing the speed profile of the main lanes and looking for dips in speed. These dips generally show where vehicles from an entrance ramp are merging with the mainline, but they may also show where the traveling public views a particular curve as dangerous at normal speeds. It is often useful to perform an analysis before and after traffic is switched to a detour.

The instrumented vehicle is also used to calibrate computer models. The following sections describe such a calibration for a computer model developed by The University of Texas at Arlington.

TEMPO: A Traffic Diversion Simulation Model

This particular area of study first received attention once it was learned that the TEMPO software package, developed at The University of Texas at Arlington, was capable of predicting traffic flow diversion patterns resulting from closure of one or more links of a previously "mapped" highway network (Ref 14). This software was originally developed to assist transportation officials in management of the transportation network following major earthquakes. "Mapping" consists of electronic cataloguing of route nodes and links using a coordinate system similar to GIS mapping. The program runs continuously in a graphics interactive mode.

TEMPO was found to have immediate application to traffic control situations related to the NCE reconstruction. During the course of the reconstruction, the number of lanes available for traffic will vary; bridges will be taken out of service according to a programmed sequence, completely eliminating these links for extended periods of time. In addition to programmed closures, a number of situations have arisen (and can be presumed to continue to arise) requiring temporary lane closures. What happens to diverted traffic had rarely received analytical attention; the mitigation measures previously described were the primary measures taken to minimize likely adverse effects of diverting traffic. The TEMPO software provides the capability to quickly analyze the diverted traffic flow ramifications of proposed closures.

Constructing the Transportation Network for the North Central Corridor. The first step toward utilizing the TEMPO software for the NCE reconstruction project was to devise the transportation network for the area affected by construction activities. The TEMPO database included an existing Dallas mapped network (Fig 21) and isolated the North Central Corridor. The original network did not include frontage roads, nor were some of the more significant local/collector routes included, especially in the CBD. Amendments included isolating overpasses and adding frontage roads, on-ramps, off-ramps, and streets (Fig 22). Traffic volumes, available lanes, distances, and speed limits for each link were updated, allowing a better portrayal of existing conditions and options available to motorists when overpasses were closed for demolition and reconstruction.

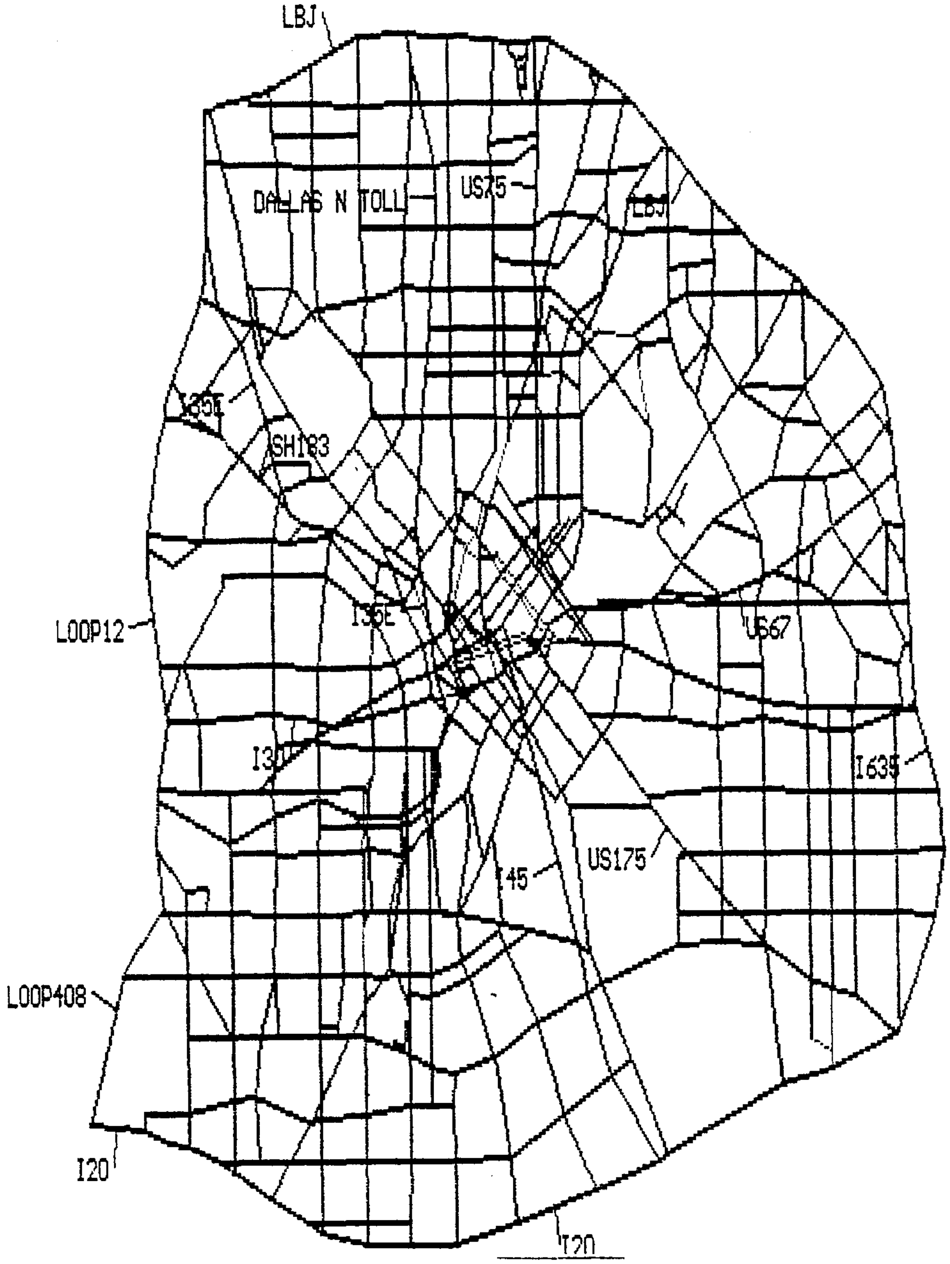


Figure 21. Existing Dallas mapped network isolating the North Central Corridor

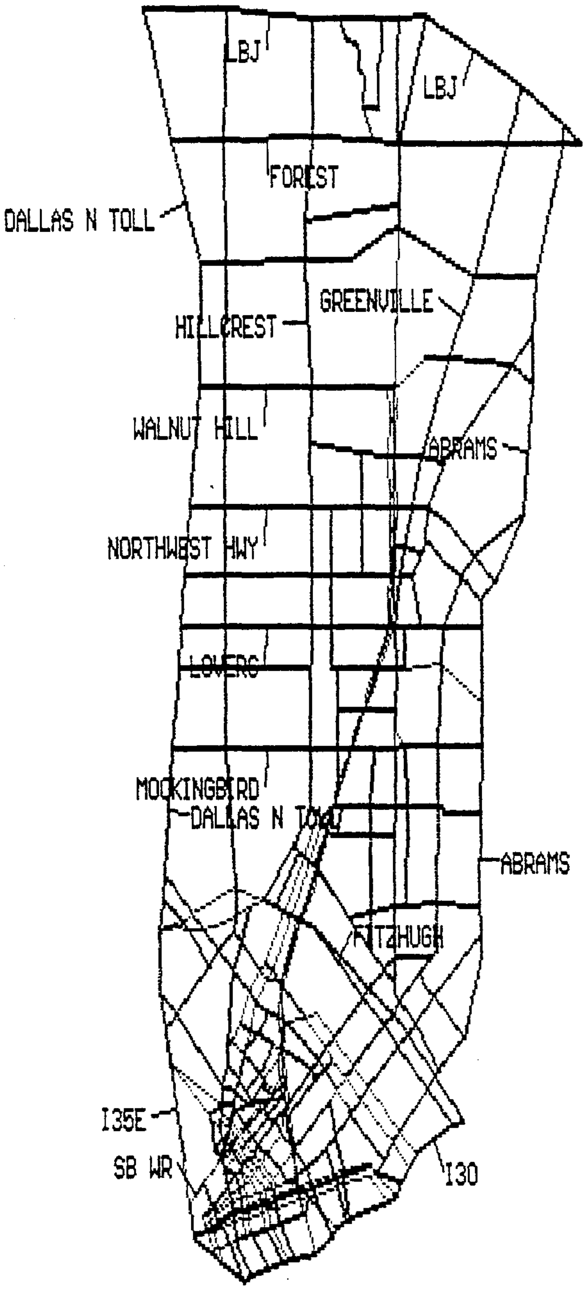


Figure 22. Amended North Central Corridor mapped network

Modification of existing data is accommodated through an editing menu. Exact geometry created by precise positioning of nodes through entry of their "true" coordinates is not necessary to derive credible diversion results. For this model, nodes are added by using zoom controls and a cursor to position the node "approximately" with respect to existing nodes and links. The length of a newly created link is more critical, and is entered independently of any actual geometric distance between applicable node coordinates. The program allows the user to edit/define the following parameters:

For nodes:

node designation (1 - 4 digits),
x-coordinate, and
y-coordinate.

For links:

beginning node,
end node,
street name,
length,
number of directions (1 or 2),
number of lanes (in each direction),
parking allowed (none, 1-side, 2-sides),
speed limit (or other measure of free-flow speed on the link),
capacity (vph per lane), and
total volume (vph per direction - peak hour volumes are generally used).

Three networks were created: one contained a.m. peak volumes, one contained p.m. peak volumes, and one contained estimates of off-peak volumes. The traffic volumes were obtained from the City of Dallas (Ref 15) and TTI (Ref 12). Manual counts were also made for various links. The off-peak volumes were estimated by multiplying the a.m. peak volumes by a correction factor. The correction factor was determined by comparing the a.m. peak volumes and off-peak volumes from TTI (Ref 16, 12). Tables containing these data and plots of the distribution of the factors for the various types of links are shown in Appendix C.

Calibrating the Model. After the networks are created, the model must be calibrated to assure that it is representative of the actual field conditions. This is done by comparing travel times predicted from TEMPO to actual travel times measured with the instrumented vehicle previously mentioned.

The TEMPO model has an option called "Routing" which is run through the "Utilities" menu. The origin and destination nodes are defined and the TEMPO algorithm chooses the shortest path based on two options, shortest distance and shortest travel time. The travel time for these paths is then displayed on the computer screen. Currently, field travel times from seven separate routes (Fig 23) have been recorded during the a.m. peak time period (7:30 a.m. to 9:00 a.m.).

A paired t-test was conducted to determine if there were statistically significant differences between the travel times predicted by TEMPO and those obtained in the field from the instrumented vehicle runs. The null hypothesis states that the travel times predicted by TEMPO are, on the average, statistically equivalent to the travel times recorded in the field. The alternate hypothesis states that the travel times predicted by TEMPO are not statistically equivalent to the travel times obtained from the instrumented vehicle runs.

$H_0: X = \mu$

$H_1: X \neq \mu$

The data used for the paired t-test is shown in Table 9. The values of W were calculated by subtracting the travel times predicted by the model from the travel times recorded in the field.

W = Field Travel Time - Model Travel Time

The formula used to calculate t (calculated) is:

t (calculated) = W(ave)/(s_w //n)

where,

W (ave) = average of W values

s_w = Standard deviation of W values

n = Number of observations

The acceptable value of t was determined by:

t (table) = value from a statistical table (Ref 16), using (n-2) degrees of freedom and $\alpha/2$ = 0.05

If t (calculated) is less than t (table), then H_0 cannot be rejected, and the travel times predicted by TEMPO are not statistically different from the travel times obtained in the field.

As can be seen, the null hypothesis was not rejected. This shows that TEMPO provides reliable travel time estimates for the chosen routes. This is an important result since the TEMPO diversion algorithm relies heavily on travel time estimates for feasible routes connecting various origin-destination pairs. Travel time estimates are essential for the identification of the best alternate routes along an incident or link blockage.

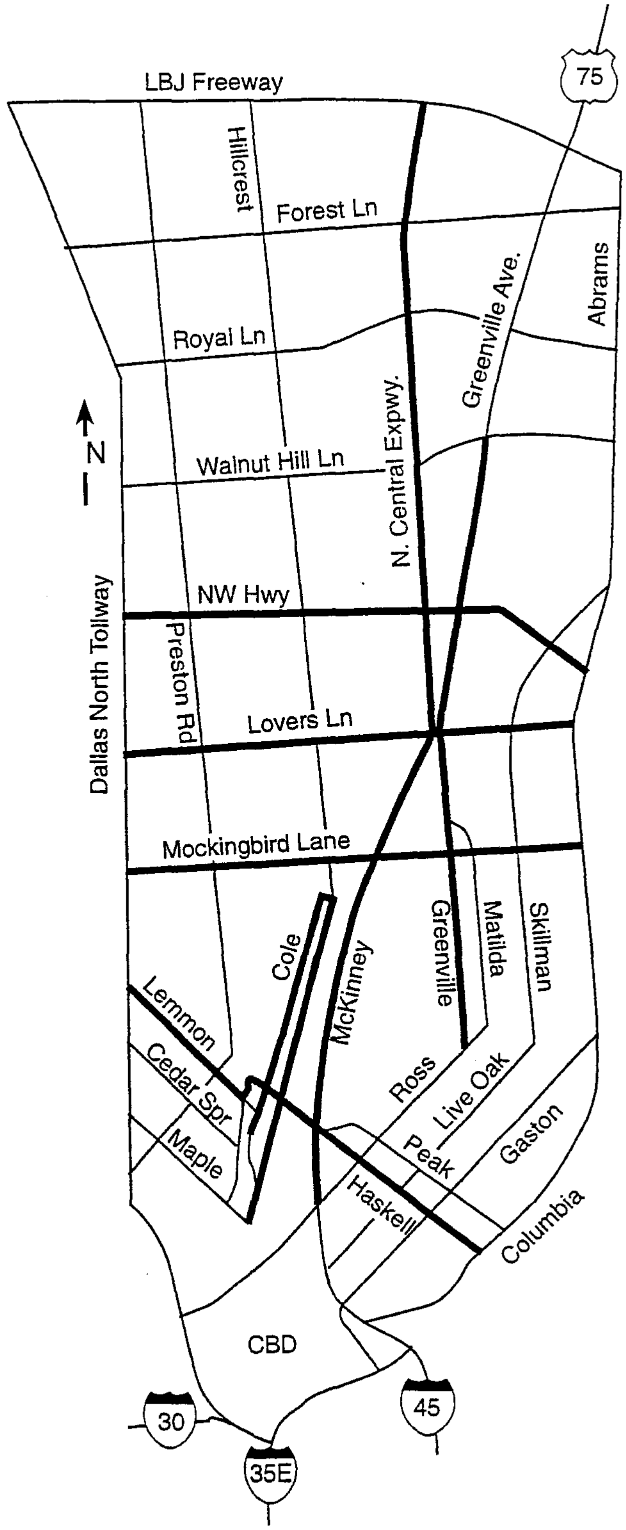


Figure 23. Calibration routes

Table 9. A.M. peak paired t-test

Run Description	Field Travel Time (minutes)	Model Travel Time (minutes)	W (F-M) (minutes)
SB U.S. 75	21.40	22.50	-1.10
SB U.S. 75	22.70	22.50	0.20
SB U.S. 75	24.75	22.50	2.25
SB U.S. 75	25.08	22.50	2.58
NB U.S. 75	21.07	19.50	1.57
NB U.S. 75	21.81	19.50	2.31
NB U.S. 75	19.30	19.50	-0.20
WB Lovers	13.60	16.10	-2.50
WB Lovers	13.60	16.10	-2.50
EB Lovers	10.53	10.50	0.03
EB Lovers	10.22	10.50	-0.28
WB Lemmon	7.88	6.70	1.18
WB Lemmon	6.88	6.70	0.18
EB Lemmon	6.02	5.90	0.12
EB Lemmon	6.63	5.90	0.73
NB Greenville	15.75	12.60	3.15
NB Greenville	13.63	12.60	1.03
NB Greenville	15.78	12.60	3.18
SB Greenville	11.62	14.40	-2.78
SB Greenville	13.58	14.40	-0.82
SB Greenville	13.70	14.40	-0.70
SB Greenville	11.82	14.40	-2.58
WB Mock	12.90	20.30	-7.40
WB Mock	13.92	20.30	-6.38
EB Mock	16.22	10.10	6.12
EB Mock	15.30	10.10	5.20
NB McKinney	9.47	7.30	2.17
NB McKinney	8.77	7.30	1.47
NB McKinney	8.48	7.30	1.18
NB McKinney	8.0	7.30	0.70
SB Cole	5.87	5.60	0.27
SB Cole	6.57	5.60	0.97
SB Cole	6.83	5.60	1.23
SB Cole	6.75	5.60	1.15
WB NW Hwy	8.20	8.70	-0.50
WB NW Hwy	8.90	8.70	0.20
EB NW Hwy	5.98	7.20	-1.22
EB NW Hwy	6.33	7.20	-0.87

$n = 38.00$
$W(ave) = 0.25$
$S_W = 2.57$
t (calculated) $= 0.59$
$t\ (0.05;37) = 1.69$
t (calculated) $< t$ (table) so accept H_0 that the data sets are equal

It is important to realize that the free flow speeds of some routes was adjusted as part of the calibration process. Also, as part of the calibration process, all capacities were adjusted according to the following criteria:

For arterial, frontage roads and ramps:	Capacity = 800 vphpl
For highways that are not grade separated:	Capacity = 1200 vphpl
For highways that are grade separated:	Capacity = 2200 vphpl
For grade separated highways in a construction zone:	Capacity = 2000 vphpl

Currently, work is being done on calibrating TEMPO for the p.m. peak and off-peak networks. In addition, a survey will be administered to examine the possibility of using estimates of user peak hour travel times as a faster method of calibrating the model.

Operating the Diversion Simulation. Once the model is calibrated, diversion simulations can be run through the "Utilities" menu. An "influence area" must first be defined by a chain of perimeter nodes. In determining diversions, TEMPO's algorithm assumes that all trip origins and destinations are located on the previously defined perimeter and any traffic engaging this area from outside the perimeter is "through traffic" and will leave the perimeter at some other point. Therefore, boundary choice for the influence area is extremely important and will affect the outcome of the diversion simulation. The optimum boundary will consist of the nearest major arterials and freeways encompassing the closed roadway links. In addition, one should try to choose links with equal or greater capacity characteristics than those of the closed link(s).

Once the perimeter is established, links are selected for closure and the diversion algorithm is activated by entering the number of steps in incremental assignment (10 steps suggested). Trips previously assigned to links which are now designated "closed" are reassigned to alternative links offering the best available travel times. Options to observe the results of the diversion are then presented; affected links can be designated in terms of those which received an increase in a user-selected minimum volume, or in terms of those which experienced a user-selected minimum volume-to-capacity ratio. Once these choices are entered, the affected links are highlighted on the electronic map. A further option is possible by first pressing "Ctrl," then "S," while holding down the "Ctrl" key. This changes the highlighted links into a series of dashes moving in the direction of the applicable diverted flow. Printouts can be selected which provide a spreadsheet of the affected links, street name, old volume, new volume, new volume-to-capacity ratio, old travel time, and new travel time. In the current version of the program, printouts of the map are not possible without a laser printer, nor can an electronic copy of the spreadsheet be saved, although a hard copy could be obtained.

Testing the Diversion Simulation Option. Verification of the results of the diversion simulation utility is done by performing a diversion simulation with the model and then comparing field data to the predicted volume increases.

The south-bound entrance ramp south of Fitzhugh was closed permanently on April 18, 1997. Two simulations were conducted with the TEMPO model to simulate this closure. The boundaries for the first simulation (Fig 24) were chosen because it is likely that most of the traffic using the ramp will have destinations on IH 35E or I30. In addition, most of the origins will be south of Fitzhugh because motorists north of Fitzhugh will probably use the south-bound entrance ramp south of Knox-Henderson. The boundaries for the second simulation (Fig 25) are the closest arterials to the closed ramp, encompassing a small area surrounding the closure.

The two simulations were done to show the importance of the boundary selection. The primary routes for which TEMPO predicted increased traffic volumes are shown in Figures 26 and 27. These figures indicate that the predictions from TEMPO are vastly different for the different selected boundaries. For example, Figure 26 shows that for the first simulation, TEMPO predicted that most of the traffic would divert along the frontage road and enter the expressway south of Hall Street. Table 10 summarizes information about the links that TEMPO predicted would have volume increases of greater than 50 vehicles. In the second simulation (Fig 27), on the other hand, TEMPO predicted that traffic would follow various routes north in order to enter the expressway by way of the south-bound entrance ramp south of Knox-Henderson.

