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16. Abstract

A policy of building frontage roads alongside freeway mainlanes avoids the purchase of access rights when upgrading existing highways to freeway standards, and generally supplements local street networks. It also may affect corridor operations, land values, and development patterns. This paper seeks to provide a comprehensive evaluation of frontage road design policies by summarizing research results related to legal statutes affecting public access to roadways, discussing access policies and practices across the states, comparing land development and operations of corridors with and without frontage roads, summarizing studies on access-right valuation, and evaluating construction cost distinctions.

A literature review concluded that a wide variety of options are available to agencies for limiting access to and improving flow and safety along freeway corridors. Statistical analyses of paired corridors suggested that land near frontage roads is associated with lower household incomes, lower population densities, lower percentages of bike trips to work, lower vehicle occupancies for work trips, and higher unemployment rates than those without frontage-roads. Lower employment densities along freeway corridors also emerged when frontage roads were present. Operational simulations of various freeway systems demonstrated that frontage roads may improve the operation of freeway mainlanes in heavily developed areas, but not in moderately developed areas (e.g., purely residential). Arterial systems in these simulations were supplemented by frontage roads and thus also performed better in their presence. The financial costs associated with frontage-road facilities were found to be considerably higher than those associated with non-frontage road facilities, except in cases of extremely high access-right values. It is hoped that these results, in addition to efforts by other researchers, will assist in constructing a solid, formal policy for all states and regions to follow in providing access along new and existing freeways in the decades to come.

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by

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Jenny Peterman, and Susan Handy

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Investigation of the Impact of Frontage Roads
as an Element of Controlled-Access Facilities

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CHAPTER 1: PROJECT OVERVIEW AND OBJECTIVES

1.1 Introduction

AASHTO's Green Book bills frontage roads as "the ultimate in access control" (1995, p.528). And, until recently, frontage roads have been Texas' primary design solution to the issue of access along freeways. A policy of building frontage roads avoids the purchase of access rights when upgrading existing highways to freeway standards and generally supplements local street networks. Such a policy may also impact corridor operations, land values, and development patterns. This research investigated frontage roads as an element of limited-access highway design with an objective of providing a comprehensive evaluation of frontage-road design policies and the legal, financial, land-development, and operational issues associated with such policies. This paper summarizes the research effort by reviewing legal statutes affecting public access to roadways, summarizing access policies and practices across states, comparing land development and operations of corridors with and without frontage roads, summarizing studies on access-rights valuation, and evaluating construction cost distinctions.

Optimal frontage-road policy is likely to be highly site specific, depending on present land uses alongside freeway corridors, local zoning designations, expectations of future development, public sentiment, and design constraints (such as topography and network connections). The results of this work will enable the Texas Department of Transportation (TxDOT) to objectively weigh the costs and benefits of frontage roads and modify practices so that the best projects for the state and its communities result. The general questions motivating this 2-year research project are the following: When should TxDOT build frontage roads? When should TxDOT avoid the construction of frontage roads? What alternatives exist to constructing frontage roads? And what design practices, legal issues, and operational aspects should TxDOT consider under either scenario?

In the first year of this 2-year project, an extensive literature review was conducted in order to ascertain the current legal attitudes and operational strategies involving frontage roads. This information is presented here to place this work in its proper context. Subsequent sections detail results of investigations into design policies, corridor land development, frontage-road safety, corridor operations, and comprehensive construction costs. The report concludes with an overall assessment of the competing factors and recommendations for future design policies. Owing to space constraints, only key results are presented here; for additional information, readers may care to consult the previous work by Kockelman et al. (2000), Overman (2000), Madi (2001), and Peterman (2000).

CHAPTER 2: LEGAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

2.1.1 Recent Developments in Frontage Road Policy

Presently, frontage roads are a fact of life in Texas. Many interstate corridors and other major routes throughout the state are lined on both sides by frontage roads for property access and the linking of freeway mainlanes to cross streets. But policymakers, planners, and engineers have begun to question whether the practice of building this form of access is something the Texas Department of Transportation (TxDOT) should continue. The Texas Transportation Commission (Commission), a body that oversees the activities of TxDOT, decided that the new I69 freeway would be built "without frontage roads wherever feasible" and "industrial and local development" would be limited to "adjacent arterials." The Commission believes that "a high-volume Interstate freeway should be designed with as few access points as [are] feasible, because access points lead to congestion on the mainlanes" (Greenberg 1999). More recently, the Commission has ordered that TxDOT construct limited-access roadways without frontage roads wherever possible (Commission Minute Orders 108544 [text provided in Appendix F]) and work with local governments to ensure that state and local networks operate efficiently (Commission Minute Orders 108545 [text provided in Appendix F]). Michael Behrens, Executive Director Elect of TxDOT recently issued a statement to all district engineers stating that "the intent of this policy is for new controlled-access facilities to be planned and constructed without frontage roads, except where engineering studies and economic analyses of access rights versus right-of-way and construction costs indicates otherwise." (See also Chapter 7.)

In the past continuous frontage roads were believed to be a less expensive way to provide access to otherwise landlocked properties (Greenberg 1999). However, deeper analysis of the economics of frontage-road construction has dispelled much of that myth and has led transportation officials to examine more carefully this issue. Additionally, recent concerns related to issues of congestion, safety, sprawl, cost, route circuity, and the undermining of mass transit modes suggest that a comprehensive examination of frontage-road policies is important. In the future, TxDOT engineers will be asked to justify the inclusion of frontage roads based upon economic or safety issues. The TxDOT

Transportation Planning and Policy Division draft guidelines for freeway design state that the Commission "may consider exceptions when…there is no other feasible means to maintain safe and efficient operation of the state highway system." The guidelines also state that the providing of frontage roads will be allowed when "unlandlocking the remainder of a parcel of land which has a value that exceeds the cost of the frontage road (or)…the appraised damages, resulting from the absence of frontage roads, would exceed the cost of frontage roads" (TxDOT 2001).

2.1.2 Introduction to Legal History of Frontage Roads

A summary of relevant laws is presented here, providing a legal background on the provision of landowner access to the public property of highways. This discussion is extended to the valuation of access rights and damages warranted when a property's access is removed. A section on access management and corridor preservation suggests a variety of strategies that may eliminate many future landowner and road authority conflicts before they can arise. Lastly, a section on the operational advantages and disadvantages of frontage roads as well as scientific design recommendations from the literature provides some insight into the performances of these systems in different situations.

Limiting access to property often requires the state or responsible local authorities to pay damages—or incur the cost of providing alternate means of access. Frontage roads are a means of providing access to abutting landowners while also serving operational purposes, such as the segregation of high- and low-speed traffic, provision of operational flexibility and continuity of networks, and stimulation (or preservation) of relatively intense commercial development alongside freeways. However, the right-of-way requirements, geometric constraints, and construction costs these facilities entail are not trivial; for these and other reasons, frontage roads are rarely found in the U.S. outside of the state of Texas, where fully 4,514 centerline miles of frontage roads presently exist (TxDOT 1999).

Many interstate highways in Texas are lined on both sides by frontage roads. These roads can serve several different functions depending on the highway class they front. When used on freeways, their "primary function is to distribute and collect traffic between local streets and the freeway interchanges" (AASHTO 1994, p. 370). In addition to providing access from local roads to the highway, frontage roads also provide access to property along the highway. This function is particularly important when high traffic volumes are observed, such as in the case of urban corridors where commercial and residential development generates the need for access. In addition, frontage roads perform the task of controlling access to major arterial highways by separating high-speed through traffic on the freeway from slower local traffic. Another function of frontage roads is relief of traffic congestion on freeway mainlanes during peak periods or when an accident or other disruption of flow occurs. Messer, Whitson, and Carvell note that this objective "would require that the frontage road operate, at times, like a major arterial and not in its traditional role as an access facility" (1974, p. 1).

Although these functions seem to encourage the practice of building frontage roads, the Texas Transportation Commission (Commission)[1] has decided that new freeway projects should be built with no frontage roads wherever practical, and that commercial and residential development should be restricted to adjacent arterials. The Commission believes that the policy of building frontage roads has generated sprawl in rural areas and added to congestion in urban areas (Kockelman et al., 2000, p.1). The Commission further stated that high-volume interstate freeways should be designed with limited access points because they lead to mainlane congestion (Greenberg 1999). Congestion problems may be one of the reasons other states have avoided frontage-road construction; other reasons may be related to safety and cost (Greenberg 1999).

However, policies that limit landowner access may be extremely costly for the state. In fact, some expect that continuous frontage-road provision is the cheapest form of property access (Greenberg 1999). Poor design of freeway corridors, however, can render frontage roads problematic, deteriorating the traffic flow movement on both the freeway and frontage road itself. In later chapters, this work examines many of these specific questions in detail. Before turning to those discussions, a series of legal issues are presented here, to provide context to design decisions.