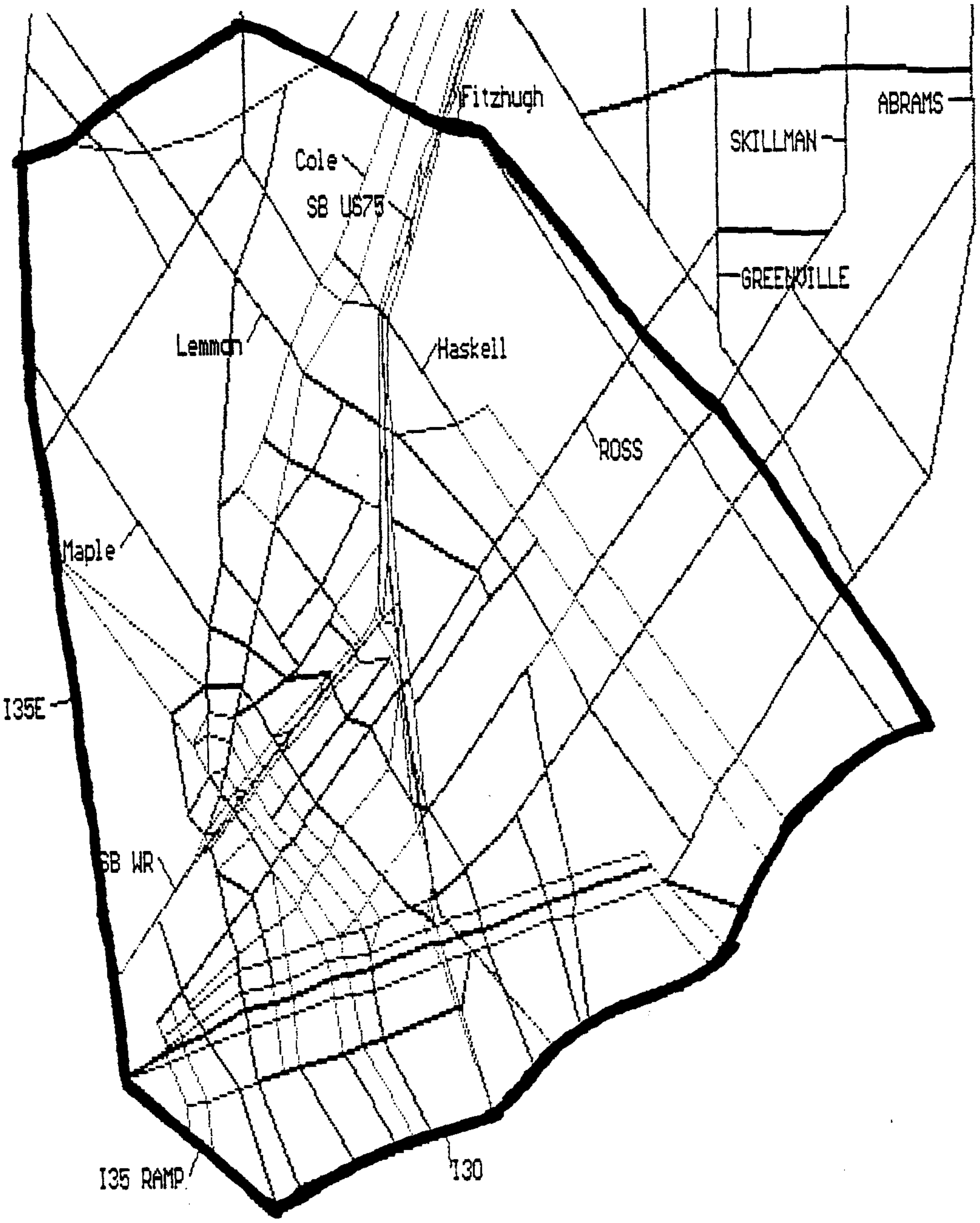


Figure 24. Influence Area 1

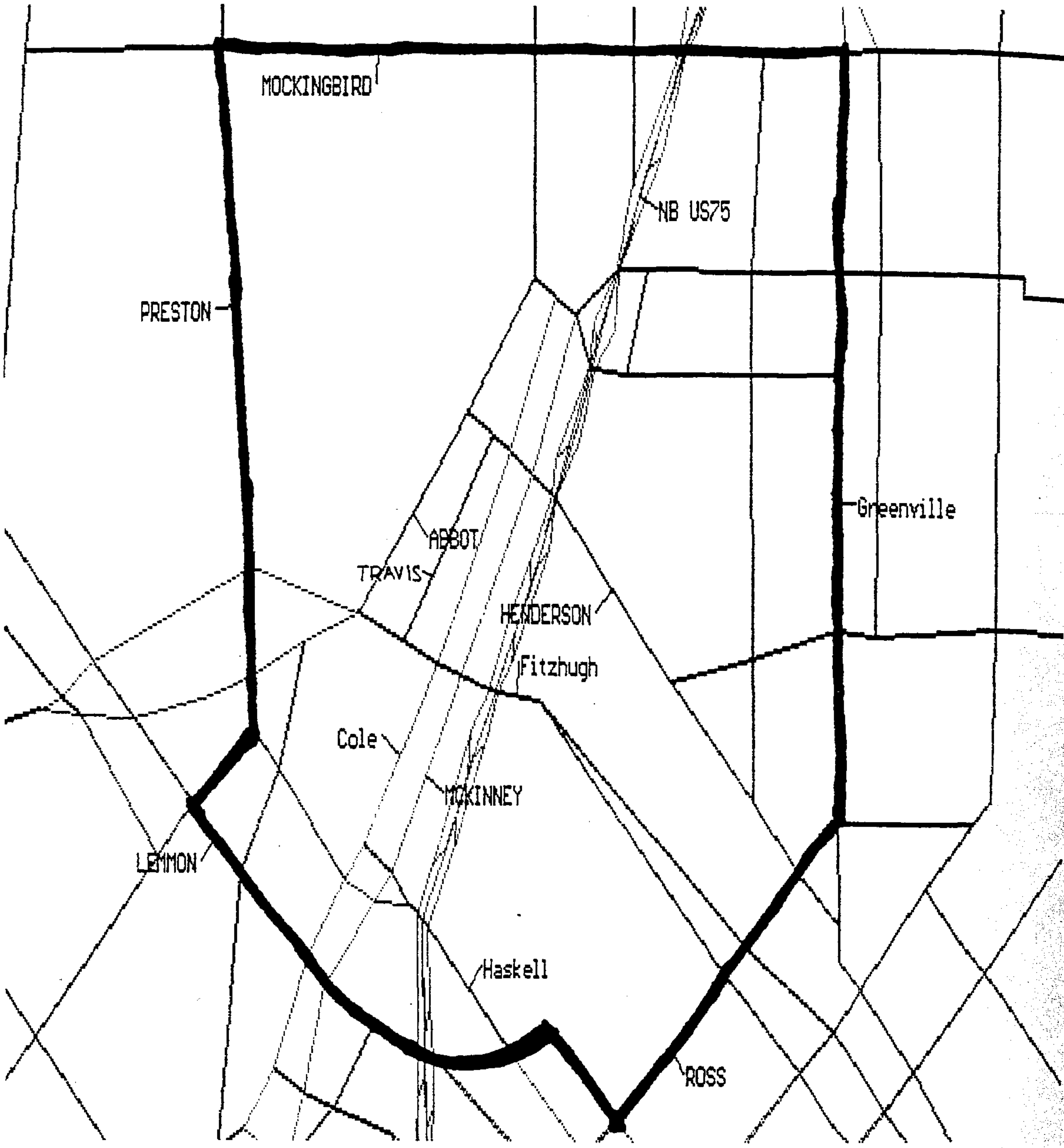


Figure 25. Influence Area 2

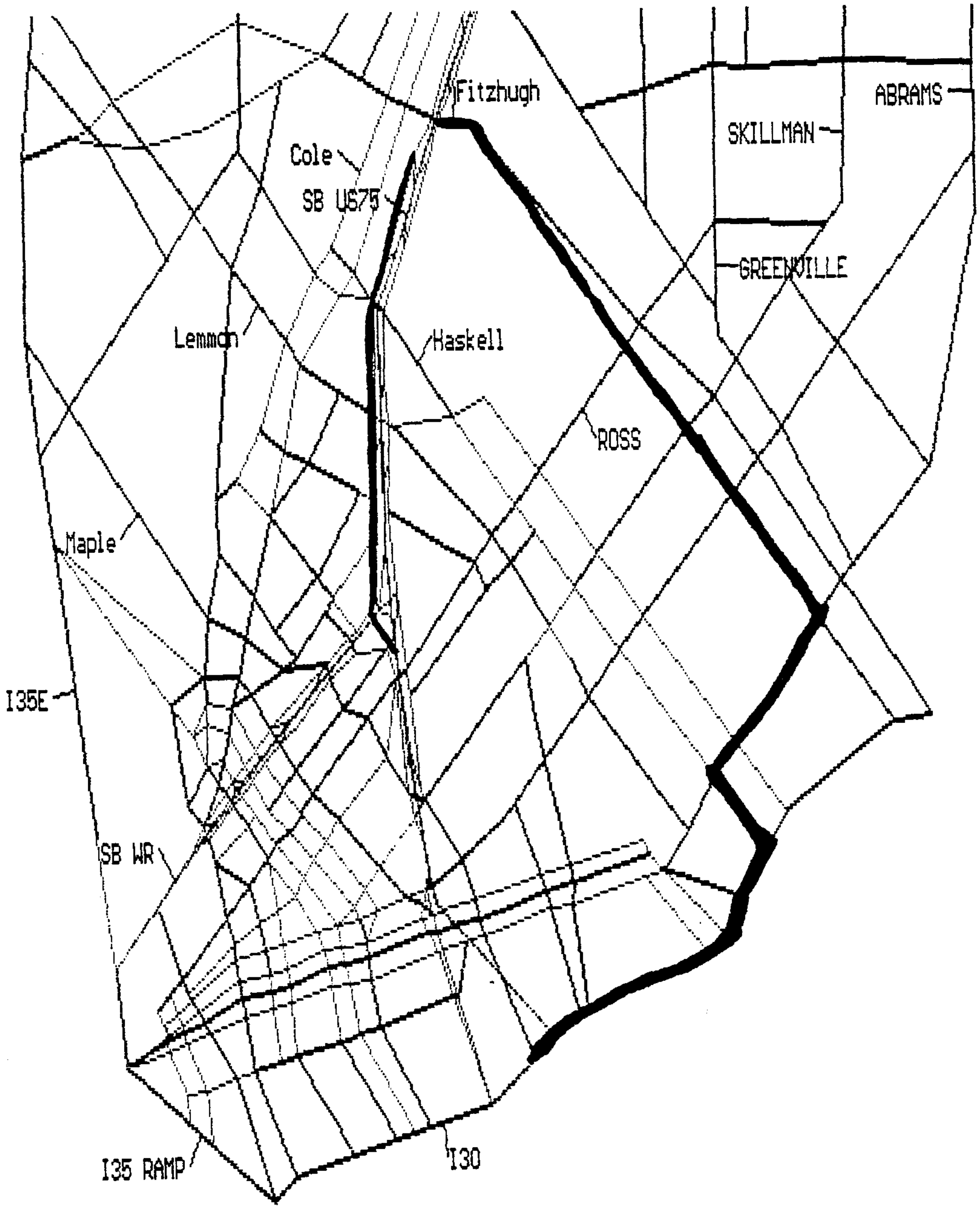


Figure 26. Routes for Simulation 1

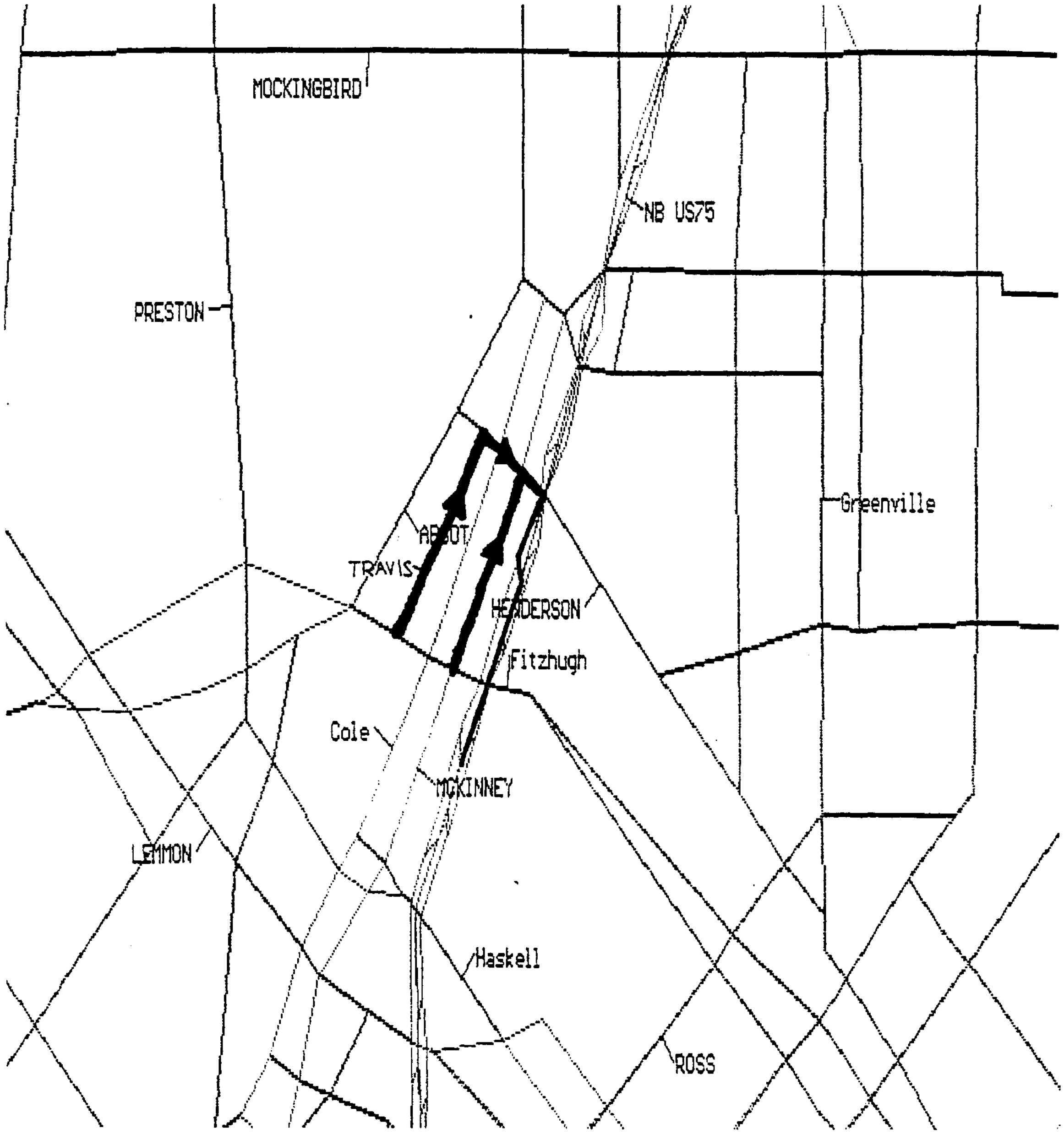


Figure 27. Routes for Simulation 2

Table 10. Data From Simulation 1

Org. Node	Dst. Node	Street Name	Old Vol vph	New Vol vph	New Vol/CP	Old Time mm:ss	New Time mm:ss
308	309	SBFR U.S. 75	600	815	0.509	0:52	0:58
309	4011	SBFR U.S. 75	600	815	0.509	0:50	0:56
314	316	Fitzhugh	150	254	0.318	0:30	0:35
316	317	Fitzhugh	150	254	0.318	0:11	0:13
317	318	Fitzhugh	150	254	0.318	0:11	0:13
318	508	Fitzhugh	150	254	0.318	0:46	0:52
334	314	Fitzhugh	190	294	0.367	1:23	1:34
335	4109	SBFR	750	615	0.384	0:20	0:19
489	488	I30	4000	4104	0.466	0:10	0:10
503	489	I30	4000	4104	0.466	0:46	0:47
504	503	I30	4000	4104	0.466	0:07	0:07
505	504	I30	4000	4104	0.466	0:10	0:10
506	505	I30	4000	4104	0.466	0:15	0:15
508	509	Main	360	464	0.290	0:48	0:51
509	510	Main	240	344	0.215	0:13	0:13
510	506	Haskel	264	368	0.153	0:23	0:24
4011	4023	U.S. 75 FR	600	815	0.509	0:16	0:18
4023	4210	U.S. 75 FR	500	715	0.447	0:16	0:19
4104	334	Fitzhugh	520	624	0.780	0:14	0:16
4104	335	Fitzhugh OP	1001	939	1.174	0:07	0:06
4109	4115	U.S. 75 Ramp	350	0	0.000	0:18	N/A
4109	4110	SBFR	400	615	0.384	0:32	0:36
4110	308	SBFR	750	965	0.603	0:47	0:53
4115	4116	SB U.S. 75	4250	3899	0.975	0:30	0:28
4116	4117	SB U.S. 75	4250	3899	0.975	0:20	0:18
4117	4130	SB U.S. 75	4250	3899	0.975	1:32	1:26
4130	4240	SB U.S. 75	4000	3650	0.912	0:32	0:30
4197	4271	SB U.S. 45	4000	3650	0.415	0:21	0:20
4198	4221	SB U.S. 45	4000	3895	0.443	0:12	0:12
4200	488	SB U.S. 45	4000	3895	0.443	0:17	0:17
4210	4272	WR FR	400	615	0.384	0:06	0:07
4221	4237	SB U.S. 45	4000	3895	0.443	0:08	0:08
4237	4200	SB U.S. 45	4000	3895	0.443	0:43	0:42
4240	4197	SB U.S. 75	4000	3650	0.830	0:25	0:23
4271	4198	SB U.S. 45	4000	3865	0.439	0:21	0:21
4272	4271	WRFR-U.S. 45 Ramp	400	615	0.769	0:29	0:36

Field studies were conducted to verify which simulation results were more realistic and traffic counts were done one day before the closure to determine base state volumes. After the closure, it was immediately apparent from the field counts that the predicted route from the first simulation had significant volume increases.

Traffic counts were done on five separate days for fifteen minute intervals and multiplied by four to get hourly volumes. Counts were made at two locations along the routes that TEMPO showed would have the maximum volume increases for each diversion simulation. A t-test was conducted to determine if there were significant differences between the volumes predicted by the first simulation and those measured in the field. The null hypothesis states that the predicted volumes are equal to the corresponding average measured volumes. The alternate hypothesis states that the volumes predicted by TEMPO are not statistically equivalent to the volumes measured in the field.

$H_0: X = \mu$

$H_1: X = \mu$

The formula used for t (calculated) is as follows:

t (calculated) = (X - μ)/(s//n)

s = standard deviation of sample volume counts
n = number of volume counts performed

The value of t (table) is determined from the t statistic table using a value of n-1 for the degrees of freedom and significance level, α, of 0.1. The results of the t-test are summarized in Table 11. As can be seen, the null hypothesis was not rejected for all four locations. This indicates that diversions chosen by motorists were the same diversion routes that TEMPO predicted for the first simulation.

Table 11. Comparison of field a.m. peak volumes to predicted a.m. peak volumes

Location	Date	Volume	Average volume	Standard deviation	TEMPO prediction	t (calculated)	t (table)	Result
South-bound frontage road south of Fitzhugh	21-Apr	540	622.40	82.30	615	0.20	2.13	Cannot reject
	22-Apr	552						
	23-Apr	632						
	28-Apr	744						
	29-Apr	644						
South-bound Knox-Henderson entrance	21-Apr	404	377.60	47.72	350	1.29	2.13	Cannot reject
	22-Apr	304						
	23-Apr	376						
	28-Apr	432						
	29-Apr	372						
South-bound frontage road at Hall	21-Apr	864	829.60	36.07	815	0.91	2.13	Cannot reject
	22-Apr	772						
	23-Apr	852						
	28-Apr	820						
	29-Apr	820						
East-bound Knox at south-bound frontage road	21-Apr	300	322.40	41.43	300	1.21	2.13	Cannot reject
	22-Apr	312						
	23-Apr	396						
	28-Apr	304						
	29-Apr	300						

Additional tests will be performed to further analyze the accuracy of the diversion utility of the TEMPO model. Currently, data are being collected to analyze the accuracy of TEMPO in predicting consequences of opening a link in a network. The procedure will be to create an imaginary link in the TEMPO network. Simulations will be performed showing the closure of this link. TEMPO will predict increases along various routes in the surrounding network, and statistical tests will then be performed to determine if equivalent decreases are observed along these routes. In addition, a TEMPO network is currently being constructed for the LBJ-Central interchange area. The reconstruction of this interchange is scheduled to begin in late 1998. This area is highly congested and the preliminary traffic control plans involve closures of ramps and cross-street bridges for extended periods of time. Figures 28 and 29 show a TEMPO network being constructed for the transportation network near the LBJ-Central interchange.

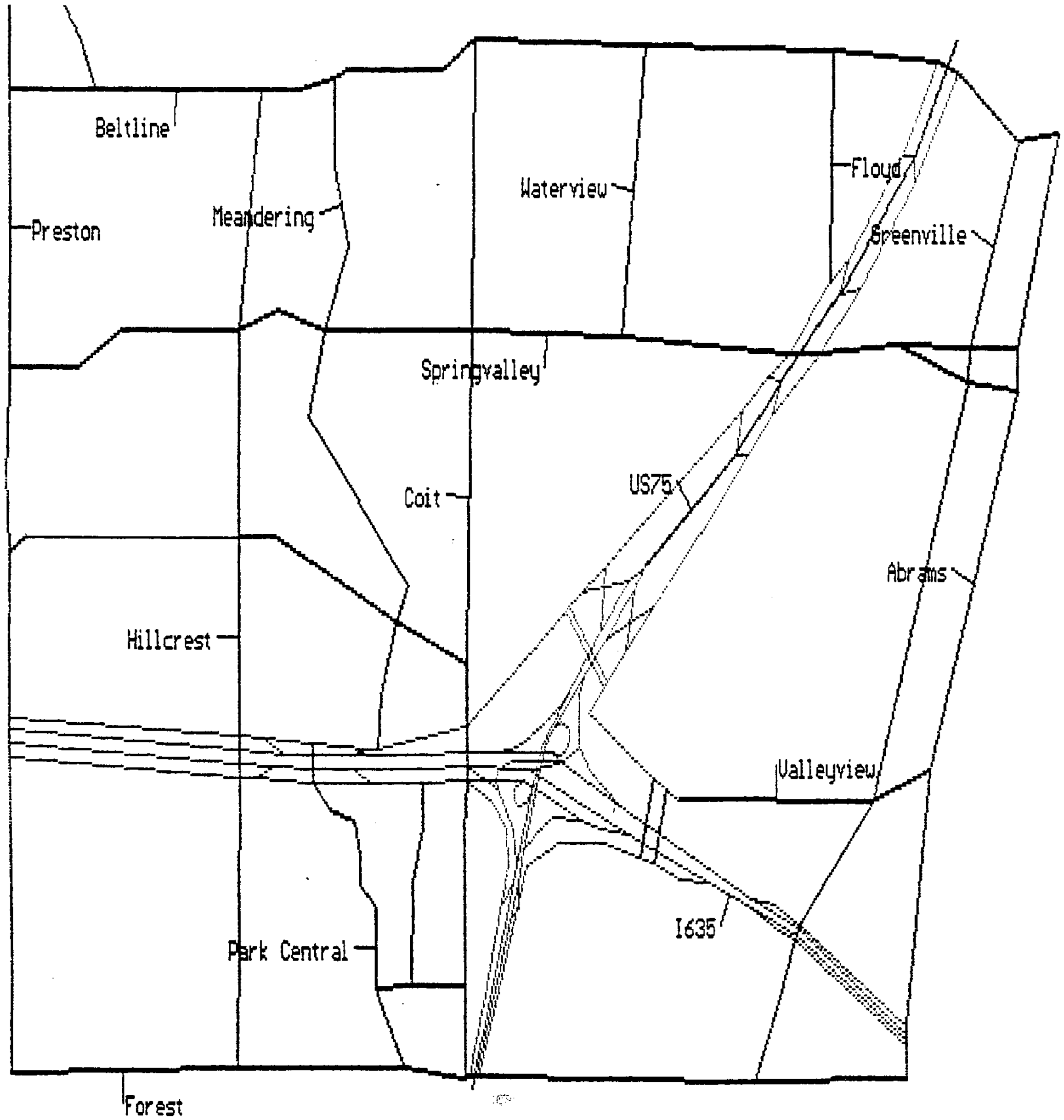


Figure 28. The LBJ/Central Expressway interchange

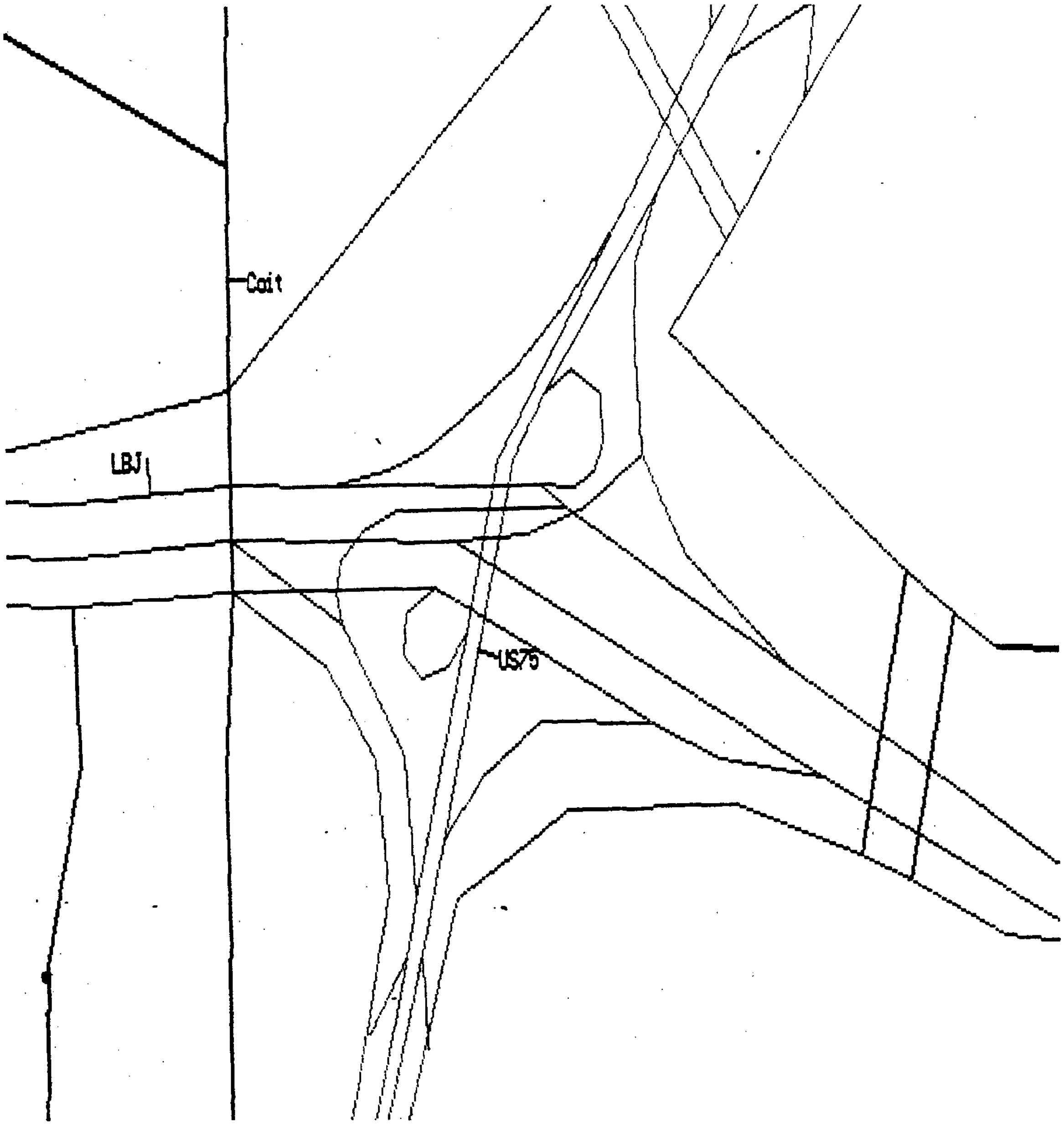


Figure 29. Close-up of the LBJ/Central Expressway interchange

If the predicted volume increases are proven to be statistically equivalent to those observed in the field, traffic engineers may be willing to adjust signal times based solely on the predictions from the TEMPO model.