2.2 Access-Rights Law

English common law was one of the first written documents delineating the rights of property owners whose land abutted a public roadway (FHWA 1976). The first roadway

[1] The Texas Transportation Commission body oversees the activities of the Texas Department of Transportation

network in the United States to fully limit access along its length was the system of interstate and defense highways. In fact, a 1944 congressional study leading to the Federal-Aid Highway Act, which founded the interstate system, strongly recommended that states pass laws permitting them to either pay damages for access lost or provide an alternate means of access (Netherton 1963). To control access, some states chose to purchase access rights with the acquisition of parts of each parcel, while others purchased large tracts of land on either side of the interstate, essentially circumventing access issues. Years after the congressional study's recommendation, few state legislatures had granted their state highway departments the legal right to limit access. In 1950 the Bureau of Public Roads and American Association of State Highway Officials (AASHO) gave this guidance:

> Where State laws permit, control of access shall be obtained on all new locations and on all old locations wherever economically possible. … In those States which do not have legal permission to acquire control of access, additional right-of-way should be obtained adequate for the building of frontage roads connecting with controlled access points, if and when necessary. (Netherton 1963, p. 90)

In 1961 AASHO called for access control on all of the interstate system, either by "acquiring access rights outright prior to construction or by the construction of frontage roads or both" (AASHO 1961, p. 3). Acquisition of the necessary right-of-way had been recognized as a problem well before interstate construction ever began. Many states did not have statutory authority to purchase rights-of-way prior to highway construction. A major step in getting the highways built was the 1956 Highway Act, which allowed the U.S. secretary of commerce to acquire land and/or access for any state to build its sections of the interstate highway system (AASHO 1961, p. 4).

2.2.1 Highways on New Location versus Highways on Existing Corridors

Issues dealing with right-of-way and highway access can be divided into two categories: highway construction at an existing location and construction at a new location. Where a highway is constructed on existing right-of-way, travel routes and patterns have already been established. Major issues arose when interstate highways were located over existing highways where access had not previously been controlled or limited. In these situations, it was deemed that abutting landowners were entitled to access rights. States then had several choices for providing this access. One was to use the existing highway as a frontage road, allowing access along the outer edge and purchasing enough right-of-way on the opposite side of the freeway to build another frontage road. Another solution was to purchase the entire parcel of land, thus removing the property owner's right of access (AASHO 1961). This second solution was used most often in urban and suburban areas, because access rights were felt or found to be such a significant part of the property's value. There also was the option to purchase all the property between streets or alleys parallel to the freeway corridor and use these streets or alleys as frontage roads (AASHO 1961). A rarely used strategy involved the state purchasing only the access rights to the property while not acquiring any actual land. This situation was useful in rural areas where land values were not so closely tied to access because they had residual value as agricultural properties. In urban and suburban locations, however, land is of little value without access, and most property owners would rather sell the land outright than be left with a tract of land without development potential.

In some instances in Texas, rights-of-way were preserved between the frontage roads for later construction of freeway lanes. The state then had little choice but to retain the frontage roads. And, in many cases, state engineers and the transportation department have been under considerable pressure to connect the frontage roads to the mainlanes via a series of closely spaced ramps (Lee 2000; Luedecke 2000). Unfortunately, short inter-ramp spacings can create serious merging and diverging issues as well as foster significant commercial development along a frontage road, producing congestion and accidents along both the frontage roads and mainlanes.

Access to highways in new locations has also led to controversy in the past. "Remainders" are small pieces of land left over after highway construction divides a property. Guidelines in the 1950s allowed a state to choose one of the following remedies: build frontage roads to connect remainders to public highways, provide continuity in a system of existing roads, or reestablish connection between two portions of a property severed by the new highway (AASHO 1961). Although courts have ruled that property owners do not retain rights of access to highway facilities on entirely new locations, they often have sided with the property owners in cases where there was a combination of old and new rights-of-way used (Netherton 1963).

2.2.2 Frontage Roads as a Means of Access

Frontage roads have been used as methods of alternate access to the public property of highways when highways are brought up to limited-access standards. In a California court case, *People v. Ricciardi* (144 P.2d 799, 803, 1943), the landowner was given access to a frontage road in place of access to the mainlanes of an arterial highway (Netherton 1963). In this case, the California Supreme Court ruled that an "abutting property owner has right to free and convenient use of an access to highway on which his property abuts" (Netherton 1963, p. 53). However, in 1952 the California Supreme Court ruled in *Schnider v. State* that an abutter does not retain the right of access to a new right-of-way and its accompanying roadway.

TxDOT design policy formally states that "(f)rontage roads may be included in planning … when: 1. It is necessary to unlandlock … a parcel of land, which has a value equal to or nearly equal to the cost of the frontage road. 2. The appraised damages, resulting from the absence of frontage roads…, would exceed the cost of the frontage roads. 3. It is necessary to restore circulation of local traffic…. 4. An economic analysis shows the benefits derived more than offset the costs of constructing and maintaining the frontage roads" (TxDOT 1984, pg. 4-77). Strict adherence to this policy requires significant cost-benefit information from planning and design divisions. The TxDOT Design Division is now emphasizing this policy, in response to concerns about frontage-road overuse (Woodall 2000).

In 1961 AASHO published guidelines as an attempt to standardize the application of frontage roads. However, the states could choose to treat their systems as they saw fit and within their budgets. The Texas Highway Department (now TxDOT) had specific authority to eliminate intersections along a highway, but there was no statutory provision for when and where the state must provide frontage roads (Netherton 1963). Texas House Bill 179 enabling legislation for the construction of interstate highways within the state, allowed the Texas Department of Highways to design the interstates both with and without frontage roads (TxDOT 1984).

2.2.3 Court Rulings Describing Rights of Landowners and Governments

A landowner's right to access is not absolute in some legal opinions. "This right [of the property owner to protected right of access] does not encompass the right to access the public road at any and all points along the boundary between his property and the road…. Thus, the property owner's right of access is restricted to the right of reasonable access" (Vance 1988, N346). A property owner must be provided with substitute and *reasonable* access to the roadway; this may be via a frontage road or some other road connecting his or her property to the new highway. The state must ensure that this substitute access does not substantially impair the former right of access; otherwise, the state may be liable for damages. Frontage-road construction is argued to provide reasonable access, and the landowner is due no compensation when a frontage road is constructed and other access removed, as long as the frontage road connects to the new highway within a reasonable distance (*Teacher's Insurance and Annuity Association of America v. City of Wichita*, 221 Kan. 325, 559 P.2d 347). However, the definition of what is reasonable remained an issue for some time in the courts, and varied on a state-by-state and sometimes ruling-by-ruling basis. The following court decisions eventually seem to settle the reasonable issue in definite numerical distance terms.

A 1961 Wisconsin court decision stated that, "If no land is taken for the converted highway but the abutting landowners' access to the highway is merely made more circuitous, no compensation should be paid" (Wis.2d 511, 109 N.W.2d 71). A 1970 Arizona court (in *State ex rel. Herman v. Schaffer*) decided that an access distance of 2,000 feet did not oblige damages from access limitations. Denial of access to freeway mainlanes and construction of a service road in Florida required shopping center patrons to travel an additional 100 yards, yet the court found no substantial diminution in access had occurred and awarded no severance damages (*Florida Department of Transportation and Pinellas County v. ABS, Inc.*, 1976). Similarly, in many cases where the landowner only needed to travel 0.25 mile or less to the nearest highway interchange or access point, the access was held to be reasonable. (See, for example, Kansas's *Brock v. State Highway Commission*, 1965, and *Ray v. State Highway Commission*, 1966; Minnesota's *State v. Gannons, Inc.*, 1966; Nebraska's *Berlowitz v. State Department of Roads,* 1966; and New Mexico's *State ex rel. State Highway*

Commission v. Silva, 1962.) Courts found the access provided to be unreasonable in cases requiring the landowner to travel 1 mile or more (Arizona's *State ex. rel. Herman v. Jacobs*, 1968; California's *People by Department of Public Works v. Renaud*, 1961; Nebraska's *State ex rel. Department of Highways v. Linnecke*, 1970). And cases involving intermediate distances (between 0.25 and 1 mile) are somewhat evenly divided in their determinations of reasonable and unreasonable access (Vance 1988).

2.2.4 Determining Compensation for Taking Land and/or Access

The amount of landowner compensation required when unreasonable access is imposed is the "difference in market value of the affected property immediately before and after the impairment of access occurs, based on the highest and best use of the property before and after the damage takes place" (Vance 1988, N355). Likewise, Roger Hornsby, an independent appraiser based in Austin, Texas, stated that the same formula is used in determining TxDOT damage payments to landowners (Hornsby 2000). Damages caused by traffic diversion such as fewer vehicles flowing past the property and their impact on business revenues are generally excluded, because the "abutting owner has no right to the continuation of a flow of traffic in front of his property…. The owner of abutting land has no property right in the traveling public using the highway" (Kansas's *Brock v. State Highway Commission*, 1965). Other court decisions mirror this decision (e.g., *Arkansas State Highway Commission v. Bingham*, 1960; California's *People v. Becker*, 1968; and Idaho's *James v. State*, 1964). These prior legal decisions are likely to be important for state transportation policy, because many property owners will make such an argument in favor of ramp installation or bypass avoidance.