FUTURE ACTIONS

As the NCE is reconstructed, temporary ramps and detours must be constructed to ensure continuous traffic flow, and it is very important to maintain an adequate level of safety and mobility for both the users and construction workers. This study examined the safety of a particular ramp with a high level of recorded incidents, and suggestions were made for the placement of traffic control devices (Ref 13). In addition, an instrumented vehicle and a diversion simulation computer model were examined. The instrumented vehicle was used to calibrate the computer model, which can be used to view traffic control plans prior to their implementation.

The main conclusions and recommendations drawn from this aspect of the research study are now presented.

a. Case study of Lovers Lane exit ramp. Observing a film of several hours of traffic interactions at the ramp proved to be an ideal methodology for analyzing the safety issues of this ramp. It is likely that other ramps could be easily analyzed in a similar manner if necessary. The conclusions and recommendations for this case study are presented in a 1994 CTR report (Ref 13).
b. Utilizing the instrumented vehicle. The instrumented vehicle was a useful tool for quickly determining trouble spots in the construction zone and for calibrating the TEMPO computer model.
c. Development of TEMPO, a traffic diversion simulation model. The TEMPO model shows potential for viewing impacts of traffic control plans before their implementation. Preliminary results show that the diversion module accurately shows optimum diversion routes during temporary or permanent closures. Construction of a GIS traffic network proved to be uncomplicated and research is being done to speed the calibration process. In addition, future research will examine if TEMPO can accurately predict what happens when a new link is opened in a network. Such an application could make TEMPO a useful planning tool.

CHAPTER 4

ENHANCING CONSTRUCTION PLANS

INTRODUCTION

In the previous chapters, the importance of the NCE as a major thoroughfare for the city of Dallas was emphasized. Multiple shifting of main lane, frontage road and cross street traffic is required to maintain mobility in this important corridor throughout the reconstruction process. Therefore the construction sequence and traffic control plans were very complex.

In the early stages of construction on the S2 project, TxDOT and Granite Construction Company (GCC) realized that the construction sequence plan for one of the cross-street bridges (Mockingbird Lane) could be streamlined. In January, 1994, GCC initiated the idea to change the traffic control plan for Mockingbird Lane and in May of 1994, TxDOT contracted with CTR to help analyze the situation. Later, a conflict arose with DART at the Lovers Lane intersection and CTR was asked to assist in the alteration of the traffic control plan for this vicinity. While implementing the Mockingbird plan changes, a large section of right-of-way was purchased that allowed GCC to streamline the main lane construction plan. TxDOT asked CTR to help analyze the changes to the quantities and the effects on safety and mobility. Later, in February, 1995, GCC was awarded the S1 project adjacent to the south of the S2 project, and they immediately began work on plans to extend the changes to the main lane construction sequencing of the S2 project to the S1 project. TxDOT asked CTR to help analyze the changes to the S1 plans and during this analysis, CTR realized that changes similar to those made on Mockingbird Lane could be implemented for the Knox-Henderson and Fitzhugh bridge construction plans (BCP).

LITERATURE SEARCH

Reported research relevant to this project can be found in three major study fields: construction engineering, transportation engineering, and decision-making.

Safety on Highway Construction Projects

Because highway accidents are more frequent within construction zones (Ref 18), much research has been conducted to assess, analyze, and enhance safety within these construction zones. Studies examining the relationship between highway configuration and safety performance of the highway were relevant to this study.

Glennon (Ref 19) investigated the effect of alignment on highway safety. This study included the effects of horizontal curves, cross sections, and vertical alignment. The study was designed to assess the impact of road design parameters on road safety. The results can also be used to evaluate construction detours. Regarding horizontal alignment, the study found that the average accident rate for highway curves is about three times the average accident rate for highway tangents, the average single-vehicle run-off-road accidents (ROR) rate for highway curves is about four times the average ROR for highway tangents, and the degree of curve, curve length, and shoulder and lane width are the major factors correlated to accident rate.

However, the study concluded that all previous research which tried to develop a model to estimate the impact of these factors on the expected accidents rates were not successful. Most of these model results have low correlation with the actual data measured. Moreover, the study found that these models usually contradict each other. The study therefore concluded that there is no single model to objectively evaluate a priori the accident rates based on alignment design data. Regarding vertical alignment, the study found that grade sections have higher accident rates than level sections, steep sections have higher accident rates than mild grades, and downgrades have higher accident rates than upgrades

Another relevant study done by Zeeger and others (Ref 20) investigated the effects of lane width, shoulder width, and shoulder type on highway safety. One of the conclusions from this study is that lane width has a greater effect on accident rates than shoulder width.

Bridge Constructability Studies

The concept of constructability has gained popularity in recent years. Based on interviews conducted with field personnel, McCullouch and others (Ref 21) concluded that there is a significant need for a system to explain "why we do what we do" during design with an example plan and checklist for each step, and field personnel need assistance in the design and evaluation of traffic control planning.

Lee and Clover (Ref 22) developed another knowledge base of lessons learned for highway projects. The knowledge base includes a separate section for bridge lessons learned, allowing designers to document and retrieve lessons learned form actual sites. In addition, they investigated the issue of change orders in highway projects, suggesting a system to analyze change orders to reduce the review time and to learn from each case.

O'Connor and others (Ref 23) approached the issue from the specification point of view. The study investigated specification-related problems in the field of highway and bridge construction, and developed a problem structure for the most frequent problems encountered in the field. These problems were then analyzed with respect to classification frequencies and apparent casual factors. It also developed a specification problem information base, based on interviews with TxDOT and contractor personnel. The study concluded that pavement and bridge specifications deserve particular scrutiny and common apparent casual factors that lead to problems include information, communication, and project scoping.

Design Evaluation Studies

Very few design evaluation studies exist in literature. A leading study was conducted by Tucker and others (Ref 24), focusing on the evaluation of the design process and its outcomes from a professional point of view (budget, schedule, quality of drawings). To evaluate the design process, the evaluation model used the following parameters: accuracy of design documents, usability of the design documents, cost of the design effort, constructability of the design, economy of the design, performance against schedule, and ease of start-up

Summary of Literature Search

Highway layout and alignment have direct impacts on traveler safety, and these impacts have to be considered when designing work activities for any highway construction. There is a need to develop a model to evaluate a BCP during the design phase, because designers lack any objective BCP evaluation tool to and no previous research has investigated this issue.

Research which investigated bridge constructability showed that a BCP has a tremendous impact on the surrounding environment. Its optimization is desirable in order to balance the conflicting needs of the project. Hence, a BCP evaluation model will have a positive impact on bridge project performance.

ENHANCING BRIDGE CONSTRUCTION PLANS

A BCP is defined as a comprehensive plan to build a bridge which includes details of bridge construction methods, detailed sequence of activities, general specifications of construction safety, and a traffic control plan (TCP). The decision to select a certain BCP has a direct impact on the overall project success. During the work on the Mockingbird BCP, the team realized the need for a systematic way to evaluate BCP's. A list of five major project objectives which are affected by the plan was developed for this evaluation: safety, accessibility, freeway carrying capacity, overall project duration, and overall project cost. The BCP should therefore optimize these five objectives and use them as the basis for evaluating the effectiveness of the BCP. A more detailed list of objectives/criteria was used to evaluate the BCP, as shown in Table 12.

Table 12. Performance measures

OBJECTIVE	MEASUREMENT PARAMETER
Traveler Safety	Interaction with equipment Detour configuration Lane width Detour alignment Detour length
Worker Safety	Interaction with traffic Interaction level Interaction duration No. of traffic changes Proximity to accidents
Accessibility	Traffic Business access Construction equipment
Carrying Capacity	No. of lane closures Duration of lane closures
Project Duration	% Duration savings
Project Direct Cost	% Budget savings

Safety for both the traveling public and construction workers is the major concern for all parties involved in the project. A good BCP will reduce the probability of accidents within the site and at the same time reduce accident severity. Direct interaction between running traffic and heavy construction machinery like cranes and pavers can cause accidents and a good BCP will separate both of them, assuring a straightforward roadway for traffic. The design of detours is also a critical factor in assuring traveler safety. Detours can cause confusion to traveling public, especially the one-time users of the highway, and the following sub-items should be considered in evaluating the effect of detours on traveler safety:

a. Lane width: Narrow lanes increase the probability of accidents, especially when trucks use the highway. A good BCP will allow enough space for both trucks and other vehicles.

b. Detour length: The longer the detour, the more likely an accident will occur. The BCP should work to shorten or eliminate unnecessary detours.

c. Detour alignment: Detour horizontal and vertical curves have a great influence on accident probability and severity. The BCP planner should work to simplify the detour to avoid any sharp curves or obstructions to sight distance.

A good BCP will also provide construction crews with an adequate and safe work area. Laborers usually work adjacent to running traffic, either during the erection of the bridge or during traffic shifts. A good BCP will also minimize the required number of traffic switches and situations where laborers work within the traffic stream because the longer the interaction with the traffic, the more likely an accident will occur. In addition, a good BCP should prepare a set of actions to manage site accidents. The work zones should be easily accessible to evacuate injured laborers if an accident does occur.

Another major requirement of a BCP is to provide adequate access and mobility throughout the site for both traffic and construction equipment. One should insure that traffic access to the site is not interrupted, construction equipment access to and from the freeway is unobstructed during material handling, and interruption to local businesses is minimized. In addition, a BCP should strive to maximize the carrying capacity of the highway during construction by minimizing the number of lane closures and by minimizing lane closure duration.

A BCP has a great influence on project duration and the ideal plan will reduce the total project duration without jeopardizing safety. In addition, a plan achieving a reduction in total project cost will have a better chance for successful application.

TxDOT Restrictions

During the work on Mockingbird, TxDOT specified several objectives for the revised BCP which were also set for the other BCP revisions. These objectives, to reduce construction duration and traffic interruptions and to assure good traffic flow during the project, include the following restrictions:

a. a minimum carrying capacity of two lanes in each direction for both the main lanes and the bridges should be maintained throughout the project,
b. diverting main lanes' traffic to the frontage road can only occur on weekends or nights. During these diversions, a minimum of three lanes should be opened to traffic with two lanes for the main lanes and one for the frontage road,
c. during demolition of any portion of the bridge, the entire bridge must be closed, and
d. frontage road traffic should not be blocked.

Objectives

On the basis of the restrictions imposed by TxDOT and the information gathered about the project, the team realized that any construction plan should balance and integrate both traffic and construction needs. Thus, the objective in each case was to develop a BCP that optimized project duration without jeopardizing safety or hindering traffic flow.

The team then developed a more specific list of objectives in the following priority:

a. maximize safety for construction workers and travelers,
b. minimize traffic interruption,
c. reduce the construction duration, and
d. reduce the direct project cost.

Study Activities

After setting the objectives, the CTR team drafted a plan of action. The following flow chart (Fig 30) describes the sequential steps taken in this effort. These steps were followed initially in the Mockingbird revisions and later in the other bridge revisions.

Initially, the general contractor suggested that several BCPs could be simplified and safer plans that offered time and money savings might be implemented. The team visited the sites to assess the following characteristics of each bridge: space availability, traffic flow, business locations, and business access. During these visits, the team discussed ideas with the contractor and with TxDOT representatives. An initial analysis was conducted to assess the existing project situations and, based on this analysis, the team identified that the site conditions were hazardous, the projects heavily impacted the surrounding neighborhoods, and the project duration was relatively long. Also, parties involved in the decision process (TxDOT, the contractor, and the city of Dallas) did not include parties directly affected by the plans (abutting businesses and the traveling public).

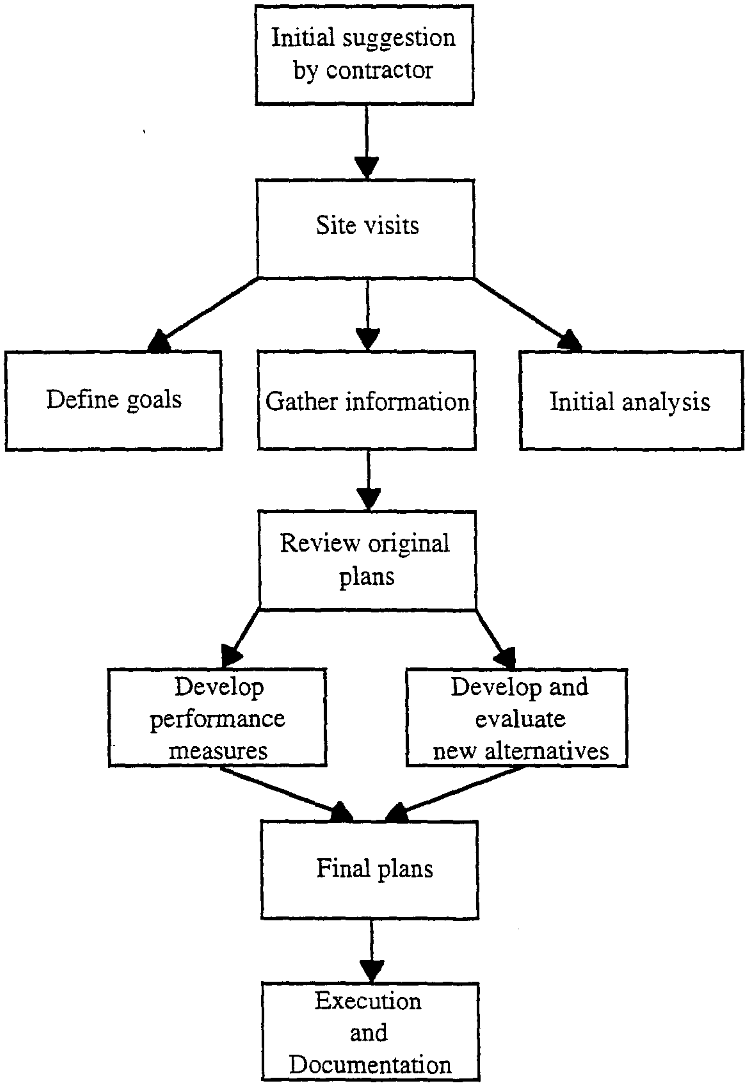


Figure 30. Study plan flow chart

In approaching the problem, the team focused on two major goals: optimizing the overall project objectives (safety, accessibility, carrying capacity, project duration, and project cost), and simplifying the plans. In order to achieve the previously mentioned goals, the team conducted several meetings with the owner and the contractor to explore the problem areas and elicit their knowledge about the site and the project. The two parties provided the team with numerous insights about the project. The basic information gathered included project general documents such as contract specifications and bills of quantity, the original project plans, traffic counts, and business locations.

TxDOT then provided the team with a complete set of the original plans, which the team reviewed carefully. Each step was analyzed to assess the possibility of elimination, of combining with another step, or of simplification.

Suggestions on how to rebuild the bridges were developed by either the CTR team or the contractor. The team realized the need for a system to evaluate these ideas before going to the detailed planning phase, and developed a list of performance measures that should be satisfied by any acceptable plan (Table 12). This list was derived directly from the project objectives, owner's restrictions, and team members' experience with traffic control plans (TCPs).

With all necessary background information about the project in hand, the project team generated alternative plans for each bridge. During this brainstorming process, several creative approaches were advanced, resulting in defined plans. These plans were then evaluated against the performance measures developed by the team.

During this evaluation, safety was the dominant issue. The team sought to reduce the interaction between construction activities and traffic to the lowest level possible. All plans and ideas generated during this phase were carefully investigated to ensure adequate work space away from traffic for the construction workers.

For the issue of traveler safety, the team focused on reducing the total number of traffic diversions on the main lanes and on the overpass. Horizontal and vertical curves were carefully examined to ensure sufficient sight distance and complete compliance with OSHA standards.

Site accessibility was another important issue in the team's analysis of the BCP. Each plan was analyzed to evaluate its effect on public traffic accessibility, construction equipment, and surrounding businesses.

Construction activities cause traffic congestion along the highway. With the heavy traffic volume on NCE, any reduction in project duration will have a considerable impact on user cost. In addition, the negative impact on surrounding businesses will be reduced. The team focused on eliminating unnecessary steps, rearranging the construction logic to combine several steps, performing different activities in parallel instead of in serial sequence, and simplifying (and thus accelerating) the construction sequence

The elimination of unnecessary steps (e.g., the temporary bridge) also has the potential for saving a substantial amount of money. In this regard, the team focused on eliminating the need for the temporary bridges and detours and reducing the number of traffic shifts. On the basis of this approach, several plans were developed.

The team then held meetings with the owner and the contractor to select a specific plan for each bridge being considered from the previously developed options. After a plan received initial approval from both parties, the team concentrated on developing a more detailed plan. In subsequent meetings, owner and contractor preferences were elicited and added to the plan. Following that, the plan was put on computer using Microstation 5, allowing the team to discuss and add finishing details.

Finally, the team decided to document the construction activities with slides and a journal of important construction activities. At the time of this report, work has progressed on each bridge as planned with the exception of a few minor changes due to bad weather conditions or conflicting project activities.

Mockingbird Bridge

Description of the Mockingbird Lane Intersection. Mockingbird Lane crosses NCE in an east-west direction. It is a major link to many important areas in Dallas (e.g., Southern Methodist University and Love Field Airport), and the traffic volume on the bridge is considered heavy.

The old bridge had a double-span frame with each span being 14.6 m (47.9 ft) wide and a width of 24.3 m (80 ft), accommodating a U-turn and two lanes in each direction. The new bridge will deploy double-span, pre-cast girders with each span being 27.6 m (90.5 ft) long. The bridge is designed to accommodate four lanes in each direction and double U-turns, and varies in width from 78 m (256 ft) to 111 m (364 ft). The project also includes rebuilding Mockingbird Lane east and west of the bridge to accommodate the new bridge capacity and reconstructing the frontage roads on both sides of the NCE.

The available ROW at the location is extremely limited. Because of this limited ROW, most of the widening work on the frontage roads and Mockingbird Lane had to be divided into small sections to accommodate both traffic and construction work. This division forced the construction to be sequential, slow, and to include many traffic switches (changes in the location of the traffic to open up areas to be reconstructed).

The available space around the main lanes is confined by the piers of the old bridges and by the existing frontage road. The construction of the new highway will require shifting the highway traffic back and forth many times within this limited space.

Revisions to the Mockingbird Lane BCP. The original plans included building a complete two-lane detour to carry the main lane traffic during bridge construction. This detour was allocated just east of the existing bridge abutment. Putting the main lane traffic on this detour required excavating east of the existing Mockingbird Bridge, which necessitated the construction of a temporary bridge. This temporary bridge would be demolished before building the new bridge. The team noticed that the east span of the existing Mockingbird bridge could, with a slight change in sequence, be used to accommodate this detour, eliminating the need for the detour and the temporary bridge.

There were two major problems with the reconstruction of the Mockingbird Bridge. The first was the question of how to demolish the old bridge and build the new one. The original plan solved this problem by dividing the old bridge into six parts with each part being demolished in a separate step. Immediately after the demolition of one part, a part of the new bridge was to be built.

The new plan handled the matter in a different way. The bridge was divided into two parts — north and south. The north part was two lanes wide and the south part was four lanes wide. The north part was demolished first, immediately followed by erection of the whole northern part of the new bridge which would carry four lanes of traffic. Then the traffic was shifted to the new bridge to allow the demolition of the south part of the old bridge and erection of the remaining half of the new one. This eliminated the need for the temporary bridge, saving three months of construction time and a total direct cost of $160,000.

The second problem involved keeping four lanes of traffic moving on the highway. Because the old plan divided the bridge into six parts, the new bridge columns on the east side were to be constructed early in the project. positioned in the middle of the east side of the Mockingbird Bridge. As a result, the east side could no longer be used to carry the main lane traffic. During construction of the west side, a new detour outside the bridge was to be built, requiring the installation of a complete detour east of the bridge with a temporary overpass.

In the new plan, the traffic was put on the east span before any columns were built. At the same time, the complete detour was constructed under the west span of Mockingbird. Traffic used this detour for the remainder of the project. Main lane traffic would be switched to the frontage roads only during demolition or hanging of pre-cast girders, both of which occurred on weekends or at night.

The plan reduced traffic switches and eliminated the construction of a temporary bridge. This corresponds to about a 30% time reduction, leading to a significant decrease in indirect costs. The total direct cost savings is estimated at $450,000.

Detailed drawings of the Mockingbird BCP are shown in Appendix D. The reconstruction of Mockingbird Bridge began in January 1995 and the research team has continued to monitor the actual execution of the project.

Lovers Lane Bridge

Description of Lovers Lane Intersection. Lovers Lane is another important link crossing the NCE in an east-west direction with heavy traffic volumes.. The old Lovers Lane bridge had a single-span frame with a span length of 22.11 m (72.5 ft) and width of 29.3 m accommodating a double U-turn and two lanes in each direction. The new bridge will deploy double-span, pre-cast girders. Each span will be 23.8 m (78.1 ft) long and is designed to accommodate four lanes in each direction with double U-turns. The width of the new bridge varies from 67.1 m (220.1 ft) to 90.2 m (296 ft). The project includes rebuilding Lovers Lane east and west of the bridge and the frontage roads on both sides of the NCE. Like the Mockingbird site, there is limited ROW and, in addition, the construction of a bridge for the DART light rail is in the vicinity of the intersection.

Revisions to the Lovers Lane BCP. Two major issues under study for this site were: 1) simplification of the BCP including eliminating a proposed temporary bridge, and 2) facilitating surface traffic on Lovers Lane.

After analyzing the original plans, the team realized that the first goal of eliminating the temporary bridge was not possible due to limited span clearance beneath the bridge. The second goal of facilitating surface traffic on the bridge, therefore, became the focus of the research.

A pier supporting a bridge for the DART light rail was located in the middle of Lovers Lane. The construction of the Lovers Lane bridge required shifting of traffic back and forth several times around this pier, and both TxDOT and the contractor expressed concern regarding the safety of construction workers and the traveling public. The research investigated traffic paths and radii in each construction step and developed a surface traffic control plan that enhanced detour quality and provided safer space for workers.

Knox-Henderson Bridge

Description of the Knox-Henderson Intersection. Knox-Henderson also crosses NCE from east to west and the traffic on this bridge is also considered heavy. The existing bridge has a double-span frame (14 m [45.9 ft] long for each span). The current bridge width is 22.2 m (72.8

ft) and accommodates two lanes in each direction. The new bridge will deploy double span, pre-cast girders, and each span will be 23.3 m (76.4 ft) long, designed to accommodate three lanes in each direction with double U-turns. The width of the new bridge varies from 61 m (200.1 ft) to 84 m (275.6 ft).

Revisions to the Knox-Henderson BCP. The original plans called for construction of a temporary bridge to carry traffic during demolition and reconstruction of the old bridge. Traffic was to be switched to the pre-cast portion of the north half of the new bridge as soon as possible, and the temporary bridge was to be demolished. Then the pre-cast portion of the south half of the new bridge was to be constructed. Following this, the cast-in-place portions of the bridge were to be constructed in halves (north half and south half) directly over main lane traffic.

The team realized that a BCP similar to that of Mockingbird could be implemented successfully for the Knox-Henderson bridge. The temporary bridge was eliminated and the pre-cast portion of the south half of the new bridge was constructed adjacent to the old bridge with the traffic remaining on the old bridge. In this case, no partial demolition was necessary because there was enough space to construct the south portion of the new bridge. Traffic was then switched to this portion of the new bridge while the pre-cast portion of the north half of the new bridge was constructed. In addition, a major constructability problem with the reconstruction of the Knox-Henderson was discovered. The (pre-stressed) cast-in-place portions of the new bridge were to be constructed in halves (north half and south half) and, with the shoring system that GCC utilized, it was impossible to maintain four lanes (two in each direction) of main lane traffic beneath this construction. Therefore, the new BCP called for construction of the cast-in-place portion of the new bridge in fourths instead of halves. With this change, the east cast-in-place portion of the bridge could be constructed while the main lane traffic was pushed against the west retaining wall. Following this, the main lane traffic could be pushed to the east retaining wall and the west cast-in-place portion of the new bridge could be constructed.

The time and cost savings from this plan are not yet known because the schedule and quantity changes are still being determined.

Fitzhugh Bridge

Description of the Fitzhugh Intersection. Fitzhugh is another important street crossing NCE from east to west with heavy traffic volumes. The existing bridge has a double-span frame (14.2 m [46.6 ft] long for each span), with a width of 26.6 m (87.3 ft) and accommodating two lanes in each direction. The new bridge will deploy triple-span, pre-cast girders. The first span will be 26.2 m (86 ft) long, the second will be 21.9 m (71.9 ft) long, and the third, designated for a ramp, will be 13.1 m (43 ft) long. The new bridge is designed to accommodate four lanes in each direction with no U-turns, and varies in width from 41 m (134.5 ft) to 61 m (200.1 ft).

Revisions to the Fitzhugh BCP. Like the Knox-Henderson bridge, a temporary bridge was to be constructed to carry traffic while the old bridge was reconstructed. With traffic on the temporary bridge, the entire south half of the new bridge (both pre-cast and cast-in-place components) was to be constructed. Traffic was to be switched to the south half of the new bridge after it was constructed, and the temporary bridge was to be dismantled. Then the entire north half of the new bridge (pre-cast and cast-in-place) was to be constructed. Again, portions of the cast-in-place part of the bridge were to be constructed over mainline traffic.

The new plan is much like the Mockingbird and Knox-Henderson plans. First, a 3-m (10 ft) wide segment along the north edge of the old bridge is demolished. There are some problems with providing vertical clearance under the new bridge so main lane detours are constructed under the bridge to lower the grade. Then the pre-cast portion of the north half of the new bridge is constructed. Traffic will be then switched to this portion of the new bridge and the remaining portion of the old bridge is demolished. Following this, the pre-cast portion of the south half of the new bridge is constructed. With traffic on the pre-cast portion of the new bridge, the cast-in-place portion is constructed half at a time. Again, cast-in-place construction over main lane traffic is avoided by constructing the west half while the main lanes are pushed to the east and the east half while the main lanes are pushed to the west.

The time and cost savings from this plan are not yet known because the schedule and quantity changes are still being determined.

ENHANCING MAIN LANE CONSTRUCTION PLANS

Reconstruction of a major thoroughfare such as NCE involves demolition and construction of main lane paving as well as overpasses. In the case of NCE, the main lanes will be depressed about 8 m (25 ft) below the elevation of the frontage roads. This involves a considerable amount of excavation and construction of retaining walls. In addition, except for brief closures for special activities such as demolition of cross-street bridges, extremely high levels of traffic must be maintained throughout the reconstruction project. An efficient mainline construction plan with a minimum number of traffic switches is desirable to expedite construction and avoid confusion to the traveling public.

The Phase Consolidation Plan for S2

In the summer of 1994, while finishing the frontage roads and implementing the revised Mockingbird BCP, GCC started looking at the mainline work area and the other bridges. TxDOT asked CTR to assist in the analysis of the safety and mobility of any alternatives to the mainline construction plan that GCC offered and in the review of associated change order quantities.

What is PCP? It became apparent early in the S2 project that the main lane construction was not in phase with the bridge construction. The original plans called for a bridge building phase, which was to last almost a year. During this phase, essentially no work was to be done on the reconstruction of the main lane. Following the bridge building phase, the main lanes were to be constructed in thirds (outside east lanes, outside west lanes, then center lanes and median). The cast-in-place portion of the S2 bridges, however, were to be constructed in halves. Main lane detours were to be placed against the retaining walls to provide a work area for the bridge construction. These detours were to tie into the existing main lanes between the bridges, resulting in grade changes of approximately 7 m (20 ft) and alignment changes of up to 20 m (60 ft). In addition, the original plan contained many traffic switches. The phases of the original plans were as follows:

- Phase 1: construct frontage road detours, drainage collection structures, and sound-wall;
- Phase 2: construct cross street paving and outside lanes of the frontage road;
- Phase 3. construct detours around existing bridges and construct the new bridges;
- Phase 4. shift north-bound traffic against the center line and construct permanent paving for the outside two north-bound main lanes, inside north-bound frontage road, and north-bound cantilevered frontage road;
- Phase 5. shift south-bound traffic against the center line and construct permanent paving for the outside two south-bound main lanes , inside south-bound frontage road and south-bound cantilevered frontage road; and
- Phase 6. shift north- and south-bound main lane traffic against the retaining wall and construct permanent paving for the inside two south- and north-bound main lanes and center median.

In November, 1994, GCC offered an alternative to the main lane construction plan which brought it into phase with the bridge construction. This plan was called the Phase Consolidation Plan (PCP) because it combined bridge construction with main lane construction. It also allowed construction of the main lanes in halves instead of thirds. This was accomplished by pushing the north-bound and south-bound traffic to the west of the centerline throughout the project. In order to accommodate four lanes of traffic to the west of the centerline, the width of the shoulders in the detour areas was reduced and, in some places, eliminated. The "Vehicle Removal" item was increased to compensate for the smaller shoulder width. In addition, turnouts (areas large enough to park several cars) were added wherever there was room to allow space for stalled vehicles. The basic phases of the PCP are as follows:

Phase 1. same as original plans;

Phase 2. same as original plans;

Phase 3. construct main lane detour against west retaining wall throughout the entire project and construct pre-cast portion of cross street bridges;

Phase 4. shift north- and south-bound traffic to main lane detours (against west retaining wall) and construct four lanes of north-bound main lane permanent paving, outside north-bound frontage road, north-bound cantilevered frontage road, and east cast-in-place portion of cross street bridges;

Phase 5. shift north- and south-bound traffic to the permanent north-bound main lane paving and construct south-bound main lane permanent paving, outside south-bound frontage road, south-bound cantilevered frontage road and west cast-in-place portion of cross-street bridges; and

Phase 6. shift south-bound traffic to permanent south-bound main lane and construct center median.

Factors that Made PCP Possible. Working with current information available to the field engineers (such as location of utilities, vertical and horizontal clearances, and acquisition of right-of-way) was crucial for the initiation of the PCP. For example, early acquisition of a piece of property provided a sizable work area along the west side of the expressway between Mockingbird and Yale, an area not available during the design phase. In addition, the contractor was able to check the horizontal clearances in the field to determine that all four main lanes (two in each direction) could be shifted to the west of the centerline throughout the project.

Benefits of PCP. The detour constructed in Phase 3 moved both the north- and south-bound traffic to the west retaining wall, allowing unhindered construction of all four lanes of the north-bound main line. Figure 31 illustrates the difference in horizontal alignments between the PCP and the original plans. In addition, the detours between the bridges were lowered approximately 3 m (10 ft), which cut the vertical change in half from 7 m (20 ft) to about 3 m (10 ft). Figure 32 illustrates the difference in vertical alignments between the PCP and the original plans. As shown by these two figures, the PCP provides a straighter, smoother traffic configuration and therefore provides added safety to the traveling public.

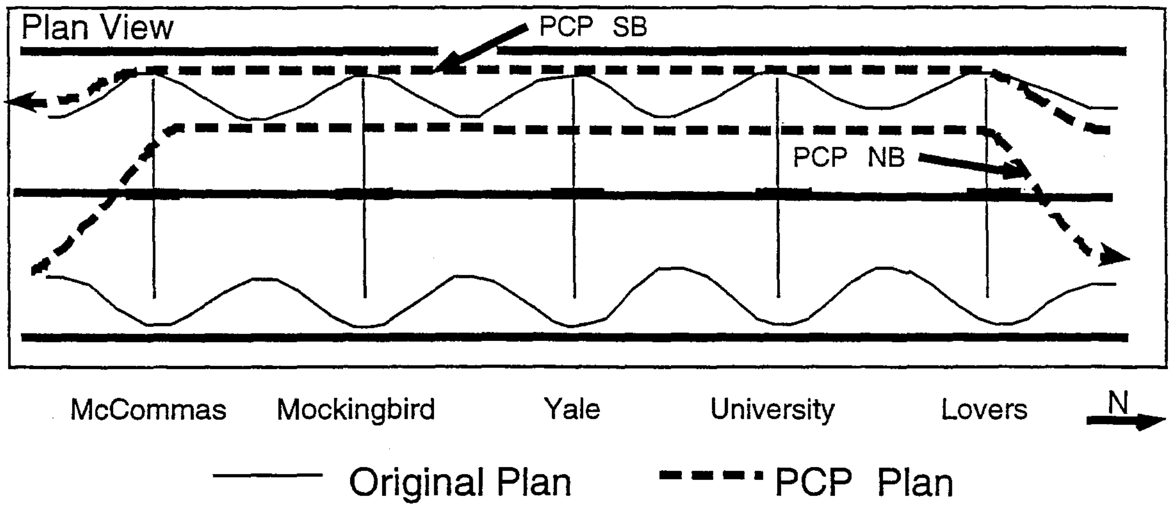


Figure 31. Horizontal alignments

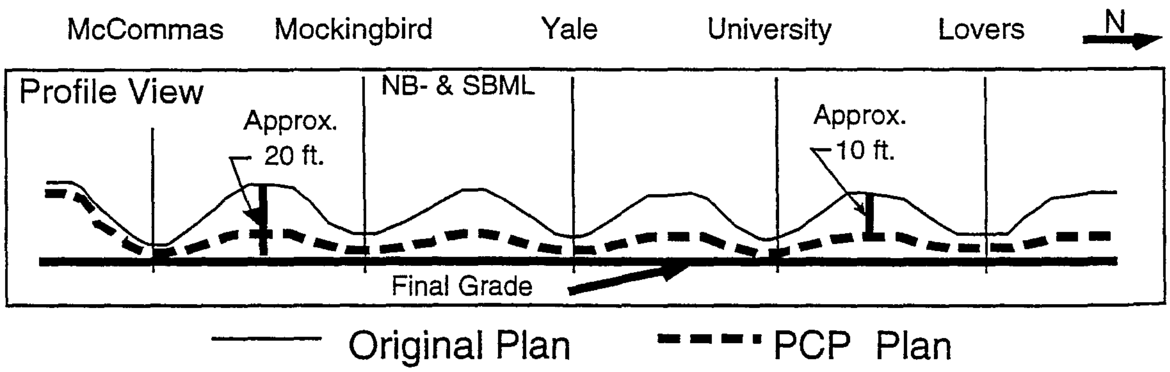


Figure 32. Vertical alignments

The PCP decreased the number of traffic switches on the main lane by half. Construction workers implementing traffic switches must work adjacent to high speed traffic. In addition, traffic switches often confuse the traveling public; consequently, any reduction to the number of switches provides safety benefits to the construction workers and the traveling public.

The PCP also allows traffic to be switched to permanent paving earlier than anticipated in the original plans, which called for this switch to occur by mid-October of 1998. The PCP switched all traffic except a small portion (about 135 m [500 ft]) north of Lovers Lane to permanent paving by early 1997. The remaining portion north of Lovers Lane is scheduled to be switched to permanent paving in spring of 1997. This early switching to permanent paving offers considerable safety benefits of wider lanes and acceleration and deceleration lanes at entrance and exit ramps.

In addition to the safety benefits, the PCP offers both indirect and direct cost savings. As previously mentioned, the PCP allows the bridges to be constructed concurrently with the main lane, allowing the project to be completed up to six months ahead of schedule for an estimated savings in user costs of $36 million ($200,000 per day). There is also a direct cost savings from reduction of temporary bridge materials, temporary drainage, and temporary shoring. The estimate of the total savings to TxDOT is about $680,000.

The Stage Consolidation Plan for S1

The S1 contract was awarded to GCC and construction began in April, 1994, while the PCP was being implemented. GCC immediately began working on plans to extend the S2 PCP into the S1 Project.

What is the Stage Consolidation Plan? Like the S2 project, the north half of the main line for the S1 project was to be constructed in thirds (outside east lanes, outside west lanes, then center lanes and median). The original construction sequence was designed this way to provide a smooth transition between S1 and S2. However, the PCP changed the sequence such that construction in halves provided a better transition between S1 and S2. In addition, the concurrent construction of a DART rail station near the Cityplace Building at the south end of the project conflicted with the original plans. The original plans called for constructing the frontage road where the DART construction activities were and then shifting the main lane traffic to the east near this frontage road area. It became apparent that the DART construction activities would cause substantial delays to this area of the project. Therefore, GCC suggested an alternate main line construction plan for S1, called the Stage Consolidation Plan (SCP). SCP is an extension of the original S2 PCP to bring the construction of the north portion of S1 in phase with the construction of S1. The SCP also includes plans to eliminate the main lane temporary bridge at Lemmon and the cross street temporary bridges at Monticello, Knox-Henderson, and Fitzhugh.

Factors That Made the SCP Possible. As with the PCP, current information available to the field engineers was crucial for the initiation of SCP. In this case, the crucial information was the fact that the S2 construction sequence had been altered, that there was adequate horizontal clearance to fit four lanes on one side of the centerline, and that there was adequate vertical clearance under the cross-street bridges. Also, it was not apparent during the design phase that the DART construction activities would conflict with the original plans. In addition, after community discussions, the field engineers determined that the Monticello temporary bridge could be eliminated without significantly affecting the traffic.

Benefits of SCP. The expected benefits of the SCP are similar to those of the PCP. The SCP provides safety benefits to the traveling public and the construction workers by reducing the number of major traffic switches (switches that cross the centerline) from five to two, and by switching traffic to permanent pavement, ramps, and bridges earlier than originally planned. In addition, the SCP eliminated the need for several temporary ramp closures, which helped traffic mobility through the corridor.

Another important benefit is the previously mentioned fact that a substantial delay due to conflicting DART construction activities is avoided. Also, the original plans called for construction of the bridges in a separate phase, after the main lane paving was completed. Because of the shoring towers required to construct the cast-in-place portion of the bridges, confining the traffic to two lanes throughout the project would be required. The SCP allows for construction of the bridges concurrently with the construction of the main lane paving, allowing all four lanes of the new main lane paving to be utilized by the traveling public as soon as they are completed. In addition, this may allow the project to be completed earlier than originally scheduled.

The details of the SCP are currently being considered, but it is already clear that, like the PCP, SCP will provide both indirect and direct cost savings. The team anticipates that the SCP will allow the north end of the project (Knox-Henderson to north project limit) to be completed approximately at the same time as the S2 project. In addition, there will be direct cost savings from reduction of temporary bridge materials, temporary drainage, and temporary shoring. The extent of the time and cost savings is not known at this time, as the cost estimates and scheduling information are still being completed.

CONCLUSIONS AND RECOMMENDATIONS

Reconstruction of the NCE in Dallas is potentially disruptive to both users and those working, living, and transacting business in the catchment area. However, this study shows that impacts can be lessened in two ways: (1) by reducing the overall construction time (schedule compression), and (2) by focusing on the early completion of those construction elements impacting accessibility. In addition, construction costs can be lowered by reducing the number of items like temporary bridges, detours, drainage, and shoring. Finally, safety can be increased by providing smoother detours and reducing the number of required traffic switches.

The main conclusions and recommendations drawn from the study undertaken to streamline the construction process are now presented.

a. Critical Element of a Strong Partnering Attitude. A cooperative approach between the owner, primary contractor, subcontractors, and academia enhanced project performance and resulted in significant benefits. Comments from both TxDOT and the primary contractor indicate that without the strong partnering attitude that has been prevalent throughout this project, few of the changes made to the TCPs would have been possible. In this case, The University of Texas, acting as an independent party, was able to contribute to the effort and allow students the opportunity to gain valuable experience and knowledge.

b. Creating a BCP Matrix. A model methodology was developed to evaluate BCP options and select the best among them (Ref 25). The model was successfully used in the evaluation of the NCE cross-street bridge construction plans and substantial benefits were realized. In this case, the methodology used for the bridge construction sequencing of Mockingbird Lane (saw cutting and demolishing part of the bridge allowing clearance for partial construction of the new bridge while the remaining portion of the old bridge is used to maintain continuous cross-street traffic) was easily applied to similar bridges in the project. Time savings of around 30% and cost savings of around 16% are estimated for each of the bridges under study.

c. Streamlining the Main Lane Construction Plans. The PCP allowed the main lane to be constructed in halves instead of thirds and thus produced substantial savings in both time and costs. The study estimates that the PCP will allow the S2 project to be completed up to six months ahead of schedule, which will reduce the impacts to businesses and save millions of dollars in indirect user costs and overhead costs to TxDOT. In addition, it is estimated that the PCP will save about $680,000 in direct costs and the SCP for the S1 project will likely produce similar savings. The PCP also provided safety benefits by offering safer detours (better curves, longer radii of curvature, and smaller grade differences) and allowed traffic to be switched to permanent pavement approximately five months earlier for the north-bound main lane and almost 13 months earlier for the south-bound main lane.

d. Recommendations for Future Projects. The study team recommends that several construction options should be developed in the design phase to identify the optimum BCP. In addition, bridge constructability analysis, construction sequencing and TCPs should be integrated when determining the optimum BCP. In this regard, TxDOT could seek to hold pre-construction conferences (constructability symposiums) with interested contractors. As a final recommendation, TxDOT should be allowed to start value engineering initiatives since current regulation limits this right only to the contractor.

CHAPTER 5.

FUTURE ACTIONS

INTRODUCTION

The work undertaken as part of the research program supporting the NCE project is necessarily broad in scope and content. The complexity of the project and the necessity of accommodating a variety of needs from those using or affected by the corridor and its construction phases has produced the wide variety of results reported in this document. And while responding to the needs of construction sequencing, traffic, and businesses, the team has also had to respond to the unexpected. Unintended consequences from the numerous decisions made monthly on a project of this size may become critical, and the CTR team made time available to play its part in responding to these challenges.

Communication remains critical and, when effective, it insures that the needs of highway and business users are taken into account at the planning and construction stages, and that decisions on key issues like traffic control plans are communicated in full to all interested parties. The NCMTF has become a successful mechanism for improving communication between all parties and efforts to strengthen its performance should continue. CTR efforts are directed to insure that the team plays its part in this undertaking.

Conclusions and recommendations have already been given at the end of each previous chapter dealing with the three main categories of traffic, construction, and business/users. Due to the different nature of the three groups, some results are broad, detailed, and final. Other areas are more narrowly focused on specific issues and results are sometimes tentative, since analyses remain preliminary. Again, this is to be expected on a project of such complexity. This final chapter will identify potential areas for further study based on the work already undertaken, and is grouped into the three areas already designated in this report to insure consistency.