Frontage roads are said to play a dual role in that they should be considered in determining both the reasonableness of access and the amount of damages awarded if unreasonable access is found (Vance 1988). The condemnation case of the *State of Texas and City of Austin v. Robert M. Schmidt et al.* is notable in its findings in this regard. The Schmidt property was located along US 183 in Austin, and the state sought to acquire a 6-foot strip of property in order to widen the freeway and construct a limited-access facility with frontage roads along its length. The property owners did not believe the $7,559 in compensation provided was adequate and were awarded $74,880 based on admitted evidence of circuity of travel, traffic diversion during construction, and visual unattractiveness of the elevated mainlanes. An appeals court upheld this decision, but the Supreme Court of Texas reversed it, ruling that the "Schmidt Factors" cited as reason for the additional compensation are not compensable (Interim Report to the 75th Texas Legislature, Committee on Transportation, 1996).

Others disagree that provision of frontage roads removes a state's liability for damages. Kaltenbach's 1967 article "The Elastic Right — Access," argued that property owners hold an absolute right to cross the boundary line between their property and the highway at every point. In Kaltenbach's opinion, this approach eliminates much of the confusion and many of the legal inconsistencies inherent in defining what constitutes reasonable access and what does not, and damages should be paid anytime this absolute right is infringed upon (Kaltenbach 1967). However, unmanaged access can create chaos on travel ways. The case of *People of California v. Ricciardi* clearly defined access as a property right, but it did not suggest that the access may occur in any form (Westerfield 1993). A Texas case, *Phillips v. Stockton*, further defined the right of a property owner to have access to and from his or her land and residence "in order to enable him to discharge the duties he owes, as a citizen, to the public"; again, however, the form of access is not specified (*Vernon's Annotated Civil Statutes*, 1954, art. 6711).

2.3 Land Value and the Valuation of Access Rights

Research conducted to reveal the effects of highway projects on land values has potential implications for estimating the amount of damages to be awarded landowners. This valuation can be very important in weighing the costs of building access via frontage roads versus paying landowners for the outright removal of access.

2.3.1 Positive Effects of Frontage Roads on Land Values

Investigations of several highway corridors show that frontage roads can positively impact the price of adjacent land. For example, the Santa Ana Freeway, now Interstate Highway 5, demonstrated that land values could rise dramatically—even for lands not directly on the frontage roads, but simply close to them (Lemley 1956). The Fresno Freeway also showed an inclination for rapid development along the frontage roads when the existing highway was realigned and converted to freeway standards (Lemley 1956). The Gulf Freeway in Houston may be one of the first examples of a controlled-access highway built with frontage roads along most of its length. It was built before 1956, along the abandoned right-of-way of the old Galveston-Houston Electric Railway. Lemley (1956) writes that industry and commerce recognized the advantages of this controlled-access freeway with frontage roads, and land values quickly rose. Such clear benefits of enhanced access, increased traffic flows, and visibility from the freeway are what compel many property owners to petition for frontage-road provision and regular ramp placement in Texas. The owners receive a payment for ascertained damages, and then enjoy all the benefits that this access provision provides.

Clearly, access is a major determinant of land value. This is especially true for urban land that depends almost entirely on access to a highway facility for its development potential. Because frontage roads generally assure adjacent property owners of relatively easy access to main travel lanes, they reduce damages to these parties. This can result in both a cost and time savings to the state — not only in terms of legal costs, but also in the many years it can take for a court decision.

A more thorough exploration of the subject of access valuation can be found in Chapter 7.

2.3.2 Effects Are Not Always Positive and Vary Depending on Mainlane Design

Rather interestingly, when all access-related, land-value changes are taken into account, some highway construction may result in an overall economic loss to certain land uses. For example, an Australian study of the South East Freeway in Brisbane estimated that losses to homeowners caused by impaired access and noise, vibration, and pollution totaled $10.1 million; this greatly exceeded the increase in property values owing to improved highway access ($2.3 million), producing a net loss of 8.8% of the total property value of nearby residences (Williams 1993). After recognizing travel-time savings and other possible benefits, the project may have a benefit-to-cost ratio well above 1.0, but the land-value impacts are not necessarily positive.

The impact a roadway has on land values also depends on its design. Lewis et al. (1997) developed models to estimate the social, economic, and environmental effects of depressed and elevated freeways using examples from Lubbock, Dallas, Houston, and San Antonio. Overall, land values adjacent to elevated freeways showed the smallest increases after construction, but this was not true in all cases. A study by Downs (1982) also found a marked decrease in values for property adjacent to freeways under construction. Values tended to rise to preconstruction levels approximately 5 years after construction, and land values in some cities (especially those with strong controls on land use) kept rising past their preconstruction levels (Tomassik 1987). Depressed freeway sections were associated with the highest land values for residential properties while commercial land uses had the highest value along at-grade roadways. Residential and commercial land-value changes generally were positively correlated with the level of accessibility provided to the facility (Lewis et al. 1997). However, Lewis et al. did not control for the presence or lack of frontage roads along the highway corridors.

2.3.3 Models to Predict the Value of Access

Some researchers have created models to estimate the value of access rights. Westerfield (1993) estimated appraised access-rights values per square foot of parcel size as a function of average daily traffic, whether or not the parcel was on a block corner, land-use type, linear feet of access taken, and whether the commercial property depended on the highway for customers. She used TxDOT right-of-way acquisition records, but only thirteen of these records offered parcels where access rights were purchased separately from real property in urban areas, substantially limiting her findings (Westerfield 1993). Gallego (1996) extended Westerfield's work by adding an average-vehicle-trip-ends variable obtained from ITE's *Trip Generation Manual* (5^{th} Edition 1991). This new variable plus the land-use variable predicted over 83% of the variability in the compensation paid for access rights. Gallego's data set (shown in Table E.2, in Appendix E) brought the number of data points from thirteen to twenty-one, but the applicability of the results based on such a small data set remains quite limited.

2.4 Access Management and Corridor Preservation

Access management and corridor preservation are two forms of policy critical to long-term control of access with or without frontage roads. Corridor preservation is a series of steps that state highway departments can use to gain control of or protect the right-of-way for planned transportation facilities. When used during a project's planning stages, corridor preservation can eliminate access issues and perceived needs for frontage roads.

2.4.1 Authority of Governments to Control Access

Vernon's Texas Statutes and Codes Annotated (1994) states in §203.002 that governmental agencies may convert an exiting street, road, or highway into a controlled-access highway meeting modern standards of speed and safety. Section 203.031 gives more detail as to what the Commission may do for access control, but mentions that the Commission is still required to justly compensate parties for any damages caused by such action. Justice Scalia of the U.S. Supreme Court had agreed that prevention of excessive congestion falls within the realm of exercising police power:

> …the common zoning regulations requiring subdividers to observe lot-size and setback restrictions, and to dedicate certain areas to public streets, are in accord with our constitutional traditions because the proposed property use would otherwise be the cause of excessive congestion… (Williams and Forester 1996, p. 25).

In §203.052(b)(9), the Commission is given the power to acquire an interest in real property to accomplish any purpose related to the improvement, maintenance, preservation, or operation of a state highway. This provision of state code may become more important as access management policies receive greater use and support around the country. For example, the Commission may wish to acquire additional rights-of-way to shield a corridor from intense development, or limit subdivision and driveway spacings so as to facilitate frontage-road flows while enhancing safety.

A legal basis must be established before any sort of corridor preservation program can effectively begin. Enabling legislation in Kansas (KSA 68-423a) states that property may be acquired "in advance of actual construction for the purpose of eliminating economic waste occasioned by the improvement of such property immediately prior to its acquisition for highway uses" (Stokes 1995, p. 16). This particular program was touted as reducing landowner and environmental impact and right-of-way costs, as well as encouraging consistent development. However, the effectiveness of any similar program depends on the degree of interdepartmental cooperation within a state department of transportation (DOT) (Stokes 1995).

2.4.2 Useful Access Management Strategies

Access management strategies guide the location and spacing of access points along public roadways in order to improve safety and facilitate traffic flows. Developing large frontage parcels to reduce the number of access points needed and shifting access points to the rear of the properties rather than allowing them along the main road are two strategies found useful in Australia (Westerman 1990). Based on their review of state codes and practices, Williams et al. (1994) synthesized their research in this area by suggesting some regulatory techniques supportive of access management in the report “Model Land Development and Subdivision Regulations That Support Access Management.” These include regulating driveway spacing, sight distance, and corner clearance; restricting the number of driveways per existing parcel on developing corridors; increasing the minimum lot frontages along thoroughfares; encouraging joint access and parking lot cross access; reviewing lot splits to prevent access problems; regulating flag lots and lot width-to-depth; minimizing commercial strip zoning and promoting mixed use and flexible zoning; regulating private roads and requiring maintenance agreements; establishing reverse frontage requirements for subdivision and residential lots; requiring measurement of building setbacks from future right-of-way line; and promoting unified circulation and parking plans.

2.4.3 Access Management in Practice

Highways with properly managed access and signalization have been found to carry up to 30% more traffic than those without (*AASHTO Quarterly* 1992, p. 5). New Jersey’s newly adopted state highway access codes restricting and managing access to and from private property are among the most far-reaching of any state, including those with strong access management programs, such as Colorado and Florida. The New Jersey code contains a master plan for the entire state highway system, including desirable typical sections. The codes do not bar development, but they do restrict the number of cars that can access the highway. If the additional traffic caused by development exceeds the projected capacity of the road, developers must pay to mitigate the impact by adding or extending turn lanes or adding traffic signals at an access point. The implementation and rules governing access management vary widely by state. Local governments in Florida are barred from imposing more restrictive access standards than state policy describes, while Oregon's state access standards are a minimum requirement and a municipality is allowed to enact stricter standards if it deems necessary (Williams and Forester 1996, p. 24).

AASHTO listed techniques for corridor preservation including government inducements, such as transferring the right to develop to other locations through planning agencies and use of police powers to acquire land and control access. Land acquisition may include the application of purchase options, exercise of eminent domain, and use of surplus government-owned land (AASHTO 1990). The AASHTO Task Force on Corridor Preservation suggests that corridors meeting any of the following criteria be considered for protection: (1) without protection the corridor could force the project into an environmentally sensitive area, (2) significant land development in the corridor is imminent, (3) land values are escalating rapidly, (4) the need for a project has been identified in the corridor, (5) the proposed transportation improvement is expected to be a priority within the next 10 to 15 years, (6) failure to protect the corridor ultimately could result in many more relocations of businesses and homes, and (7) cooperation from local jurisdictions and the private sector can be obtained in protecting a corridor (AASHTO 1990).

The number of driveways and unsignalized intersections per mile—i.e. access density—and their rate of use substantially impact frontage-road operations. According to Fitzpatrick et al. (1996), this is particularly true when these exceed 16 access points per mile (acc/mi) on one-way frontage roads or 20 acc/mi on two-way frontage roads. These access-point densities correspond to driveway spacings (on center) of 330 feet and 264 feet, which are much larger than those generally observed in developed corridors.

There is a sizable body of access-management literature (see, e.g., IDOT 1995; Geiger et al. 1996; Bowman and Rushing 1998; WDOT 1998; Eisdorfer 1997; Michel et al. 1996; Kors 1996; Vorster and Joubert 1997; Newsome 1997; Pant et al. 1999; and OKICOG 1986), and much of this deals with access-density topics (e.g., recommended driveway spacings). There also is some work on the safety associated with different designs (e.g., Long, Gan, and Morrison 1993, Bowman and Vecellio 1994).

In practice, coordination of roadways and land use depends on the voluntary commitment of the agencies involved. In San Antonio, Texas, for example, TxDOT staff has worked closely with city staff to coordinate access management strategies in rapidly developing areas such as the US 281/FM 1604 intersection (Lewis, Handy, and Goodwin 1999). In this example, TxDOT worked cooperatively with the city and the developer to limit the number of driveways and ensure on-site circulation across parcels through deed restrictions. To encourage similar and more formal efforts, the Florida Department of Transportation has published a brochure outlining possible access management strategies and has developed model access management regulations for cities (FDOT 1999; Williams et al. 1994).

The operations and safety of frontage roads and other developed arterials heavily depend on access-provision policies. Driveway design, spacing and location, ramp positioning, merge and diverge policies, median specifications, and other requirements may ameliorate unsafe and congested situations on freeway corridors that already have frontage roads.

2.4.4 Options Available in Texas

The 73rd Texas Legislature Committee on Transportation (1992) reviewed two policies related to right-of-way acquisition; these are the "enhanced-value" deduction and the early take procedure, and both may assist in corridor preservation. Under an enhanced-value policy, the state subtracts any value added to the remaining portion of a parcel owing to highway construction from any amount awarded for the actual takings on the parcel before compensating for land takings. Currently, TxDOT is not allowed to compensate in this manner, but the federal government and twenty-four other states have laws that allow it (*Texas Performance Review* 1991, p. 55). Early take procedures would allow TxDOT to officially condemn land and begin construction while a property owner's compensation is undergoing review in a special commissioner's court after first placing the amount of the proposed purchase price in care of the court. If the court rules that a higher compensation is warranted, TxDOT would pay this difference at the time of the court's ruling, but projects would not be additionally delayed.

Bass et al. examined the feasibility of corridor preservation strategies in Texas in 1996. Their report indicated that thirty-eight U.S. states operated programs identifying corridors for protection or preservation in 1996 versus just twenty-six states in 1988. The techniques used are quite varied; the authors identified twenty-four. Presently, TxDOT can only use five of these techniques; these are fee simple purchase (acquiring full ownership of the property); negotiated agreements (a form of fee simple purchase where the purchase takes place through a contractual arrangement instead of eminent domain); protective buying (purchasing land in advance of final project approval when development threatens to obstruct the right-of-way); eminent domain (taking private property for public use by condemnation or regulation and compensating the prior owner); and donations (owners voluntarily donate land to the state; the state can then use the fair market value of the property toward matching shares in federal aid highway projects). However, twelve other techniques also are thought to be viable for Texas if used in coordination with local jurisdictions or through changes in legislation (Bass et al. 1996).

2.5 Summary

As discussed above, legal issues involving frontage roads in Texas span a variety of areas. Provision of landowner access to adjacent public property is key, along with the valuation of access rights when this right is removed or access becomes unreasonable. Access management and corridor preservation strategies in other states provide guidance for models well suited for implementation within TxDOT. More information on the practices of other states follows in the next chapter, which summarizes survey responses of a number of state DOTs.

CHAPTER 3. DEPARTMENTS OF TRANSPORTATION SURVEY SYNOPSIS

3.1 INTRODUCTION

A survey of state departments of transportation was undertaken for this project. The survey was distributed in March of 2000 to contacts at thirty-two state DOTs nationwide, of which officials of nineteen states responded.[2] The survey asked about the agencies and individuals' "overall impression of frontage roads," written policies, access provision following highway conversion to freeway standards, and methods of access valuation.

3.2 SURVEY QUESTIONS

The survey consisted of the following questions:

1. What is your overall impression of frontage roads (e.g., too expensive, too land consumptive, good buffer for residential uses, etc.)?
2. Does your state have a written policy on frontage roads? (If so, could you tell us where to get a copy?)
3. How does your state generally provide access to land parcels abutting roadways when they are converted to limited-access freeways?
4. In purchasing access rights, how do you decide what to pay landowners whose access to a roadway is removed?
5. Is there anyone else you recommend we contact regarding such design issues?

Respondents' actual answers to each question can be found in Appendix A, and respondents' contact information is contained in Appendix B. Some responses to Question 2 included a policy document or other material written on behalf of the state DOT; these are contained in full in Appendix C.

3.3 SUMMARY OF RESPONSES

The responses from representatives of Massachusetts, Michigan, North Carolina, Pennsylvania, South Carolina, Virginia, and Vermont DOTs were considered to be favorable, because each of these representatives mentioned the benefits of frontage roads in their

[2] The research team searched several databases for these contacts, and all fifty states would have been contacted had contact names and information been found for them.

response. Their reasons included the ability of frontage roads to serve local traffic and keep it from congesting the freeway mainlanes, move traffic during crash situations on the mainlanes, provide advantageous access to development, and improve safety by limiting access to the mainlanes by eliminating turning movements and driveways on them.

Representatives of several states—California, Kansas, Nebraska, Montana, and Virginia—mentioned the necessity of providing frontage roads in certain situations, mostly to provide access to otherwise landlocked properties or where access without a frontage road would be circuitous. Frontage roads also are sometimes necessary to restore continuity to local street systems after construction of a fully controlled-access facility. Montana's situation is similar to that of Texas because many Montana freeways are built over rights-of-way that previously served local traffic, and therefore the state essentially was legally bound to continue serving such traffic via frontage roads.