TRAFFIC IMPACTS

The following areas are recommended for future investigation.

a. In order to improve the efficiency of the TEMPO products, the calibration process already undertaken will be duplicated for the afternoon peak and off-peak TEMPO networks.

b. To allow TEMPO to be used as a way of recommending alternative routes to highway users (with the results displayed either through variable message signs, television, radio, or newspapers), current traffic volumes and composition need to be undertaken along the streets that qualify as alternative routes in the TEMPO network. This will allow further work to be undertaken on the verification of the diversion simulation module, a critical element in the determination of alternative routes.

c. Further analyze the traffic control plans produced for bridge demolition and beam hangings on the NCE project to determine what increases in volumes may be expected on alternative routes during the demolition phases. Again, this will help produce a more efficient traffic control plan and a clearer understanding of the impacts of bridge demolition on traffic flows in the corridor area.

d. Use TEMPO to analyze the traffic impacts from the LBJ/Central interchange traffic control plan when it becomes available.

e. Communicate with city traffic operations engineers by listing locations that may be affected by the variety of closures expected in the construction sequencing plans.

f. Continue to track traffic growth and composition on the NCE main lanes as work is completed and capacity restored to the different phases. It is believed that, because of the expensive media coverage of the NCE and the resultant expectation of congestion and delays, many users who formerly traveled the corridor now use alternative routes. The question is whether they will return as the corridor construction work progresses. The numbers—what and how much—are important for planning purposes, together with an idea of timing. The significance of this may extend to well beyond the perimeters of the NCE catchment area and ultimately affect the Dallas metropolitan network. In this regard, it is important to maintain a clear understanding of the role the NCE will have on flows in Dallas and how these might be managed to maintain flow efficiency at the highest level.

These constitute a listing of the areas clearly identified by the research team. In addition, there may be further uses for the TEMPO suite of models since substantial conclusions have not yet been possible because the work has not yet been completed. Because it is felt that TEMPO is an important contribution to planning in all metropolitan urban areas of Texas (and not just limited to Dallas), a separate TEMPO report will be produced which will contain more specific conclusions and recommendations. This report will undertake to determine whether the information drawn from the TEMPO diversion simulations is representative of what actually happens in the field.

CONSTRUCTION SEQUENCING

Much of the critical work in construction sequencing and compression has been accomplished under this phase of the study program. Staff will continue to offer their assistance to TxDOT and the contractor in enabling project engineers to implement both PCPs SCPs along the lines established during the duration of this study. In addition, two further action areas have been identified.

a. Critically review the LBJ/Central Interchange plans when they are made available by TxDOT. There may be substantial opportunities to improve these plans using experience gained on the NCE.
b. Meet early with the LBJ/Central Interchange project engineers after the contract has been awarded to discuss problem areas and opportunities for streamlining elements of the plan. This interchange will critically affect both traffic flows in the areas and mobility and access to those living and working near the interchange. Again, it may be possible to substantially shorten certain phases, for example through earlier acquisition of right-of-way, and strenuous efforts will be made to mitigate adverse impacts created by this major project.

BUSINESS IMPACTS

The team proposes to build on the knowledge gained in early analyses of the construction impacts on businesses and residents during the S2, M, and N stages of the project and to determine more precisely the impacts of construction and how efforts may be undertaken to improve the issues. The proposed actions include the following:

a. Obtain data from the State Comptroller's Office on business revenues to expand the sales analyses and make them more robust and credible.
b. Continue monitoring the businesses opening and closing along the S2 and S1 segments to gain a clearer understanding of construction impacts. Previous research has stressed the difficulties that businesses experience, but failed to identify opportunities that newly constructed urban areas provide those businesses abutting the perimeters. It has already been shown in this report that the number of business openings outweigh closings and further information needs to be obtained. Such work will focus more closely on the types of businesses and the timing of their closures.
c. Begin surveys of businesses abutting the construction project to determine the level of interest shown by businesses and the most efficient way of communicating information with them. This will include the potential use of the Internet in conveying a variety of information including the latest changes to traffic plans and sequencing.
d. Perform regular windshield surveys of all businesses abutting the LBJ/Central Interchange.
e. After S2 and M construction is complete, a full survey will be undertaken of businesses to register the variety of construction impacts to those businesses. Efforts will be made to more clearly identify aspects of the communication process that were effective and those that were not to improve the NCMTF communication process.
f. Continue to explore ways of improving communications with those affected by traffic control planning and construction sequencing. These include highway users, transit, residents, and businesses. Traditional modes such as television, newspaper, and radio will be given closer attention together with more innovative areas like the Internet.

ORGANIZATION OF RESEARCH ACTIVITIES

As a final comment, it is recommended that future work be undertaken using the organizational structure developed in this stage of the research project. In this regard, the designation of a resident research engineer from CTR as part of the TxDOT and contractor team is critical and without such a position, study efforts would have been limited and less successful. Future work should therefore proceed using the resident research engineer as the link between the project and CTR faculty, staff, and students. The proximity of the resident researcher to the job, contractor, and stakeholders enables the team not only to address more formal and structural research problems, but to respond to the unexpected in a timely and effective manner.

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APPENDIX A

N1/N2 SURVEY

Table A1. N1/N2 Questions 1.1-2

Rent	78%	Renew	76%
		Not Renew	24%
Own	22%		

Questions 1.1 and 1.2 relate to the subject of owning vs. renting an establishment. Table A1 shows a high percentage of respondents (78%) rented their space as opposed to owning. This can be attributed to several reasons; the length of time a business has been at its current location, the stability of the market the business is entering, or where the business views itself in the future in terms of entering a long-term commitment through owning. For establishments who do rent, most respondents (76%) said they do intend to renew their lease agreements when the existing one expires. With the completion of frontage road construction on the N1 and N2 sections, respondents are already reaping benefits from the new roadway.

Question 1.3 tries to get an idea of how long the respondents' businesses have been operating at their current location. It is apparent that just under half had either relocated or begun conducting business after the start of construction. This shows a positive commercial effect of NCE reconstruction and that growth, as in this case, is promoted through a public works project. It is also apparent that business owners view the completion of such projects as promoting opportunities for new businesses to thrive.

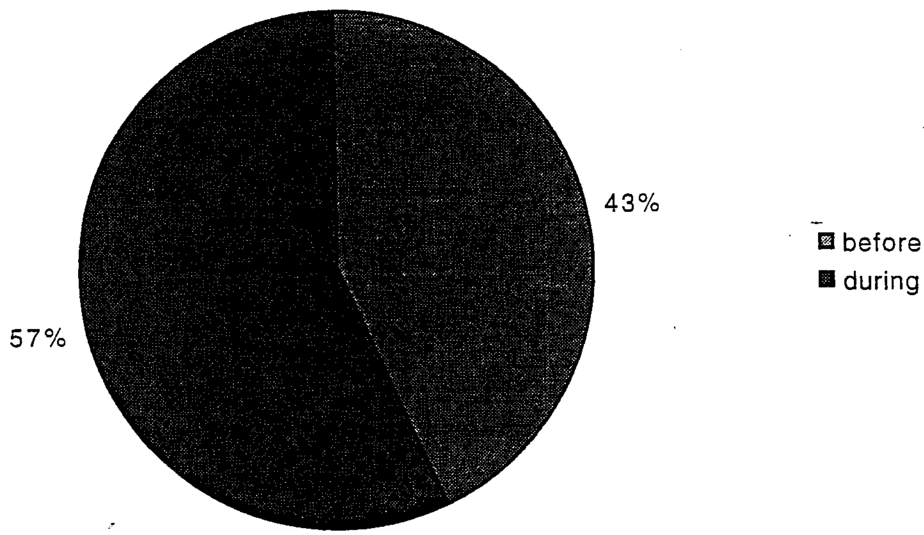


Figure A1. N1/N2 Questions 1.3
When did you start operating at this location of U.S. 75?

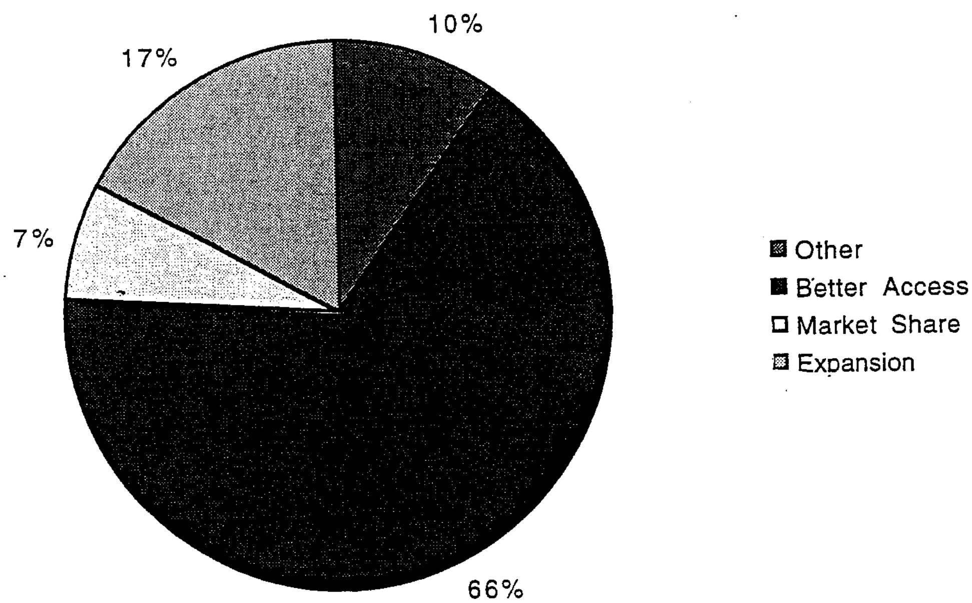


Figure A2. N1/N2 Questions 1.4b
Why did you locate your business on U.S. 75?

Question 1.4b asked why the respondents initiated their operation at their current location. Over 60% responded that access or location was the deciding factor. Others indicated that expansion or market share influenced their decision. It can be concluded that most businesses locating in this area were doing so because of its reputation as a good location or in anticipation of the benefits of the completed highway.

Question 1.5b asks when and how the respondents learned of construction activity on U.S. 75. All respondents indicated they learned of construction before it began or just as it appeared in their area. Respondents learned of construction activities either from the newspaper, television, radio, or by simply driving on the expressway (Fig 2.3). The category "other" contained responses such as flyers, general meetings, and forms of mass media. These questions show that the initial communication was adequate and most businesses were aware of the upcoming construction project.

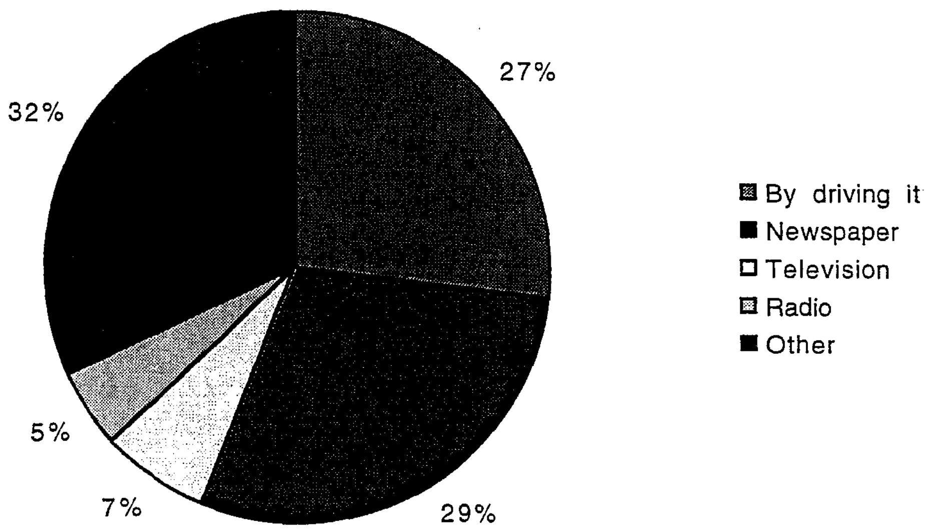


Figure A3. N1/N2 Question 1.5b
How did you learn about the construction?

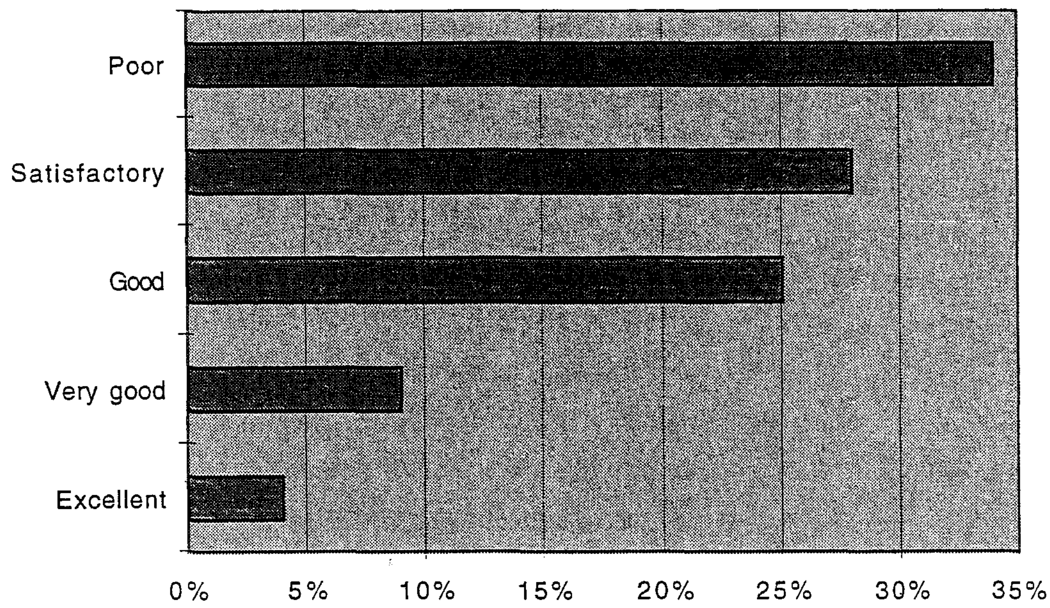


Figure A4. N1/N2 Question 1.6
How effective was the communication between TxDOT and your business?

Question 1.6 addresses the issue of the effectiveness of communication between TxDOT and the respondents' businesses concerning construction activities. Over 33% of the respondents indicated they perceived communication to be poor but 28% felt it was satisfactory. However, 25% of the respondents indicated they felt communication was good, and 13% felt it to be very good or excellent. Such a varied response to this question can be attributable to the fact that some businesses were actively involved in mitigation while others were more passive. The passive businesses would make less effort to approach officials who might be able to help them or supply them with information they could use, and therefore lead to their perception of poorer communication. This question shows the importance of mitigation between the highway department and not only the contractor but also businesses

In What Ways Were Each of the Following Affected During Construction?

Table A2. N1/N2 Question 2.2a-f

	Major Effect	Significant Effect	Some Effect	Little Effect	No Effect	Unknown
Sales	15%	23%	12%	12%	19%	20%
Driveway (Access)	11%	25%	14%	-	50%	-
Parking Space	-	-	-	-	100%	-
Customers	20%	37%	22%	8%	12%	-
Employees	-	14%	31%	-	55%	-
Driving Patterns	26%	14%	19%	19%	21%	-

Question 2.2 deals with perceived negative effects felt by businesses in six particular areas: sales, access, parking space, customer attitudes, employees, and driving patterns during the construction process. Better than 35% indicated major or significant effects on sales, driveway access, customer attitudes, and driving patterns. However, 50% indicated there were no effects felt on driveway access. It may be concluded that the problem of access was specific to only a few areas instead of being a wide-spread problem throughout the section. However, even though driveway access and parking seemed to have been the least effected, customers were effected the most. This shows that customers put value on safety and travel time as well as driveway access and parking availability.

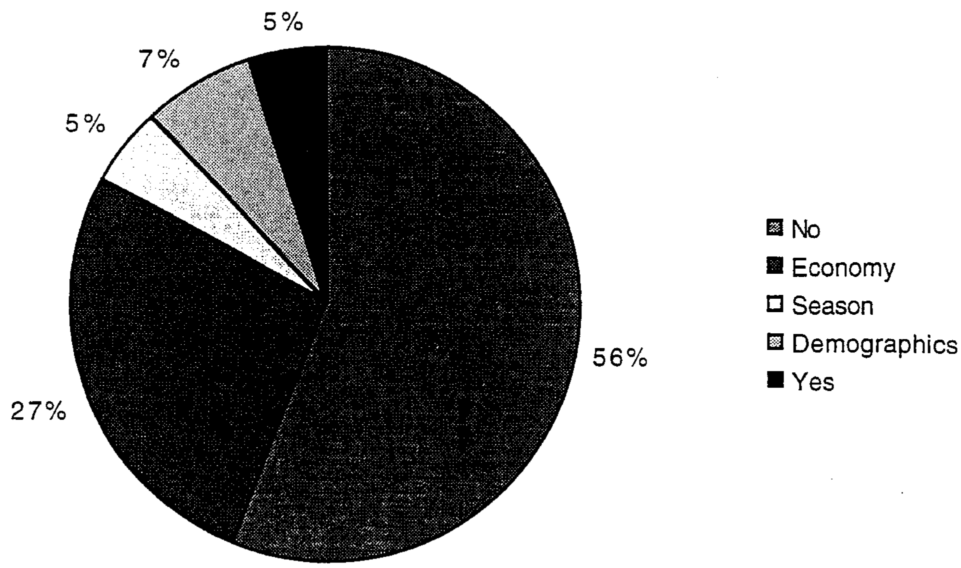


Figure A5. N1/N2 Question 2.3
Are there any other factors that could affect your business activities?

Question 2.3 tries to determine if there are any possible factors, outside of construction, that could effect respondent's business activities. Most (over 50%) indicated there were no other factors, while some indicated the season of year, demographics, and the economy in general. Where responses were "yes," there was no indication of what the factors might be.

Table A3. N1/N2 Question 2.4a-b

	Poor	Satisfactory	Good	Very Good	Excellent
Construction Process	19%	32%	33%	13%	3%
Safety	16%	34%	25%	19%	4%

Question 2.4a evaluates TxDOT's and contractor's handling of the construction process and safety. Only 3% and 4% of respondents, respectively, felt an excellent job was done while just over 50% in both cases felt either a poor or satisfactory job was done in this area, possibly attributed to the fact that since this was the first section under construction during the project,

unforeseen problems would occur that could then be avoided in proceeding sections. Furthermore, initial impacts were being felt from construction, and change from the norm in so drastic a fashion may have been perceived as being worse than was actually the case.

Table A4. N1/N2 Question 2.5 & 2.7

	Very Little	Nothing	Unaware	Positive
What was done by the Highway Department and the Contractor?	6%	50%	2%	42%
What was done by the Businesses?	-	38%	20%	42%

Questions 2.5 and 2.7 explore individual mitigation efforts by TxDOT, the contractor, and businesses. When asked what perceptions existed concerning efforts by TxDOT and the contractor, responses were mixed, with 50% indicating they were not aware of any actions and 42% indicating positive steps were taken. Positive steps included, but were not limited to, the posting of extra signs and more one-on-one communication with businesses. Although the large percentage of positive responses is encouraging, the even larger percentage indicating no knowledge of mitigation efforts shows the need for more communication

Concerning mitigation efforts made by businesses, 38% indicated there was nothing they could have done to prevent the effects on their business, while an additional 20% were unaware there were things they could have done. Forty-two percent of respondents stated they took such measures as increased advertising, greater customer sensitivity, and discounts or sales.

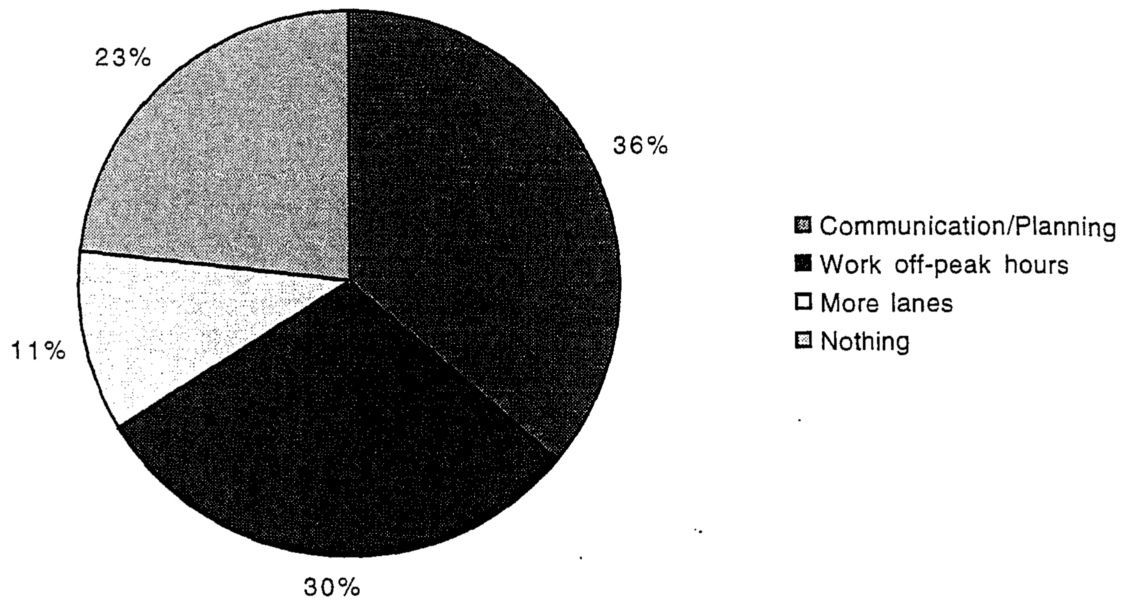


Figure A6. N1/N2 Question 2.6
What additional steps could have been taken by TxDOT/Contractor?

Question 2.6 covers the issue of what the highway department and/or the contractor could be doing differently to facilitate the construction process. Thirty-six percent of respondents indicated there could be more communication and planning with the businesses. Another 30% indicated workers could perform their construction tasks at night, during off-peak hours for the Expressway. Just over 20% indicated there was nothing that could be done. Again this shows a lack of communication. In most cases providing more lanes or working during the night was not an option due to lack of space and safety concerns. If the public was aware of this, more subjects would have said that nothing additional could have been done and the public would have a better opinion about the mitigation efforts.

Table A5. N1/N2 Question 3.1a-f

	Improving Effect	Same Effect	No Effect	Worsening Effect
Sales	41%	27%	18%	14%
Driveway (Access)	42%	23%	27%	8%
Parking Space	25%	29%	46%	-
Customers	35%	29%	6%	29%
Employees	39%	50%	-	11%
Driving Patterns	34%	28%	-	38%

Question 3.1 deals with perceived changes in effects felt by businesses in the areas of sales, access, parking space, customer attitudes, employees, and driving patterns following the completion of frontage road construction. Substantial improvements were felt by businesses in the N1/N2 sections of the NCE. However, some perceived no improvement or a worsening, especially in the categories of customers, employees, and driving patterns. These categories are still being affected from the ongoing construction of the main lane and, once again, this shows that customers and employees put value on safety and travel time as well as driveway access and parking availability.