Survey respondents listed many drawbacks to the use of frontage roads. Four states specifically mentioned the high construction costs of frontage roads as a primary reason that their state does not build many of them. Environmental impacts were also listed. Other areas of concern were the distances between ramps and intersections, as well as the distance between the frontage road and mainlanes. There was a general trend in all responses in this area that when ramps and intersections are located too near to one another (or where the frontage road and mainlanes are not separated by enough distance), there are ingress and egress problems and generally poor traffic operations result. Minnesota mentioned a unique solution of providing *backage roads*, or roads parallel to the freeway that allow development on both sides of the roadway. North Carolina recently started encouraging commercial developers to build access roads *behind* businesses to provide both visibility to the business from the major road and avoid connecting driveways. A response from Pennsylvania noted that frontage roads could be very confusing for motorists who are not used to their operation

Most states build all freeways on new locations, so property owners are not entitled to access the new roadway and no frontage road is required. Access is almost always provided by connecting the property to a cross street. Buying the property outright was another option mentioned. Michigan had a recent experience building continuous frontage roads along an 80-mile section of I69 near Lansing. An additional 150 feet of right-of-way width was purchased along one side of the existing four-lane free-access roadway, two new freeway lanes were constructed in the former median, the two other new limited-access lanes were constructed directly over two old lanes, and the remaining two old lanes were resurfaced as a two-way frontage road. The perceived additional cost and time required for this type of complicated construction is forcing a different approach in a 16-mile section of US 27 in Michigan. Land is simply being purchased on both sides of the roadway, completely removing the former landowners' access to the roadway. Michigan hopes that this approach will save on construction funds and allow the freeway to be built more quickly than those built by the previous method. North Carolina was the only state in the survey that mentioned a formal procedure (service road studies) where a cost comparison of the purchase cost of access rights and property versus the cost of constructing a frontage road determines whether or not a frontage road will be built. However, California's policy documents did mention that the construction of frontage roads is justified if their cost is less than severance damages or land acquisition costs. And, if there are more than three access points within a short distance, a frontage road may provide a better form of access than access to the mainlanes.

The Texas Department of Transportation design policy formally states that "(f)rontage roads may be included in planning…when: 1. It is necessary to unlandlock…a parcel of land which has a value equal to or nearly equal to the cost of the frontage road. 2. The appraised damages, resulting from the absence of frontage roads…would exceed the cost of frontage roads. 3. It is necessary to restore circulation of local traffic…. 4. An economic analysis shows the benefits derived more than offset the costs of constructing and maintaining frontage roads." (TxDOT 1984, pg. 4-77) Strict adherence to this policy requires significant cost-benefit information from planning and design divisions. The TxDOT Design Division is now emphasizing this policy in response to concerns about frontage road overuse (Woodall 2000).

In Question 4, most states mentioned that they simply pay the difference between the appraised cost of the property before and after access is removed, or purchase the entire parcel if it will lack alternate access. Colorado has a practice of acquiring access rights, but only pays for the acquisition if it is substantially impaired and there is no reasonable access to the local street system. Michigan sometimes leaves a small (50 foot) section of property frontage with access to the roadway; this can reduce right-of-way acquisition costs because the entire parcel does not have to be purchased.

Several states provided official policy documents that help guide the construction or avoidance of frontage roads along their state highways. California policy mentions on numerous occasions that frontage-road construction is sometimes paid for by entities other than CalTrans. California policy also forbids any landowner, without exception, to have direct access to a freeway. On expressways, which exhibit a lesser degree of access control, direct access is allowed, but only if the parcel does not have access to another public road or street.

Unauthorized widening of driveways along with a change in the nature of development from rural to suburban or urban sometimes causes safety and operational problems along roadways, according to California policy. If this is allowed to happen, the likelihood of the state prevailing in a lawsuit against a landowner is diminished, and construction of a frontage road is listed as one possible solution. The document mentions the importance of advance planning and corridor preservation in avoiding such problems. California also has frontage- road policies concerning sidewalk design and headlight glare.

Minnesota's frontage-road policies emphasize that frontage roads should intersect cross streets at locations different from the streets' intersections with freeway ramps. If this is not possible because of right-of-way or other constraints, Minnesota's policy defines the distances that must be provided from the exit ramp to the cross street and forbids any access points along this section of frontage. In terms of design policies, Minnesota favors X-configured interchanges to traditional, diamond interchanges, because they avoid weaving on the mainlanes; however, they require relatively frequent ramp spacing so that connections do not become overly circuitous.

Official North Carolina policy mentions the cost analysis to determine the financial feasibility of frontage-road construction. And when existing, unpaved service roads belonging to a municipality or subdivision are marked for improvement, part of their paving cost is shared by these other entities. Developers may request the construction of frontage roads, if they are in fact needed, but they must help pay construction costs. An interesting step away from the typical Texas case is the North Carolina requirement that, when feasible, frontage roads should be constructed between 200–400 feet from the highway in order to permit development on both sides of the frontage road. The exception is in the case of farming or pasture land, where a frontage road should be constructed adjacent to the highway itself.

Wisconsin policy reiterates the state's right to refuse adjacent landowners access along any highway constructed at a new location. It then specifically mentions frontage roads as necessary when freeways are built upon an existing alignment and the right of access is not acquired by the state. Wisconsin's official mapping authority allows the state to reserve right-of-way in advance of construction, either to eventually include frontage roads as a form of access or to eliminate access altogether.

In summary, the survey of state DOTs indicated that a state's tendency to build frontage roads depended both on past access policies within the state, which tend to depend heavily on legislation, and formal policy guidelines that specify the provisions under which a frontage road will be provided. The roadway geometry associated with frontage roads in other states was in many cases quite different from typical Texas designs. Development was often permitted along both sides of these states' "frontage roads," generous ramp-to-signal distances were required by several policy guidelines, and development adjacent to ramp-frontage-road interfaces was generally more restricted than in Texas, in order to prevent dangerous weaving maneuvers. Overall, while not every strategy given by a state DOT will apply to Texas, new and rehabilitated roadways within Texas may achieve significant operational and safety advantages by utilizing some of the techniques proven successful in other states.

CHAPTER 4: CASE STUDIES

4.1 Introduction

An analysis of case study sites from the Austin metropolitan region was undertaken as part of this work to illuminate a number of factors. Primarily, the data collection effort was geared toward establishing a link between accident/injury experience at each of the sites and variables such as vehicle miles traveled(VMT), access density, and the incidence of speeding. Visits to the sites also provided valuable information on the variety present in adjacent land development and access design decisions.

4.2 Data Collection

The twelve case study locations selected represent a cross-section of different types of frontage-road treatments and conditions in the Austin region, and range from a dense urban core location with no real access control to outlying developing suburban locations utilizing more stringent access controls. Rural locations were not included as part of this analysis. Case study site visits commenced in fall 2000 and continued for several months as more data were collected. Each site was examined several times. At each site, notes were taken regarding general location and geometric design, as well as unique characteristics such as signing, adjacent development, and traffic patterns affecting frontage road operation. During subsequent visits, speed measurements were taken using a Doppler radar speed-tracking device, and relevant driveway, intersection, and ramp distances were measured with a measuring wheel and recorded. Collection of traffic count data using road tubes took place over a 48-hour period on Wednesday, August 16 and Thursday, August 17, 2000. Crash and injury counts for the twelve sections of frontage road were compiled from the Texas Department of Transportation records for the January 1995 – September 1999, 4-year, 9-month period, and incidents on the frontage roads were separated from incidents occurring on the mainlanes or elsewhere. Only the frontage-road incidents are reported and analyzed here. Table 4.1 shows the data points collected for use in analysis.

4.2.1 Variables Considered

An "access density" variable was computed as the ratio of access length to overall section length; these ranged from a low of 0 (in the case of IH-35 at Parmer Lane) to 0.52

(along IH-35 at 38½ Street). A Doppler radar device observed off-peak morning speeds, providing estimates of each section's 85th percentile speed and its speed variance (i.e., the square of the standard deviation in speeds),[3] VMT (normalized flow counts), and crash statistics. These are described in Appendix D.2.

4.2.2 Frontage Road Case Study Locations and Descriptions

The twelve study sections were the following: US 183 northbound at Loop 360/Capital of Texas Highway; US 183 northbound at Balcones Woods Drive; US 183 northbound at Tweed Court/Riata Trace Parkway; US 183 at Peyton Gin Road; MoPac (Loop 1) southbound at Capital of Texas Highway; MoPac (Loop 1) southbound at Steck Avenue; MoPac (Loop 1) southbound at Anderson Lane/Spicewood Springs/Far West; MoPac (Loop 1) southbound at Gaines Ranch; Interstate 35 northbound at Parmer Lane; Interstate 35 northbound at FM 1325; Interstate 35 northbound at 38½ Street; and Interstate 35 northbound at Onion Creek Parkway. They ranged from having no retail development to over 765,000 square feet of retail space alongside; from having no driveways or intersecting roadways to over 50% of the frontage cut out for such access points[4]; from zero to 1,500 apartments alongside; and from 0 to over 600,000 square feet of office space.

Several sections exhibited nearby cross streets and backroads that offered viable access options for the abutting developments; such access strategies could be used to moderate or eliminate access along the frontage roads. The I-35 northbound section at FM 1325 in Austin's neighboring city of Round Rock presented the worst design case, offering drivers almost continuous access – if one were willing to drive across the dirt strip that borders the roadway. Ramp and driveway locations are poorly coordinated at this site, presenting serious safety issues. Similarly, at other sections, unnecessarily wide and frequent driveways provided minimal channelization of traffic, and certain low-intensity

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[3] High variances indicated that observed vehicles traveled at a variety of speeds, while lower variances indicated that vehicles generally traveled at speeds closer to the mean corridor speed. This variable was estimated via the following formula: $\sigma^2_{speed} = \sum_{i=1}^{N} \frac{(speed_i - speed_{avg})}{N-1}$

[4] The I-35 northbound at Parmer Lane section was the only observation without any access points, but there may be such connections made in the future. The MoPac (Loop 1) Southbound at Capital of Texas Highway section offered no intersecting driveways. It is bordered by a thin parcel of The University of Texas-owned land that buffers the frontage road from development activity (though successful and intense development has occurred nearby, along the intersecting Capital of Texas Highway).

developments had an abundance of driveways (e.g., an adult bookstore at the I-35 northbound section at 38½ Street had fully four driveways).

Complete descriptions and qualitative assessments, along with maps of each study area, can be found in Appendix D.1.

Table 4.1 Case Study Data

Location	Access Density	Traffic Count	Accidents	Injuries	Measured Distance	Incidence of Speeding	Variance of Speeds	Vehicle Miles Traveled
183 at Balcones Woods	0.1394	8208	21	24	1638.92	0.96	27.1	2547.78
183 at Tweed Court/Riata	0.1919	29781	31	30	1581.08	1.12	42.9	8917.83
MoPac at Capital of Texas	0.1179	17414	43	59	1187.58	0.78	37.1	3916.76
MoPac at Steck	0.3380	17711	23	24	378.50	0.88	38.1	1269.62
MoPac at Spicewood	0.2735	28324	46	46	1799.83	0.94	39.1	9655.00
35 at Parmer	0.0000	12588	22	18	3115.20	1.00	27.7	7426.92
35 at 1325	0.4576	15900	29	29	2334.33	1.00		7029.52
35 at 32nd	0.5219	17763	62	59	834.25	1.25	53.2	2806.59
183 at Peyton Gin	0.0951	22413	48	46	927.65	0.91	69.7	3937.77
35 at Onion Creek	0.1495	8105	11	15	1651.67	1.00	58.2	2535.38
183 at 360	0.2329	24184	116	81	2059.20	1.06	67.0	9431.76

Table 4.2 Speed Data

	183 at Tweed Court/Riata	MoPac at Capital of Texas	MoPac at Steck	MoPac at Spicewood	35 at Parmer	35 at 32nd	183 at Peyton Gin	Mopac at Gaines	35 at Onion Creek	183 at 360	183 at Balcones Woods
Number of vehicles	218	58	149	167	158	149	185	86	133	224	140
Average speed (mph)	49.9	36.8	38.5	40.0	56.5	42.5	33.4	47.3	48.7	46.4	43.1
Speed Limit	50	55	50	50	not posted	40	45	not posted	not posted	50	50
85th percentile speed (mph)	56	43	44	47	61	50	41	55	56	53	48

4.3 Descriptive Statistics and Model Development

As a first step in investigating relationships among the variables, bivariate scatter plots were produced. These related access density, incidence of speeding, speed variance, and VMT to both crashes and injuries. Positive relationships were noted in all cases; an increase in any of the variables is associated with an increase in injuries and crashes. The access density and speeding relationships exhibited very low R-squared values (less than 0.1). Correlation coefficients were better for the VMT (0.18 for accidents, 0.09 for injuries) and speed variance (0.33 for accidents, 0.25 for injuries) cases. The most obvious outlier in all cases was at the northbound US 183 at Loop 360 location, which had two exit ramps feeding the frontage road (while all other cases had only one). This unique property could explain the higher levels of injuries and crashes here. The scatter plots with least squares regression lines are shown in Figures 4.1 through 4.4.