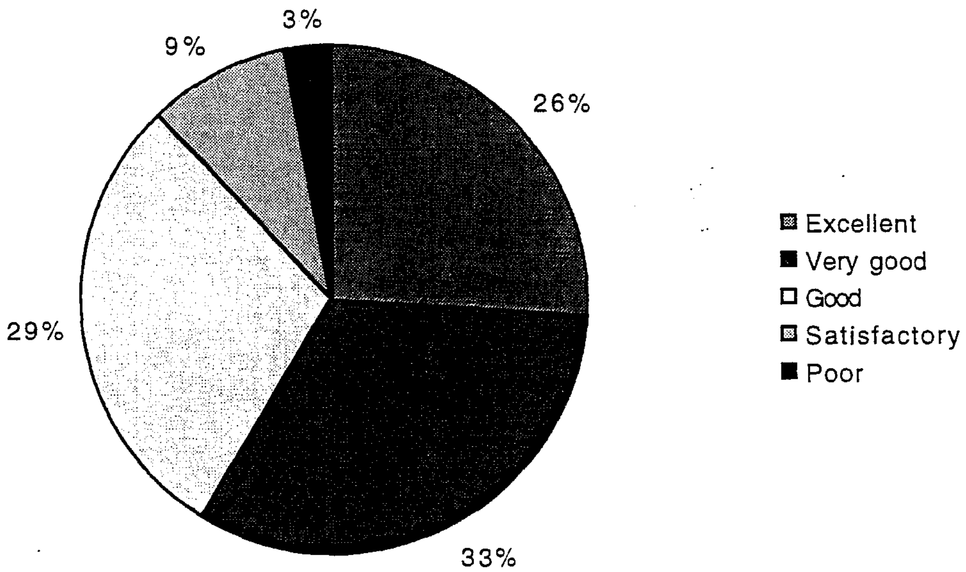


Figure A7. N1/N2 Question 3.2

How would you rate the finished frontage road?

Question 3.2 attempts to determine how respondents perceived the finished frontage road. Over 80% rated it either excellent, very good, or good, thus showing that even when construction negatively affects a business, the need for the finished project is recognized and appreciated. Only 3% felt the frontage road to be poor.

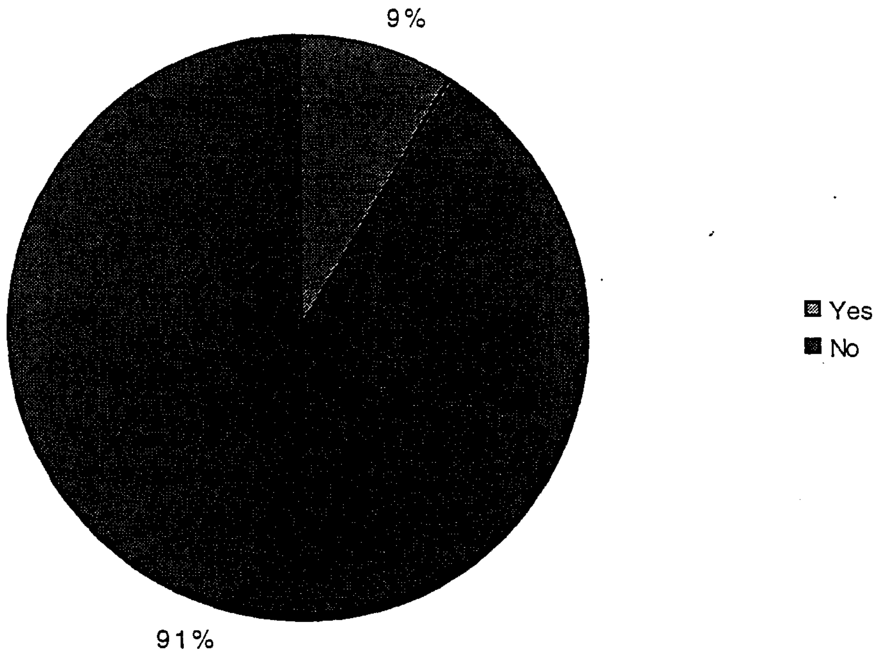


Figure A8. N1/N2 Question 4.1a
Would you consider leasing your ROW and closing your business during construction?

Question 4.1 attempts to determine if businesses would be willing to consider leasing their right-of-way to the construction agency during construction. In other words, there would be a subsidy paid to the businesses that would roughly mimic monthly average earnings of the establishment. In exchange, businesses would temporarily cease operation for the indicated period of construction, thus allowing the process to proceed more expeditiously. Overwhelmingly negative responses were given to this question, which can be attributed to the fact that when a business temporarily closes, its usual patrons must look elsewhere for that specific product, and they might not return when business reopens. This would be a long-term problem for businesses, and might terminally effect their ability to turn a profit after reopening.

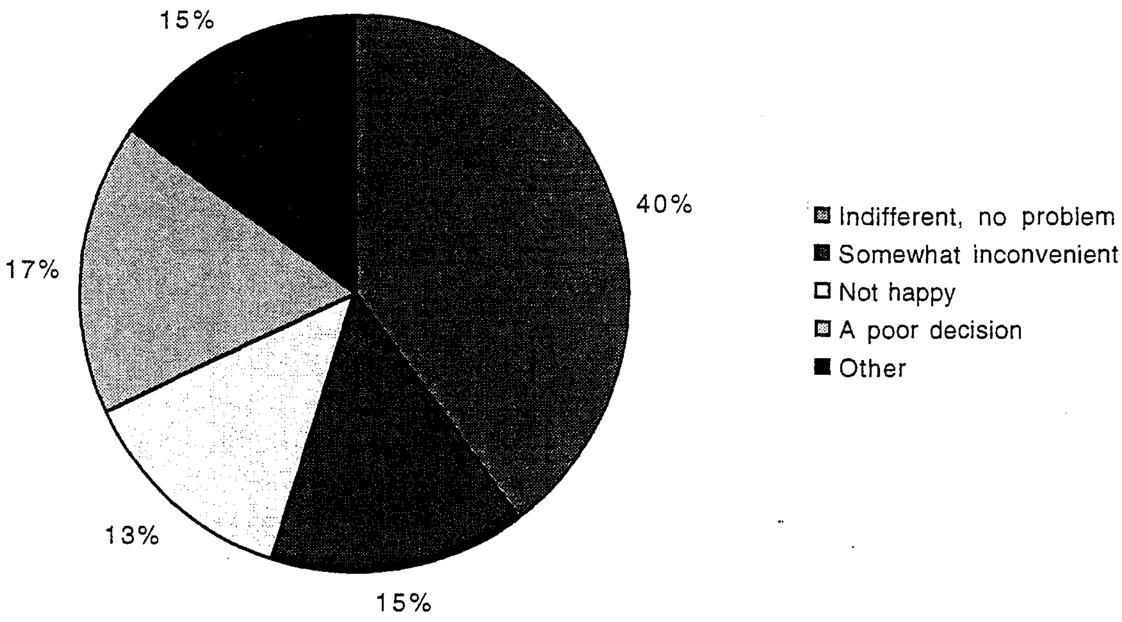


Figure A9. N1/N2 Question 4.3
Effects of the removal of the White Rock Creek U-turn?

Question 4.3 asks respondents if the removal of a U-turn along the NCE within their sections (N1/N2) has caused any problems. Mixed responses to this question were received, which might be expected due to the fact that people live in different areas, and therefore have different transportation infrastructure needs. Fifteen percent indicated the removal somewhat inconvenienced them and 40% were indifferent. Thirty percent, however, felt the removal was a bad decision and were generally not happy. Removal of this U-turn may have effected travel patterns of customers to those businesses, making the use of rival businesses more convenient. Improved communication may have helped in this situation, providing a clearer understanding of the reason for the decision to remove the U-turn (benefits to the overall reconstruction project), thus alleviating some of the negative opinions about the decision.

NORTH CENTRAL EXPRESSWAY QUESTIONNAIRE

The Texas Department of Transportation (TxDOT) is sponsoring research at UT-Austin to measure the impact of US 75 construction on the businesses in Dallas. As part of the study we would like you to answer the following questions. (Note: Use additional paper if needed.)

Identification

Business Name:	____________________	Business Type:	____________________
Contact Person:	____________________	Position:	____________________
Work Address:	____________________	Phone:	____________________

I. General

1.1 Is this space rented or owned by the business? *Circle one* *Owned* *Rented*

1.2 If you rent the space, do you intend on renewing your contract at the lease's end?

Circle One *Yes* *No*

If *yes,* why? ____

____

1.3 When did you begin operation at your current location? *Give date* ____________
month/year

1.4 Why did you locate your business at North Central?

____

1.5 When and how did you learn of the US 75 construction?

When? ____

How? ____

1.6 How effective was the communication between the Highway Department and your business in relation to the construction activities?

Circle one *Excellent* *Very Good* *Good* *Satisfactory* *Poor*

Explain: ____

____

II. During the Frontage Road Construction

2.1 How long did the construction of the frontage road last in front of your business?

Please give duration in months: ____________

2.2 Please explain in what ways each of the following were effected <u>during construction</u>.

a) Sales:

__ not at all
__ somewhat (<10%)
__ moderately (10-25%)
__ significantly (25-40%)
__ extremely (>40%)

b) Driveway:

__ not at all (no access problems)
__ partially (some access problems)
__ significantly (most of the time)
__ completely (almost no access)
__ other (explain)

c) Parking Spaces:

__ no loss of space
__ lost a few spaces
__ lost about half
__ lost most spaces
__ other (explain)

d) Customers:

__ no problems
__ indifferent (didn't care)
__ upset, stressed
__ angry
__ other (explain)

e) Employees

__ no problems
__ tardiness
__ disgruntled
__ high turnover rate
__ other (explain)

f) Driving Patterns

__ did not change
__ somewhat different
__ moderately different
__ varied greatly
__ other (explain)

2.3 Were there any other external or internal factors, besides the construction, that could affect your business activities? (i.e. business strategies, economic fluctuations)

____

2.4 How would you rate the handling of the following?

Construction Process:	Excellent	Very Good	Good	Satisfactory	Poor
Safety Issues:	Excellent	Very Good	Good	Satisfactory	Poor

2.5 What did the Highway Department and/or the contractor do to make things easier during the construction process?

__ Nothing
__ Very Little
__ Were generally very helpful
__ Unaware of what they might have done

2.6 What could the Highway Department and/or contractor have done differently to make things easier during the construction process?

__ Nothing
__ Post informative signs, etc.
__ More communication/notification towards businesses and/or public
__ Work at night, or during off-peak hours
__ Other (explain) ____________________

2.7 Did you take any additional steps to minimize any inconveniences?

__ No, what could I have done?
__ More advertising
__ Offered discounts
__ Additional customer communication/sensitivity
__ Other (explain) ____________________

III. After the Frontage Road Construction

3.1 Please explain in what ways each of the following were affected by the new frontage road:

a) Sales:

__ not at all
__ somewhat (<10%)
__ moderately (10-25%)
__ significantly (25-40%)
__ extremely (>40%)

b) Driveway:

__ not at all (no access problems)
__ partially (some access problems)
__ significantly (most of the time)
__ completely (almost no access)
__ other (explain)

c) Parking Spaces:

__ no loss of space
__ lost a few spaces
__ lost about half
__ lost most spaces
__ other (explain)

d) Customers:

__ no problems
__ indifferent (didn't care)
__ upset, stressed
__ angry
__ other (explain)

e) Employees

__ no problems
__ tardiness
__ disgruntled
__ high turnover rate
__ other (explain)

f) Driving Patterns

__ did not change
__ somewhat different
__ moderately different
__ varied greatly
__ other (explain)

3.2 How would you rate the finished frontage road?

Circle One   Excellent   Very Good   Good   Satisfactory   Poor

IV. Final Comments

4.1 Would you consider leasing your right of way and closing your business during the construction period to expedite the work? *Circle One*   *Yes*   *No*

If *yes,* would you estimate a monthly amount? $___________

4.2 Do you recall any businesses that closed due to the construction activities?

Circle One   *Yes*   *No*   If *yes,* give name(s):________________________

4.3a How do you feel about the removal of the U-turns on US75?

__ Indifferent   __ An inconvenience   __ Not happy   __ A poor decision

4.3b How do you feel about the bridges being only serving traffic in one direction?

__ Indifferent   __ An inconvenience   __ Not happy   __ A poor decision

4.4 Do you have any other additional comments concerning the construction?

____

____

APPENDIX B

M/S2 SURVEY

Table B1. M/S2 Questions 1.1-2

		Renew	67%
Rent	93%	Not Renew	10%
		Unknown	23%
Own	7%		

Questions 1.1 and 1.2 relate to the subject of owning vs. renting an establishment. Table B1 shows almost all respondents to the survey (93%) rented their space as opposed to owning, which was similar to the responses received on Questions 1.1 and 1.2 of the N1/N2 survey. This can be attributed to several reasons: the length of time a business has been at its current location, the stability of the market the business is entering, or where the business might see itself in the future in terms of being locked into a long-term commitment through owning. For establishments who do rent, two-thirds of respondents (67%) said they do intend to renew their lease agreement when the existing one expires. Interestingly, 23% indicated they were unsure as to what their decision would be. These businesses are most likely marginal, and the next few months of construction may play a significant role in determining their final decision whether or not to renew.

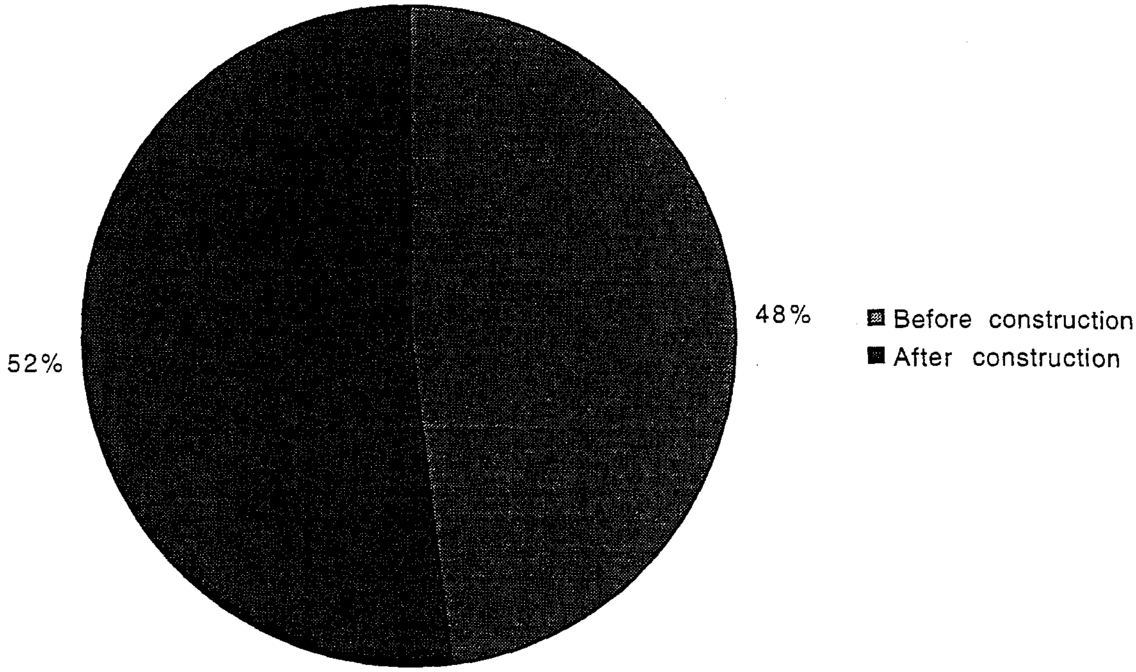


Figure B1. M/S2 Question 1.3
When did you begin operation at your current location?

Question 1.3 tries to get an idea of how long respondents' businesses have been located at their current location. It is apparent that roughly half the businesses surveyed have relocated or had begun conducting business after the start of construction. This shows how effects of reconstruction can be felt commercially, and once again how growth might be promoted through a public works project.

Question 1.4 asks why respondents initiated their operation at their current location. Responses to this question were generally the same, with the main reasons being location, access, and that the area was vigorous commercially. In conclusion, businesses located in this area were doing so because of its reputation as a good location.

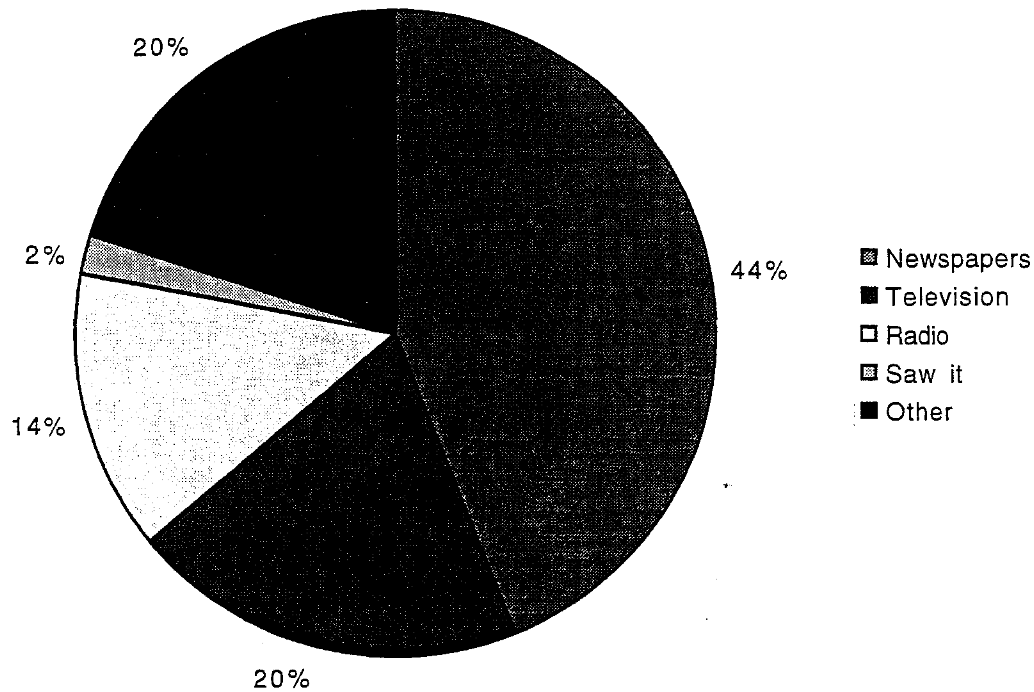


Figure B2. M/S2 Question 1.5b
How did you learn about the construction?

Question 1.5 discussed when and how the respondent learned of construction. Answers regarding when were varied, with responses ranging from a few years before to any point during the construction process. It can therefore be concluded that a majority of respondents were aware of construction either before or just after it was initiated.

Answers regarding how respondents learned about construction are indicated in the Figure B2. Respondents learned of construction activities through television, radio, the newspaper, or by simply driving on the roadway. Other responses included flyers, town meetings, and general forms of media. Again these questions show that the initial communication was adequate for informing the majority of the public of the upcoming reconstruction project.

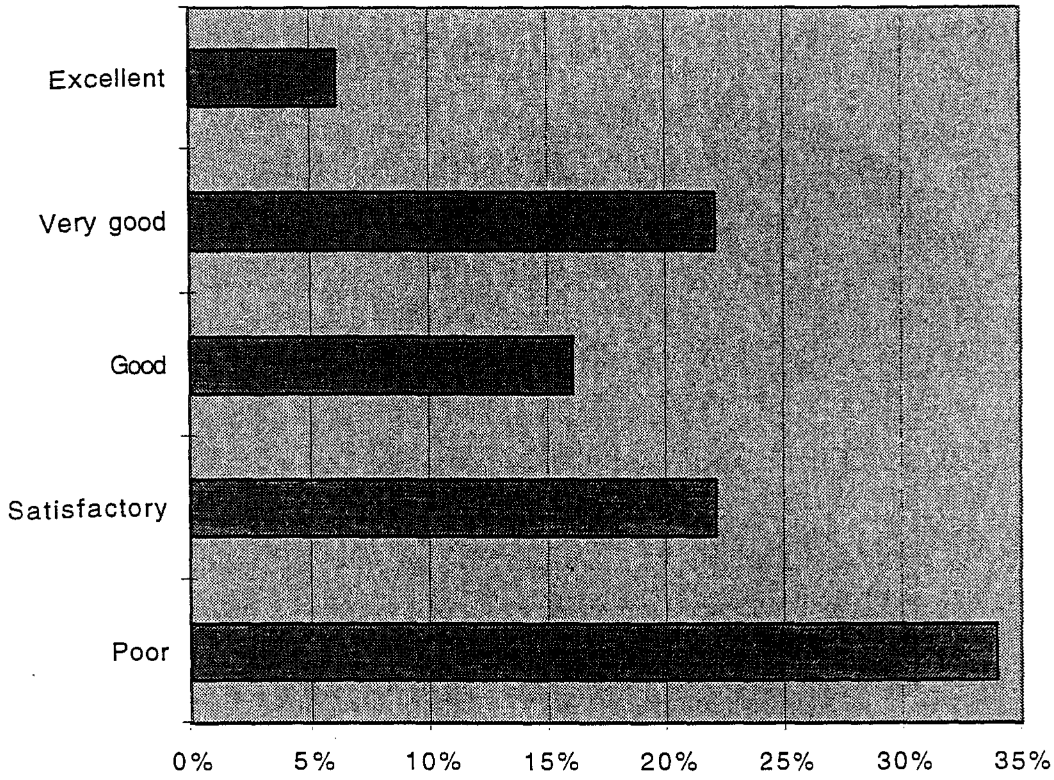


Figure B3. M/S2 Question 1.6
How effective is communication between TxDOT and your business?

Question 1.6 addresses the effectiveness of communication TxDOT and respondents' businesses concerning construction activities. Over one-third the respondents to this question indicated they perceived communication to be poor with 22% stating it was satisfactory. However, 16% of respondents indicated they felt communication to be good, 22% felt it to be very good, and 6% felt communication was excellent. Overall, this shows a slight improvement from the first questionnaire.

Table B2. M/S2 Question 2.2a-f

	Major Effect	Significant Effect	Some Effect	Little Effect	No Effect	Unknown
Sales	19%	17%	37%	19%	9%	-
Driveway (Access)	11%	39%	34%	-	16%	-
Parking Space	-	4%	-	21%	73%	2%
Customers	-	18%	64%	11%	2%	5%
Employees	2%	20%	35%	-	40%	4%
Driving Patterns	38%	27%	25%	-	9%	-

Question 2.2 deals with perceived negative effects felt by businesses in sales, access, parking space, customer attitudes, employees, and driving patterns during the construction process within the M/S2 sections of U.S. 75. As shown in Table B2, the worst effects were noted in sales, access, and driving patterns. There were moderate effects felt by customers, while there was minimal effect on parking space and employees. These results are somewhat similar to results obtained in the N1/N2 survey, with one substantial difference being that customers were less effected in the M/S2 sections than in the N1/N2 sections. One reason might be that businesses, as well as customers, had already adapted to construction during the N1/N2 phase and were better prepared for the changes.