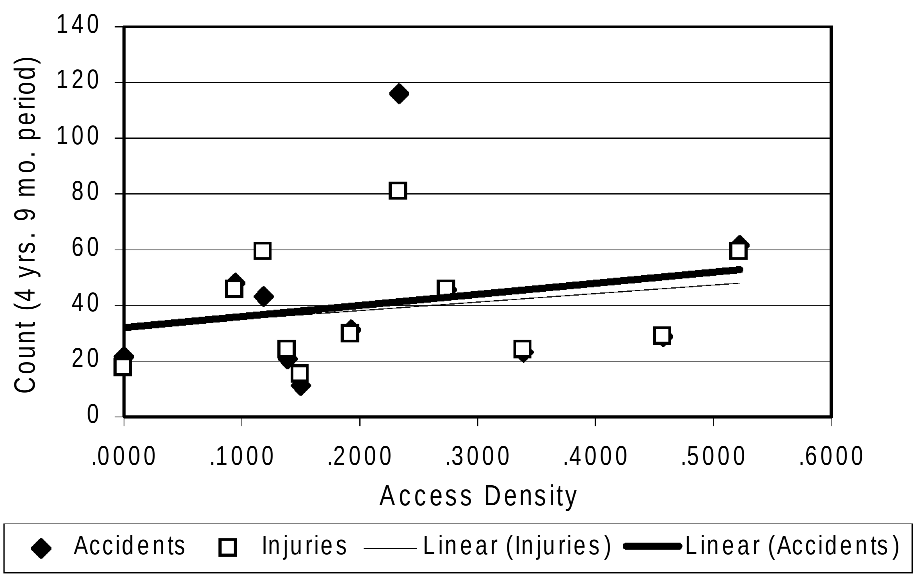

Figure 4.1 Effect of Access Density

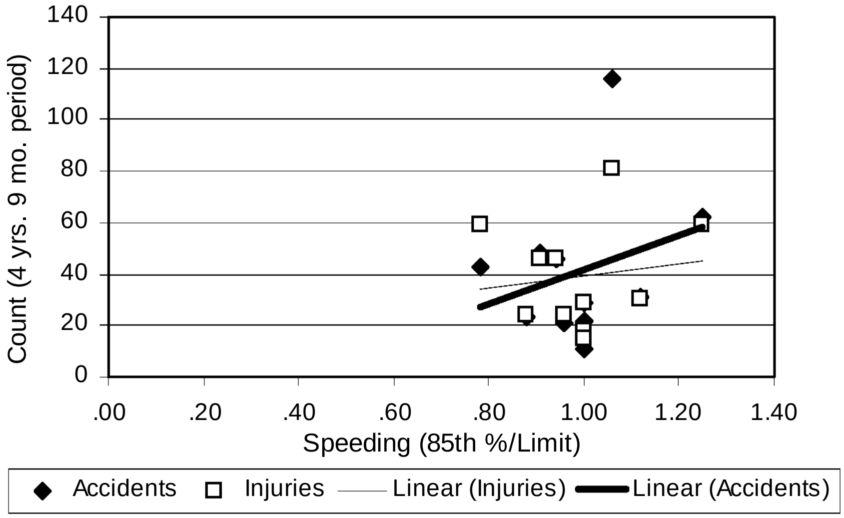

Figure 4.2 Effect of Speeding

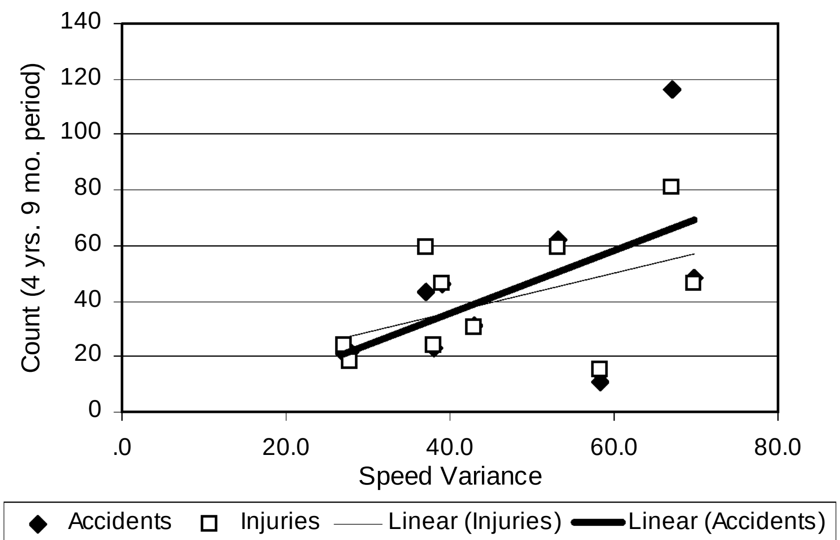

Figure 4.3 Effect of Speed Variance

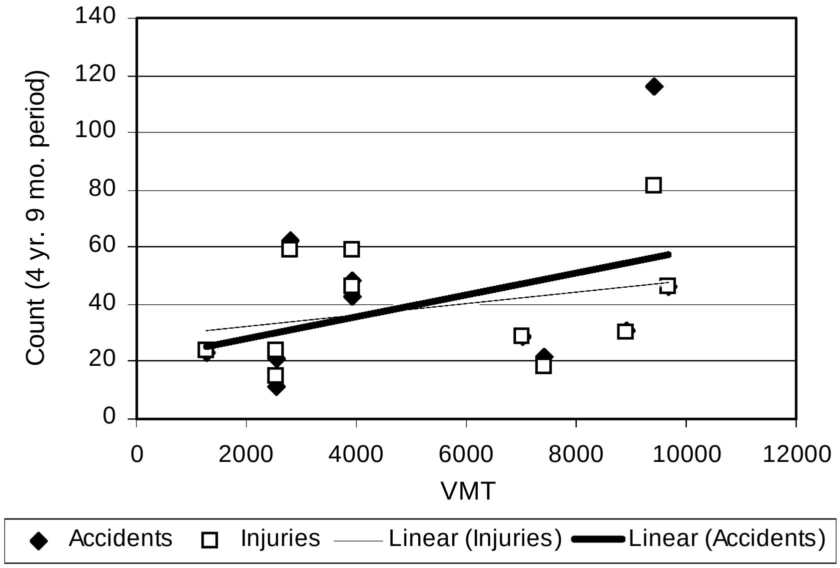

Figure 4.4 Effect of VMT

Multivariate linear regression models of accident and injury totals (for the 1996–1999 period) were estimated using access density, speed variance, and the other explanatory variables described above. Because the sample size in this analysis is extremely small (N=12), few specifications involving all variables could be tested. Basic linear-in-parameters and linear-in-variables models were used.

The use of explanatory variables that are highly correlated with one another in a multivariate regression may produce results that are counterintuitive and/or unreliable. To identify the existence of two-variable collinearity, one must examine a correlation matrix. The correlation matrix for this data is shown in Table 4.3. (Only the lower half of this matrix is shown because it is symmetric with respect to the diagonal.) The results indicate that access density and incidence of speeding are positively correlated, though not to such a degree as to significantly impact the results of the regression. This is not an intuitive result, because many drivers exhibit the characteristic to slow down when more vehicles are moving on and off the frontage road, but speed limits may be set low when many access points exist. The highest incidence of speeding is at the I35 at 38½ Street location that also exhibits the highest access density. This likely is owing to the low urban speed limit coupled with the rather low development density in this corridor (though access density is high) and the associated low volumes of turning vehicles on and off the frontage road.

One problematic instance of collinearity lay between the incidence of speeding and the variance of speeds. As will be seen, this correlation is believed to significantly impact the results. Fortunately, the other variables under study exhibited less correlation with one another—as shown in Table 4.3.

Table 4.3 Correlation Matrix for Explanatory Variables

	Access density	Incidence of speeding	Variance of speeds	Vehicle miles traveled
Access density	1.000			
Incidence of speeding	0.473	1.000		
Variance of speeds	0.193	0.257	1.000	
Vehicle miles traveled	-0.077	0.212	0.042	1.000

Because so few independent variables were available for use in this regression analysis, and because one could reasonably expect each variable to have an effect on both accident and injury occurrence, all four independent variables were included in the initial regressions. The results of these accident and injury regression models are shown in Table 4.4. Because of the clear lack of statistical significance on the incidence of speeding variable, this was removed from further model specifications. It was felt that the correlation between the two speed-related variables was producing an unexpected (though statistically insignificant) value for this variable's coefficient. The final model results are shown in Table 4.5

Table 4.4 Variable Coefficients and T-Statistics for the Initial Regression Model

Explanatory variables	Accidents (4 years, 9 months)	Injuries (4 years, 9 months)
Constant	-8.195 (-0.119)	37.473 (0.692)
Access density	85.992 (1.207)	82.738* (1.480)
Incidence of speeding	-41.245 (-0.511)	-62.858 (-0.993)
Variance of speeds	1.020* (1.814)	0.667* (1.511)
Vehicle miles traveled	5.092×10^{-3}* (1.828)	3.287×10^{-3}* (1.504)
Adjusted R^2	0.326	0.187

N_{obs} = 12, t statistics in parentheses

* Asterisks indicate statistical significance at the 20% level.

Table 4.5 Variable Coefficients and T-Statistics for the Preferred Regression Model

Explanatory variables	Accidents (4 years, 9 months)	Injuries (4 years, 9 months)
Constant	-39.851 (-1.398)	-10.770 (-0.451)
Access density	65.382 (1.189)	51.328 (1.115)
Variance of speeds	0.971* (1.871)	0.593 (1.364)
Vehicle miles traveled	4.577×10^{-3}* (1.882)	2.503×10^{-3} (1.230)
Adjusted R^2	0.409	0.189

$N_{obs} = 12$

* Asterisks indicate statistical significance at the 20% level.

As a final check on the decision to eliminate the speeding variable from the model, a final regression model was constructed with incidence of speeding appearing separately from the speed variance term. The resulting models had the lowest adjusted R-squared values of any considered, and none of the parameters was statistically significant. Therefore, the results in Table 4.5 offer the preferred model.

4.4 Results

Given such a small sample size (twelve), the sample-size adjusted R-squared values were lessened; moreover, the crash data came from dates prior to the count and speed measurements. However, the 4-year, 9-month crash totals were rather well predicted by the available variables (over 40% of the variation in crash counts was explained in the model). There are likely other variables not included here that could explain away additional variability in the incidence of accidents and/or injuries. Another reason for the low statistical significance of the models could be the fact that the data were not collected in the same time frame. The accident and injury experience was from a 4-year, 9-month period from 1995 through September 1999, speeding incidence came from various dates during October 2000, and the VMT was calculated based on counts conducted over a 2-day period in August 2000.

The only variable that may remain somewhat constant over the entire period is access density, but even this variable may have changed as developments may have arisen and new roadways and driveways may have been constructed.

These coefficients are positive in both cases and statistically significant at levels of 0.20 (or less). If the VMT had been constant for the 4-year, 9-month period and one assumed that 887 (i.e., 365 x 4.75/2) such 2-day periods had occurred over that duration, the parameter values of 4.577E-3 and 2.503E-3 would suggest one crash every 189,000 VMT and one injury every 346,000 VMT. These crash rates are a little lower than the average crash rates Kweon and Kockelman [forthcoming] have estimated across all types of driving (which are on the order of one for every 167,000 miles driven); however, it is likely that VMT rose steadily and significantly between 1995 (the first year of crash-data collection) and 2000 (the year the VMT data were taken), because the Austin metro region has experienced substantial population and driving growth. Lower actual VMT for the crash and injury counts analyzed imply even higher coefficients on this variable. Moreover, with access densities higher than zero and with variations in speed, rather standard frontage-road sections actually may be more crash or injury prone than the "average" road section (which includes local streets and freeways).

Higher access density along a frontage road segment is shown to have a positive effect on both injury and crash occurrence. This variable is statistically significant at a 20% level in the injury models and a 25% level in the crash model. Lowering the access density along a frontage road segment via access management strategies can reasonably be expected to reduce the occurrence of both crashes and injuries. A shift from an access density of 0.5 to an access density of 0.0 (as in the maximum and minimum data set values) could be expected to lead to thirty-three fewer crashes and twenty-six fewer injuries over a 4-year period (or 8.1 fewer crashes and 6.4 fewer injuries per year).

Another way to define "access density" is to count the number of businesses having "direct access to the highway" per mile, as done in work summarized by FHWA (1992). This work estimated linear crash rates (measured as crashes per 100 million vehicle miles) as a function of this access density variable and found urban areas to be roughly 50 percent more crash-prone (per VMT) than rural areas. And urban-area crash rates grew, on average, from 400 crashes per 100 million VMT assuming zero access points to 1200, assuming 80 such businesses per mile with access. It is difficult to compare the FHWA results with those provided here, due to the distinct definitions of access density, but both are suggestive of the impacts driveways (and cross-roads, in this research) frequency have on crash rates.

Another way the FHWA (1992) has presented the crash rate-access relation is by comparing crash rates across different levels of access control. Control can be broadly characterized as “full”, “partial”, or “none”; using these classes, full-access-control crash rates are much lower, on average, than partial and no-control rates. Full-control crash rates average 1.86 per million vehicle miles in the urban case and 1.51 in the rural case. Under *partial* access control the rates are 4.96 and 2.11, for urban and rural cases, respectively. For no access control, the rates are 1.86 and 1.51, respectively. *Fatal* crash rates are also higher for no-control cases, but the rural rates exceed the urban rates (and the partial-control rates for urban cases actually exceed the no-control urban fatal crash rates).

Finally, variance of speeds contributes to both crashes and injuries, as one would expect. Strategies to reduce speed variance, such as separating ramps and driveways by a sufficient distance and stopping vehicles from making drastic speed changes while accessing driveways and ramps along frontage roads, can be expected to reduce the incidence of crashes and injuries.