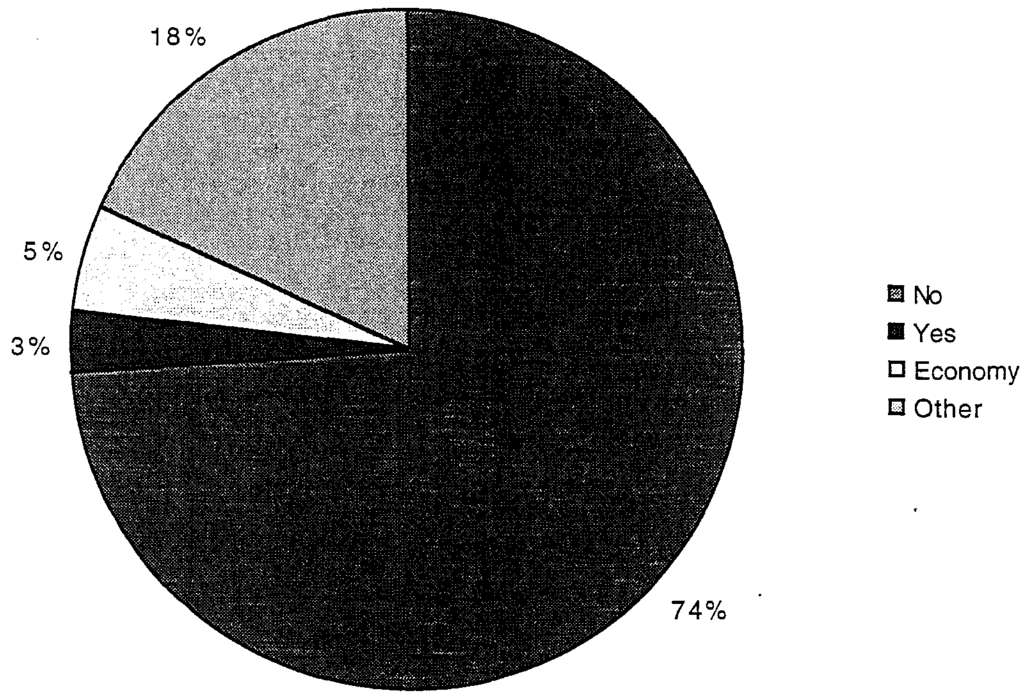


Figure B4. M/S2 Question 2.3
Are there any other factors that could affect your business activities?

Question 2.3 asks respondents if there were any other factors, internal or external, that could affect business activities. For the most part it is obvious there were not many businesses who felt there were any factors, as evidenced by the 74% response rate. This remains consistent with the previous questionnaire. Some respondents also mentioned the economy, rival businesses opening, traffic fluctuations, and business restructuring as other factors affecting business activities.

Table B3. M/S2 Question 2.4a-b

	Poor	Satisfactory	Good	Very Good	Excellent
Construction Process	6%	17%	19%	41%	19%
Safety	4%	24%	24%	32%	16%

Questions 2.4a and 2.4b ask for respondents' opinions of TxDOT's and the contractor's handling of the construction process and safety. As shown in Table B3, perceptions were more positive than in N1/N2 survey, where a poor to average job was perceived by businesses.

Table B4. M/S2 Question 2.5 & 2.7

	Very Little	Nothing	Unaware	Positive	Other
What was done by the Highway Department and the Contractor?	30%	15%	24%	24%	7%
What was done by the Businesses?	23%	38%	-	30%	9%

Questions 2.5 and 2.7 explore individual mitigation efforts by TxDOT and the contractor and by the businesses. When asked what perceptions existed concerning efforts of TxDOT and the contractor, responses were again mixed, with 24% noting they were unaware of anything being done and an additional 24% indicating positive measures were taken. Positive measures included activities such as posting of extra signs and increased one-on-one communication with businesses. Forty-five percent of businesses felt either nothing or very little was done. Interestingly, the businesses indicated that less positive measures within M/S2 sections were taken than was shown in the previous questionnaire. One reason for this could be the improved construction effort in this section, thus reducing the need for extra measures.

When asked what efforts businesses made in construction mitigation, 38% indicated that nothing could have done to prevent negative impacts, while an additional 23% thought that very little could be done. Thirty percent of respondents stated they took such measures as increased advertising, greater customer sensitivity, and increased discounts or sales.

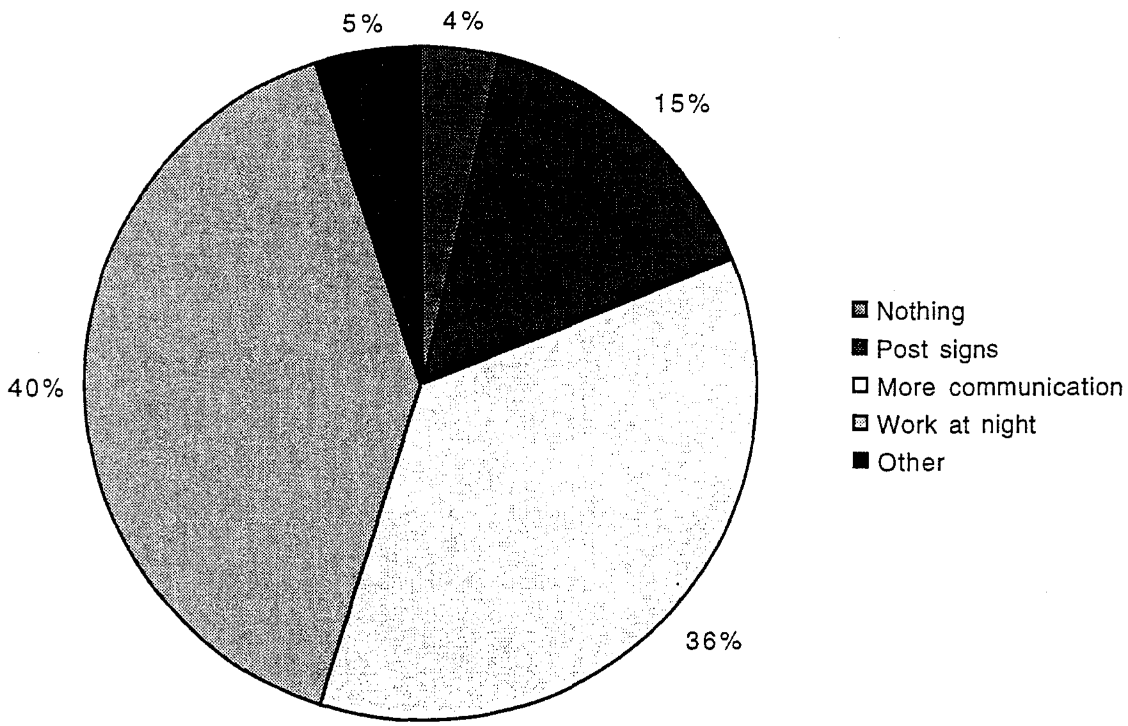


Figure B5. M/S2 Question 2.6
What could be done to facilitate the construction process?

Question 2.6 discusses what TxDOT or the contractor could be doing differently to facilitate the construction process. Most respondents felt that construction work done at night, during off-peak hours, would lessen the negative business impacts. Again, more communication was needed to explain to the public that it was not safe to work at night. However, a more positive outlook about the construction on the part of the businesses was conveyed in this survey as compared to the responses in the initial survey.

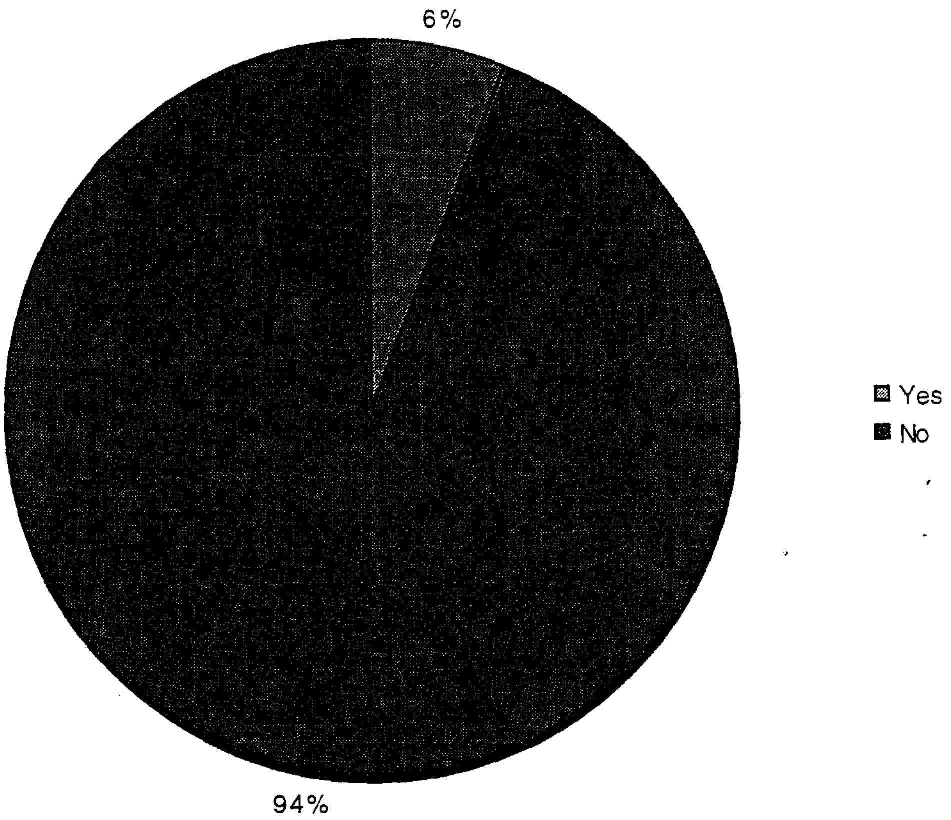


Figure B6. M/S2 Question 3.1a
Would you consider leasing your ROW during construction to expedite the work?

Question 3.1 attempts to measure the number of people who would be willing to consider leasing their right-of-way to the construction agency during the construction. Responses were predominantly negative to this question, which can be attributable to the fact that when a business temporarily closes, its regular customers must look elsewhere to shop, and they might not return when the business reopens.

Table B5. M/S2 Question 3.3a-b

	Indifferent	An Inconvenience	Not Happy	A Poor Decision
Access ramp elimination	25%	35%	25%	15%
One-way bridge traffic	17%	37%	30%	17%

Questions 3.3a and 3.3b were specific to the M/S2 section and concerned opinions about two measures taken during construction; the permanent elimination of some previously existing access ramps, and the temporary re-routing of traffic during which some bridges carried one-way traffic only. Opinions varied, with no great difference in the responses in each category. Overall, it could be concluded that there was general displeasure with the two measures taken. This displeasure may have been lessened if the reasons (benefits to the overall reconstruction project) were better communicated. It is important to note, however, that responses to these types of questions may be markedly different when asked following completion of construction, as problems are often magnified in the present compared to when they are in the past.

NORTH CENTRAL EXPRESSWAY QUESTIONNAIRE

The Texas Department of Transportation (TxDOT) is sponsoring research at UT-Austin to measure the impact of US 75 construction on the businesses in Dallas. As part of the study we would like you to answer the following questions. (Note: Use additional paper if needed.)

Identification

Business Name: ____________________ Business Type: ____________________
Contact Person: ____________________ Position: ____________________
Work Address: ____________________ Phone: ____________________

I. General

1.1 Is this space rented or owned by the business? *Circle one* *Owned* *Rented*

1.2 If you rent the space, do you intend on renewing your contract at the lease's end?

Circle One *Yes* *No*

If *yes*, why? ____

____

1.3 When did you begin operation at your current location? *Give date* ____________
month/year

1.4 Why did you locate your business at North Central?

____

1.5 When and how did you learn of the US 75 construction?

When? ____

How? ____

1.6 How effective is the communication between the Highway Department and your business in relation to the construction activities?

Circle one *Excellent* *Very Good* *Good* *Satisfactory* *Poor*

Explain: ____

____

II. During the Frontage Road Construction

2.1 How long has the construction of the frontage road existed in front of your business?

Please give duration in months: ____________

2.2 Please explain in what ways each of the following are effected <u>during construction</u>.

a) Sales:

- __ not at all
- __ somewhat (<10%)
- __ moderately (10-25%)
- __ significantly (25-40%)
- __ extremely (>40%)

b) Driveway:

- __ not at all (no access problems)
- __ partially (some access problems)
- __ significantly (most of the time)
- __ completely (almost no access)
- __ other (explain)

c) Parking Spaces:

- __ no loss of space
- __ lost a few spaces
- __ lost about half
- __ lost most spaces
- __ other (explain)

d) Customers:

- __ no problems
- __ indifferent (didn't care)
- __ upset, stressed
- __ angry
- __ other (explain)

e) Employees

- __ no problems
- __ tardiness
- __ disgruntled
- __ high turnover rate
- __ other (explain)

f) Driving Patterns

- __ did not change
- __ somewhat different
- __ moderately different
- __ varied greatly
- __ other (explain)

2.3 Are there any other external or internal factors, besides the construction, that could affect your business activities? (i.e. business strategies, economic fluctuations)

____

2.4 How would you rate the handling of the following?

Construction Process:	Excellent	Very Good	Good	Satisfactory	Poor
Safety Issues:	Excellent	Very Good	Good	Satisfactory	Poor

2.5 What are the Highway Department and/or the contractor doing to make things easier during the construction process?

- __ Nothing
- __ Very Little
- __ Were generally very helpful
- __ Unaware of what they might have done
- __ Other (explain) ____

2.6 What could the Highway Department and/or contractor do differently to make things easier during the construction process?

- __ Nothing
- __ Post informative signs, etc.
- __ More communication/notification towards businesses and/or public
- __ Work at night, or during off-peak hours
- __ Other (explain) ____________________

2.7 Have you taken any additional steps to minimize any inconveniences?

- __ No, what could I do?
- __ More advertising
- __ Offered discounts
- __ Additional customer communication/sensitivity
- __ Other (explain) ____________________

III. Final Comments

3.1 Would you consider leasing your right of way and closing your business during the construction period to expedite the work? *Circle One* *Yes* *No*
If *yes,* would you estimate a monthly amount? $__________

3.2 Do you recall any businesses that closed due to the construction activities?
Circle One *Yes* *No* If *yes,* give name(s):____________________

3.3a How do you feel about the elimination of access ramps on US75?
__ Indifferent __ An inconvenience __ Not happy __ A poor decision

3.3b How do you feel about the bridges only serving traffic in one direction?
__ Indifferent __ An inconvenience __ Not happy __ A poor decision

3.4 Do you have any other additional comments concerning the construction?

____

____

APPENDIX C

Westbound Arterials

Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Arterial	W	850	212	0.25
Arterial	W	566	155	0.27
Arterial	W	332	97	0.29
Arterial	W	1713	519	0.30
Arterial	W	968	296	0.31
Arterial	W	807	309	0.38
Arterial	W	2608	1015	0.39
Arterial	W	783	310	0.40
Arterial	W	653	262	0.40
Arterial	W	590	253	0.43
Arterial	W	1275	549	0.43
Arterial	W	1322	570	0.43
Arterial	W	1054	455	0.43
Arterial	W	1226	560	0.46
Arterial	W	698	327	0.47
Arterial	W	1323	636	0.48
Arterial	W	602	301	0.50
Arterial	W	639	320	0.50
Arterial	W	2636	1325	0.50
Arterial	W	1138	583	0.51
Arterial	W	3068	1576	0.51
Arterial	W	2148	1111	0.52
Arterial	W	992	518	0.52
Arterial	W	19	10	0.53
Arterial	W	1103	633	0.57
Arterial	W	1623	970	0.60
Arterial	W	2852	1751	0.61
Arterial	W	822	509	0.62
Arterial	W	468	292	0.62
Arterial	W	297	230	0.77
Arterial	W	340	288	0.85
Arterial	W	1032	917	0.89
Arterial	W	505	461	0.91
Arterial	W	966	892	0.92
Arterial	W	79	81	1.03
Arterial	W	1113	1263	1.13

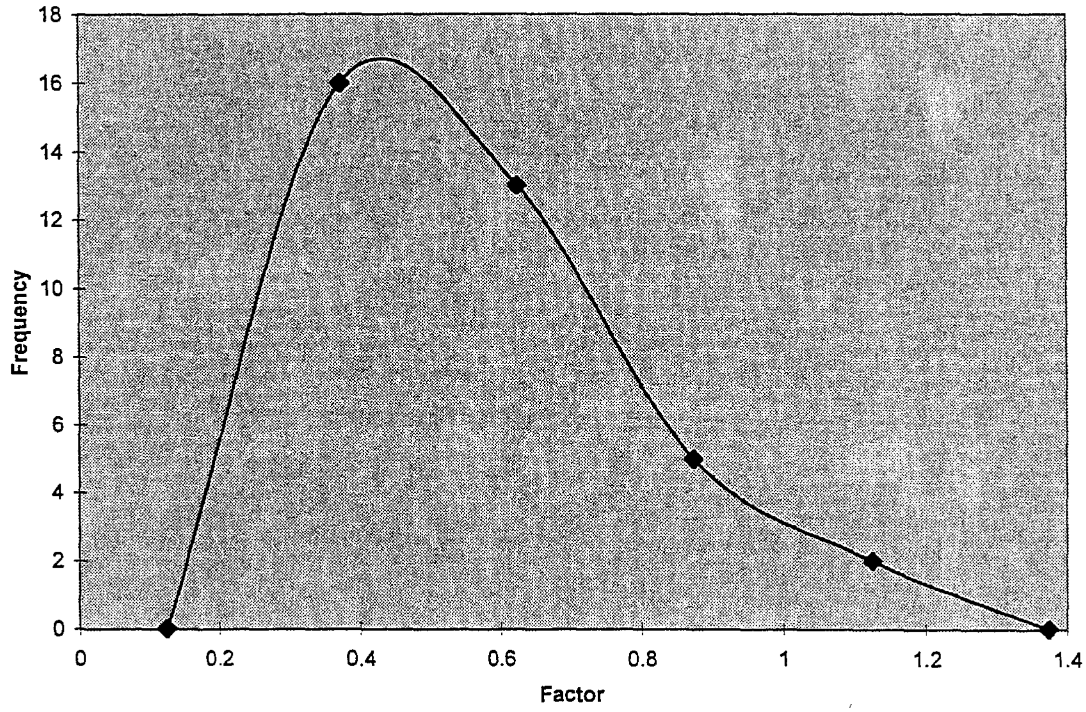
$\mu = 0.55$
$\sigma = 0.22$
$\sigma/\mu = 0.40$

Westbound Arterials

Interval	Midpoint	Freq.
0.0 - 0.25	0.125	0
0.25 - 0.50	0.375	16
0.50 - 0.75	0.625	13
0.75 - 1.0	0.875	5
1.0 - 1.25	1.125	2
1.25 - 1.50	1.375	0

$\mu = 0.55$
$\sigma = 0.22$
$\sigma/\mu = 0.40$

Westbound Arterials



Eastbound Arterials

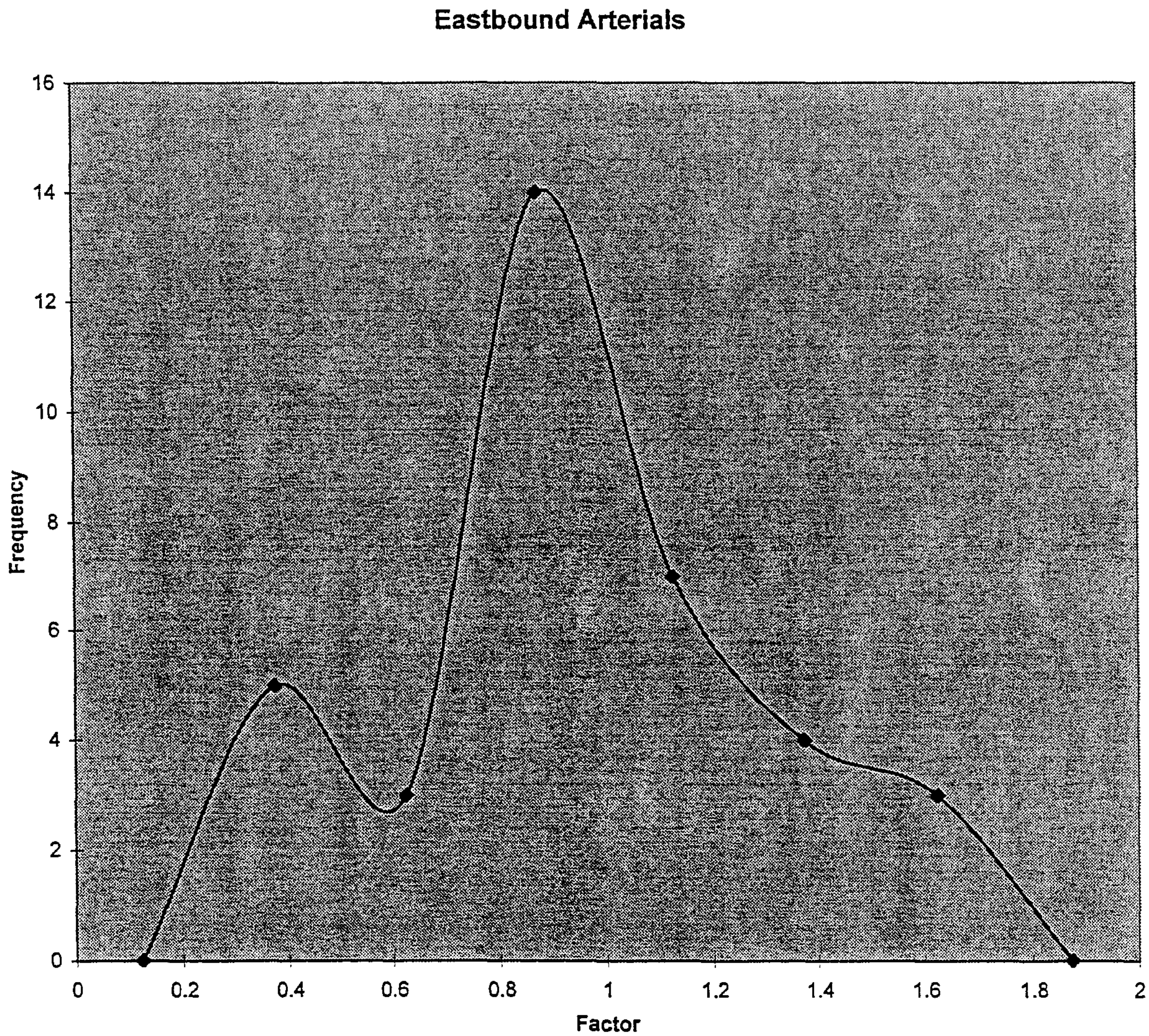
Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Arterial	E	604	208	0.34
Arterial	E	703	259	0.37
Arterial	E	1350	516	0.38
Arterial	E	369	161	0.44
Arterial	E	358	157	0.44
Arterial	E	835	498	0.60
Arterial	E	319	198	0.62
Arterial	E	1641	1219	0.74
Arterial	E	1512	1160	0.77
Arterial	E	384	304	0.79
Arterial	E	764	625	0.82
Arterial	E	252	211	0.84
Arterial	E	180	153	0.85
Arterial	E	378	342	0.90
Arterial	E	548	514	0.94
Arterial	E	980	920	0.94
Arterial	E	477	454	0.95
Arterial	E	95	92	0.97
Arterial	E	596	579	0.97
Arterial	E	184	179	0.97
Arterial	E	570	556	0.98
Arterial	E	740	734	0.99
Arterial	E	183	201	1.10
Arterial	E	161	178	1.11
Arterial	E	958	1076	1.12
Arterial	E	133	151	1.14
Arterial	E	84	97	1.15
Arterial	E	303	356	1.17
Arterial	E	126	150	1.19
Arterial	E	298	377	1.27
Arterial	E	328	429	1.31
Arterial	E	434	599	1.38
Arterial	E	428	639	1.49
Arterial	E	26	39	1.50
Arterial	E	539	835	1.55
Arterial	E	70	114	1.63

$\mu = 0.96$
$\sigma = 0.34$
$\sigma/\mu = 0.35$

Eastbound Arterials

Interval	Midpoint	Freq.
0.0 - 0.25	0.125	0
0.25 - 0.50	0.375	5
0.50 - 0.75	0.625	3
0.75 - 1.0	0.875	14
1.0 - 1.25	1.125	7
1.25 - 1.50	1.375	4
1.50 - 1.75	1.625	3
1.75 - 2.0	1.875	0

$\mu = 0.96$
$\sigma = 0.34$
$\sigma/\mu = 0.35$



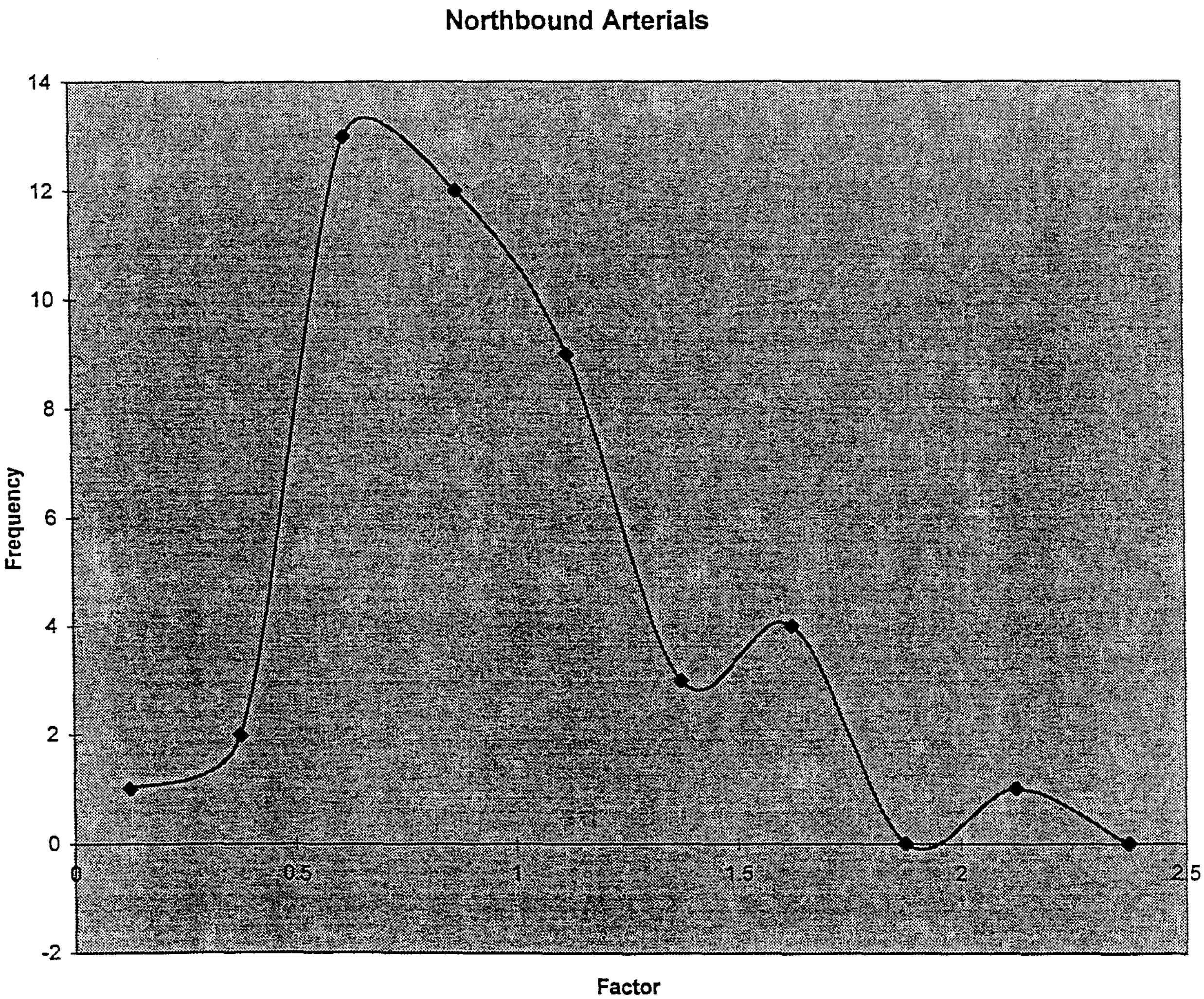
Northbound Arterials

Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Arterial	N	1270	449	0.35
Arterial	N	1123	455	0.41
Arterial	N	828	509	0.61
Arterial	N	903	570	0.63
Arterial	N	622	395	0.64
Arterial	N	353	229	0.65
Arterial	N	579	378	0.65
Arterial	N	1175	785	0.67
Arterial	N	1064	716	0.67
Arterial	N	1237	840	0.68
Arterial	N	684	471	0.69
Arterial	N	458	319	0.70
Arterial	N	1202	838	0.70
Arterial	N	1001	711	0.71
Arterial	N	753	553	0.73
Arterial	N	906	677	0.75
Arterial	N	606	455	0.75
Arterial	N	627	475	0.76
Arterial	N	600	480	0.80
Arterial	N	693	574	0.83
Arterial	N	790	664	0.84
Arterial	N	253	226	0.89
Arterial	N	412	371	0.90
Arterial	N	354	321	0.91
Arterial	N	3748	3432	0.92
Arterial	N	292	281	0.96
Arterial	N	743	737	0.99
Arterial	N	272	281	1.03
Arterial	N	335	348	1.04
Arterial	N	589	622	1.06
Arterial	N	832	879	1.06
Arterial	N	622	659	1.06
Arterial	N	920	992	1.08
Arterial	N	333	379	1.14
Arterial	N	316	379	1.20
Arterial	N	317	387	1.22
Arterial	N	500	626	1.25
Arterial	N	251	332	1.32
Arterial	N	430	628	1.46
Arterial	N	217	344	1.59
Arterial	N	191	307	1.61
Arterial	N	210	346	1.65
Arterial	N	305	526	1.72
Arterial	N	181	358	1.98
Arterial	N	160	324	2.03

$\mu = 0.98$
$\sigma = 0.39$
$\sigma/\mu = 0.40$

Interval	Midpoint	Freq.
0.0 - 0.25	0.125	1
0.25 - 0.50	0.375	2
0.50 - 0.75	0.625	13
0.75 - 1.0	0.875	12
1.0 - 1.25	1.125	9
1.25 - 1.50	1.375	3
1.50 - 1.75	1.625	4
1.75 - 2.0	1.875	0
2.0 - 2.25	2.125	1
2.25 - 2.50	2.375	0

$\mu = 0.98$
$\sigma = 0.39$
$\sigma/\mu = 0.40$



Southbound Arterials

Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Arterial	S	2254	451	0.20
Arterial	S	937	241	0.26
Arterial	S	1708	510	0.30
Arterial	S	1328	410	0.31
Arterial	S	2303	801	0.35
Arterial	S	1253	436	0.35
Arterial	S	1225	435	0.36
Arterial	S	1979	715	0.36
Arterial	S	1662	613	0.37
Arterial	S	1250	462	0.37
Arterial	S	703	261	0.37
Arterial	S	1478	556	0.38
Arterial	S	1087	420	0.39
Arterial	S	1012	410	0.41
Arterial	S	1961	798	0.41
Arterial	S	1166	526	0.45
Arterial	S	1642	784	0.48
Arterial	S	781	410	0.52
Arterial	S	1194	641	0.54
Arterial	S	1688	909	0.54
Arterial	S	1201	658	0.55
Arterial	S	1495	844	0.56
Arterial	S	1686	977	0.58
Arterial	S	609	382	0.63
Arterial	S	699	445	0.64
Arterial	S	470	300	0.64
Arterial	S	1271	815	0.64
Arterial	S	813	534	0.66
Arterial	S	169	112	0.66
Arterial	S	925	614	0.66
Arterial	S	1038	691	0.67
Arterial	S	437	295	0.68
Arterial	S	863	585	0.68
Arterial	S	609	414	0.68
Arterial	S	707	483	0.68
Arterial	S	867	599	0.69
Arterial	S	685	479	0.70
Arterial	S	1855	1311	0.71
Arterial	S	484	349	0.72
Arterial	S	795	587	0.74
Arterial	S	931	700	0.75
Arterial	S	655	494	0.75
Arterial	S	575	481	0.84
Arterial	S	862	765	0.89
Arterial	S	727	652	0.90
Arterial	S	63	58	0.92
Arterial	S	3173	3876	1.22

$\mu = 0.58$

$\sigma = 0.20$

$\sigma/\mu = 0.35$

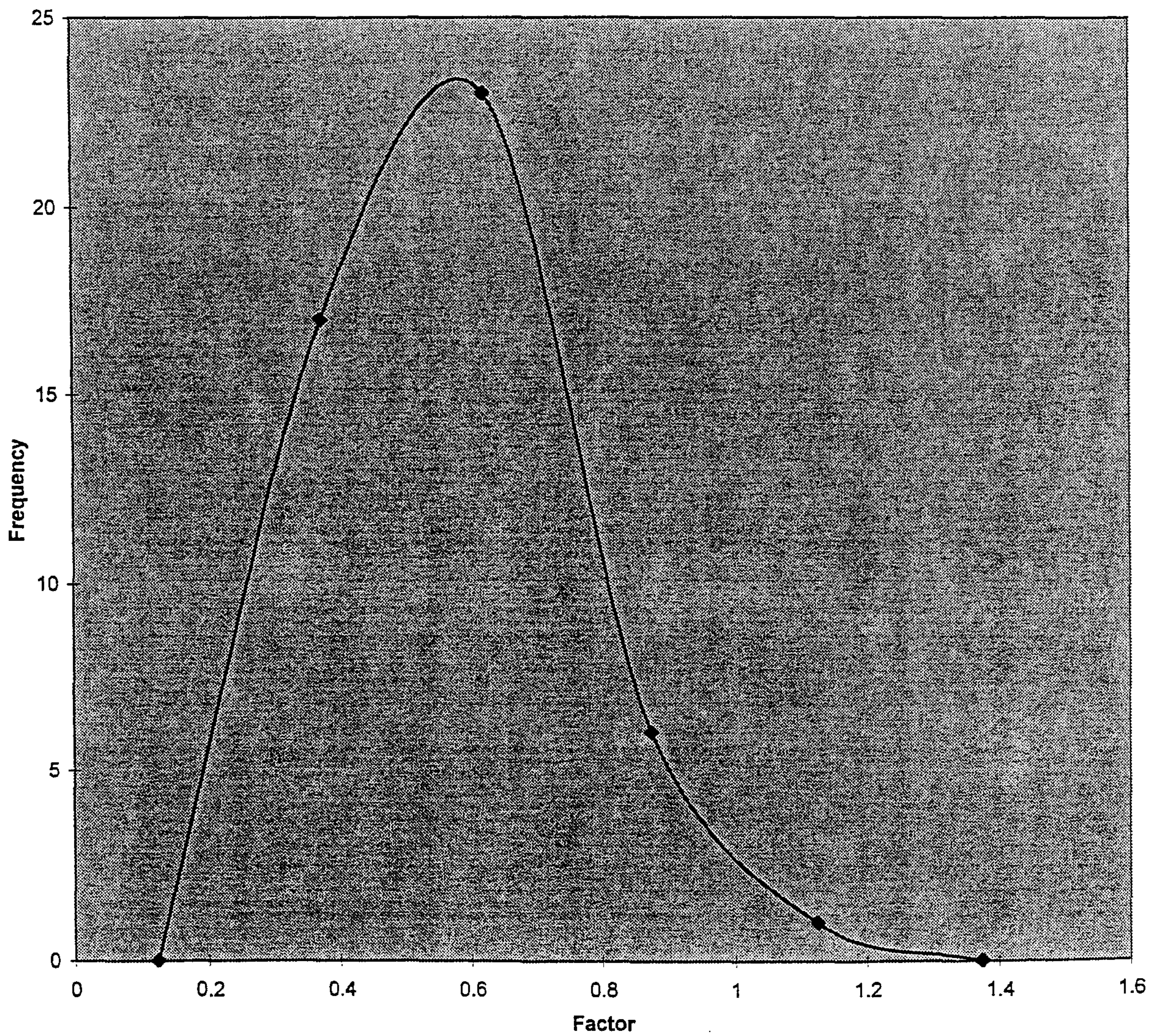
Interval	Midpoint	Freq.
0.0 - 0.25	0.125	0
0.25 - 0.50	0.375	17
0.50 - 0.75	0.625	23
0.75 - 1.0	0.875	6
1.0 - 1.25	1.125	1
1.25 - 1.50	1.375	0

$\mu = 0.58$

$\sigma = 0.20$

$\sigma/\mu = 0.35$

Southbound Arterials



Southbound Majors

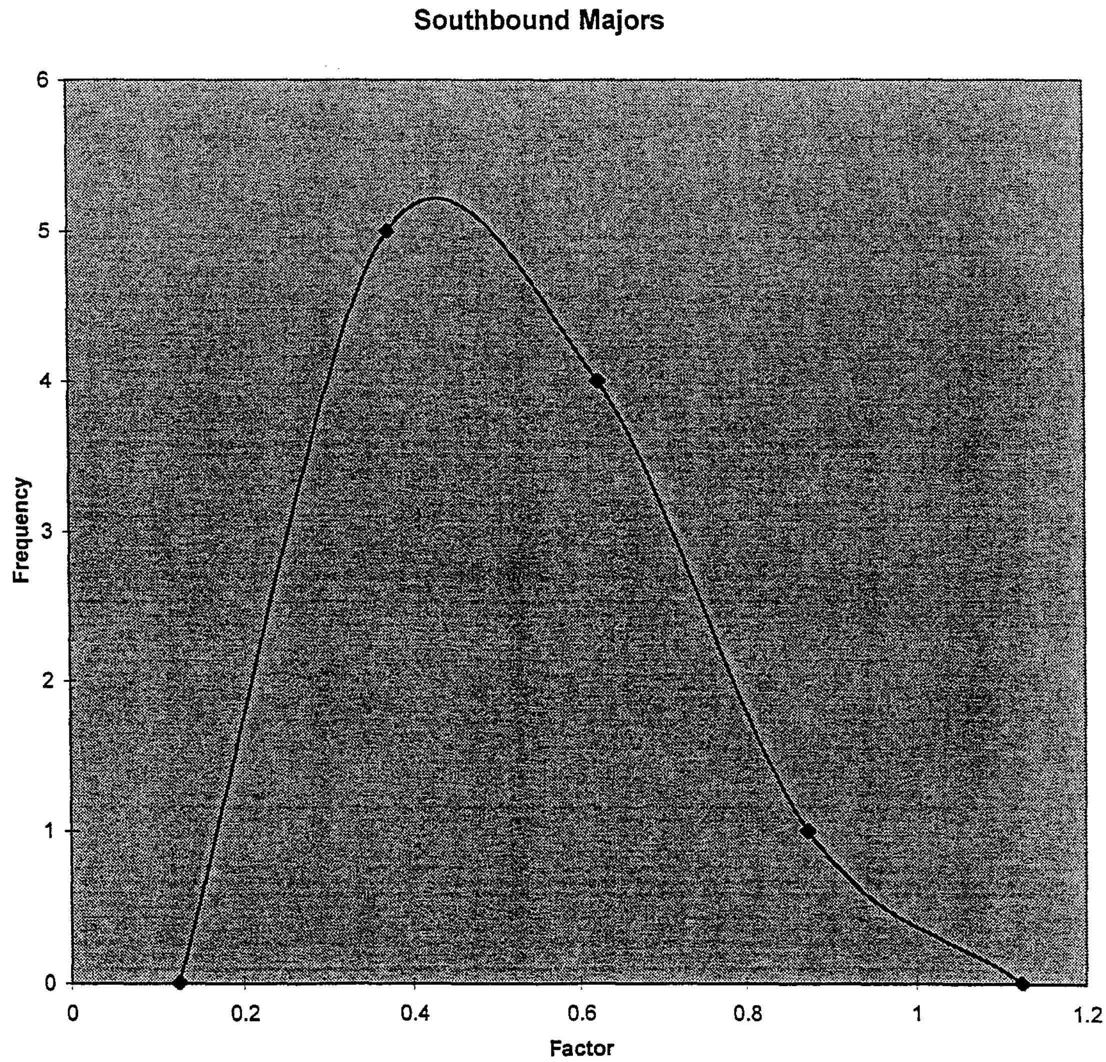
Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Major	S	4558	1883	0.41
Major	S	5930	2573	0.43
Major	S	5250	2419	0.46
Major	S	5323	2519	0.47
Major	S	5384	2605	0.48
Major	S	4434	2233	0.50
Major	S	5331	2746	0.52
Major	S	5123	2786	0.54
Major	S	5256	3763	0.72
Major	S	4558	3615	0.79
Major	S	2530	2853	1.13

Interval	Midpoint	Freq.
0.0 - 0.25	0.125	0
0.25 - 0.50	0.375	5
0.50 - 0.75	0.625	4
0.75 - 1.0	0.875	1
1.0 - 1.25	1.125	0

$\mu =$ 0.59

$\sigma =$ 0.21

$\sigma/\mu =$ 0.36



Northbound Majors

Class	Direction	AM Peak Volume	Off Peak Volume	Factor
Major	N	3291	1735	0.53
Major	N	3109	1704	0.55
Major	N	3297	1965	0.60
Major	N	2821	1730	0.61
Major	N	3173	1947	0.61
Major	N	2788	1804	0.65
Major	N	4907	3244	0.66
Major	N	4357	2972	0.68
Major	N	3804	2671	0.70
Major	N	3714	3018	0.81
Major	N	4332	3763	0.87

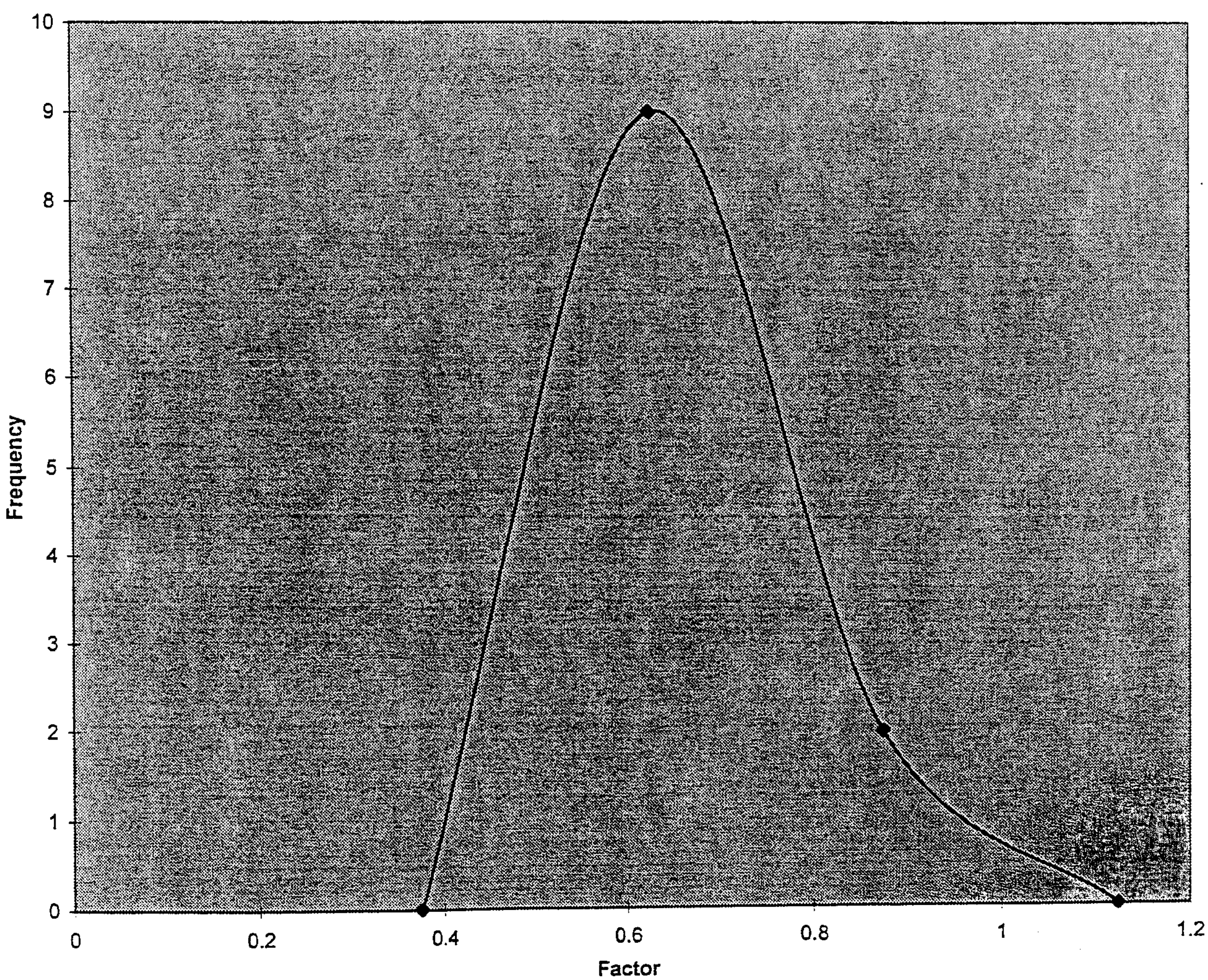
Interval	Midpoint	Freq.
0.0 - 0.25	0.125	0
0.25 - 0.50	0.375	0
0.50 - 0.75	0.625	9
0.75 - 1.0	0.875	2
1.0 - 1.25	1.125	0

$\mu =$ 0.66

$\sigma =$ 0.10

$\sigma/\mu =$ 0.16

Northbound Majors



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