4.5 Conclusion

Examining the qualitative issues surrounding different frontage-road locations can provide examples, both positive and negative, of how TxDOT and local agencies deal with access management issues on frontage roads into the future. A multivariate regression suggested that speeding has little impact on the occurrence of crashes or injuries in this small sample (after controlling for speed variance), but higher access densities and higher speed variations are associated with a higher incidence of both crashes and injuries.

CHAPTER 5: CORRIDOR PAIR ANALYSIS

5.1 Introduction

A common perception of frontage roads is that they encourage commercial development of moderate-to-high intensity alongside freeway corridors, rather than concentrating such development at major intersections. Such strip development may buffer remaining land uses from the noise and visual impacts of frontage roads, but it also may encourage automobile dependence and/or sprawl. To examine these questions statistically, pairs of frontage-road and non-frontage- road corridors were found from an atlas of maps. This search for pairs of proximate corridors resulted in thirteen pairs of data points, falling in five different states (Texas, Minnesota, Arizona, New Mexico, and Oklahoma). The proximity of each corridor to its partner was an essential criterion for the inclusion of the pair in this data set; without detailed information on each pair, spatial proximity was felt to provide some control on other variables (such as zoning laws, terrain, and major travel patterns). Data from the 1990 Census of Population and Housing were used to compare the population-weighted averages of tract characteristics along these corridors. The Dallas Fort Worth job data were made available by the region's planning organization, the North Central Texas Council of Governments (NCTCOG), permitting a look at employment by industrial sector and a census block-group distinction of corridor-relevant locations.

5.2 Data Collection

The census tracts along the study corridors outside the Dallas/Fort Worth region (corridors 3-13) come from the 1990 U.S. Census Metropolitan Statistical Area (MSA) tract maps. Additional data availability within the Dallas/Fort Worth area (corridors 1 and 2) allowed a closer inspection of demographics (at the smaller block-group level), and an analysis of employment densities (as indicators of land use). A table of selected census tracts and block groups is provided in Table 5.2 Maps of the selected block groups in the Dallas Fort Worth region are provided in Figures 5.1 through 5.5.

Table 5.1 Corridor Pair Selections

Corridor ID	Presence of frontage roads	Corridor city, county, state	Corridor location
1a	Y	Fort Worth/Arlington, Tarrant County, Texas	I-20 from I-820 to Texas 360
1b	N	Arlington, Tarrant County, Texas	I-30 from I-820 to Route 157 (Collins Rd.)
2a	Y	Dallas/Seagoville, Dallas County, Texas	US 175 from Route 12 interchange to Seagoville city limit
2b	N	Dallas/Hutchins/Balch Springs, Dallas County, Texas	I-20 at Union Pacific railroad crossing to 0.25 mile before Seagoville Rd. ramp
3a	Y	Houston, Harris County, Texas	US 59 from I-610 to Hazard Rd.
3b	N	Houston, Harris County, Texas	US 59 from Hazard Rd. to Route 288
4a	Y	Houston, Harris County, Texas	US 59 from Quitman Rd. to I-610
4b	N	Houston, Harris County, Texas	US 59 from McKinney Rd. to I-10
5a	Y	San Antonio, Bexar County, Texas	I-35 from I-10 to I-410 loop
5b	N	San Antonio, Bexar County, Texas	I-37 from US 90 to I-410 loop
6a	Y	San Antonio, Bexar County, Texas	US 281 from I-410 (inner belt) to Route 1604 (outer belt)
6b	N	San Antonio, Bexar County, Texas	US 281 from 1604 (outer belt) to San Antonio city limit (Marshall Rd.)
7a	Y	Bloomington/Richfield, Hennepin County, Minnesota	I-494 from Bush Lake Rd. to Portland Ave.
7b	N	Edina, Hennepin County, Minnesota	MN 62 (Crosstown Hwy) from MN 100 to MN 77
8a	Y	Phoenix, Maricopa County, Arizona	I-17 from 16th St. to Pinnacle Peak Rd.
8b	N	Phoenix, Maricopa County, Arizona	I-10/US 60/Route 51 from I-17 to terminus
9a	Y	Phoenix, Maricopa County, Arizona	I-17 (east/west section) from I-10/US 60 to NW curve
9b	N	Phoenix, Maricopa County, Arizona	I-10/US 60 from Route 51 to I-17
10a	Y	Tucson, Pima County, Arizona	I-10 from I-19 to W. Speedway, and I-10 from BR 10 to Gardner
10b	N	Tucson, Pima County, Arizona	I-19 from I-10 to Valencia
11a	Y	Albuquerque, Bernalillo County, NM	I-25 from I-40 to city limit (north)
11b	N	Albuquerque, Bernalillo County, NM	I-40 from I-25 to city limit (east)
12a	Y	Oklahoma City, Oklahoma County, Oklahoma	US 77 from I-44 to John Kilpatrick Turnpike
12b	N	Oklahoma City, Oklahoma County, Oklahoma	Route 74 from Route 3 to John Kilpatrick Turnpike
13a	Y	Tulsa, Tulsa County, Oklahoma	I-44 from Arkansas River to US 64
13b	N	Tulsa, Tulsa County, Oklahoma	US 64 from I-44 to 15th St. S.

Table 5.2 Census Tracts and Block Groups Selected for Corridor PaiAnalysis

Corridor ID	Census tracts	Block Group(s)
1a	1114.03	1, 2
	1115.13	1
	1115.14	1
	1115.15	1
	1115.16	1
	1115.23	1, 4
	1115.25	1, 4
	1115.27	6
	1115.28	4, 5
	1115.30	1, 2
	1115.31	1, 2, 3
	1115.32	1, 2
	1216.09	2
	1216.11	3, 4
1b	1065.03	1
	1065.09	2
	1065.11	4, 5, 6
	1065.12	1, 2
	1065.14	1, 2
	1131.06	3
	1131.07	2
	1131.08	3, 4
	1216.04	1, 2
	1216.05	1
	1217.01	1, 2
2a	170.01	1, 2, 3
	170.02	3, 4, 5, 6
2b	117	7, 8
	171	1, 2
	172.01	5
	172.02	4
3a	405.01	all
	407.01	all
	407.02	all
	419.02	all
	419.03	all
3b	306	all
	316.01	all
	404.01	all
	404.02	all
4a	205.01	all
	205.98	all
	206.01	all
	207.03	all
	207.04	all
4a	205.01	all
	205.98	all
	206.01	all
	207.03	all
	207.04	all
4b	121	all
	300.22	all
	300.23	all
5a	1503	all
	1504	all
	1505	all
	1506	all
	1511	all
	1512	all
	1513	all
	1610.85	all
	1611	all
5b	1402	all
	1403	all
	1408	all
	1410	all
	1411	all
	1414	all
	1415	all
	1416	all
6a	1211.06	all
	1211.07	all
	1211.08	all
	1912	all
	1913	all
	1914.02	all
	1914.03	all
	1917	all
6b	1219.02	all
	1918.02	all
7a	239.03	all
	240.02	all
	243	all
	246	all
	254.01	all
	255.01	all
	256.01	all
	256.03	all
	256.05	all
	259.03	all
7b	117.02	all
	120.01	all
	120.02	all
	237	all
	238.01	all
	238.02	all
	239.01	all
	240.01	all
	241	all
	244	all
	247	all
	249.01	all
8a	303.02	all
	303.18	all
	303.21	all
	1036.08	all
	1036.09	all
	1039	all
	1044	all
	1055	all
	1060	all
	1068	all
	1073	all
	1090	all
	1103	all
	1120	all
	1128	all
	1144	all
	1148	all
	1149	all
	1150	all
8b	1048.01	all
	1051.02	all
	1052	all
	1064	all
	1077	all
	1085	all
	1107	all
	1116	all
	1133	all
	1139	all
	1151	all
9a	1148	all
	1149	all
	1150	all
9b	1129	all
	1130	all
	1132	all
	1133	all
10a	2	all
	3	all
	10	all
	11	all
	23	all
	25.01	all
	45.04	all
10b	24	all
	25.01	all
	37.03	all
	38	all
	39	all
11a	29	all
	34	all
	37.03	all
	37.05	all
	37.97	all
	37.98	all
11b	1.23	all
	1.24	all
	2.07	all
	2.08	all
	3	all
	4	all
	6.01	all
	7.03	all
	7.04	all
	7.07	all
	7.08	all
	34	all
12a	1062	all
	1063.01	all
	1063.02	all
	1083.01	all
	1083.02	all
12b	1066.08	all
	1084.02	all
	1085.06	all
	1085.07	all
	1085.08	all
13a	50.01	all
	50.02	all
	51	all
	52	all
	68.01	all
	68.02	all
	69.01	all
	86	all
	87	all
13b	36	all
	39	all
	40	all
	42	all
	53	all
	70	all

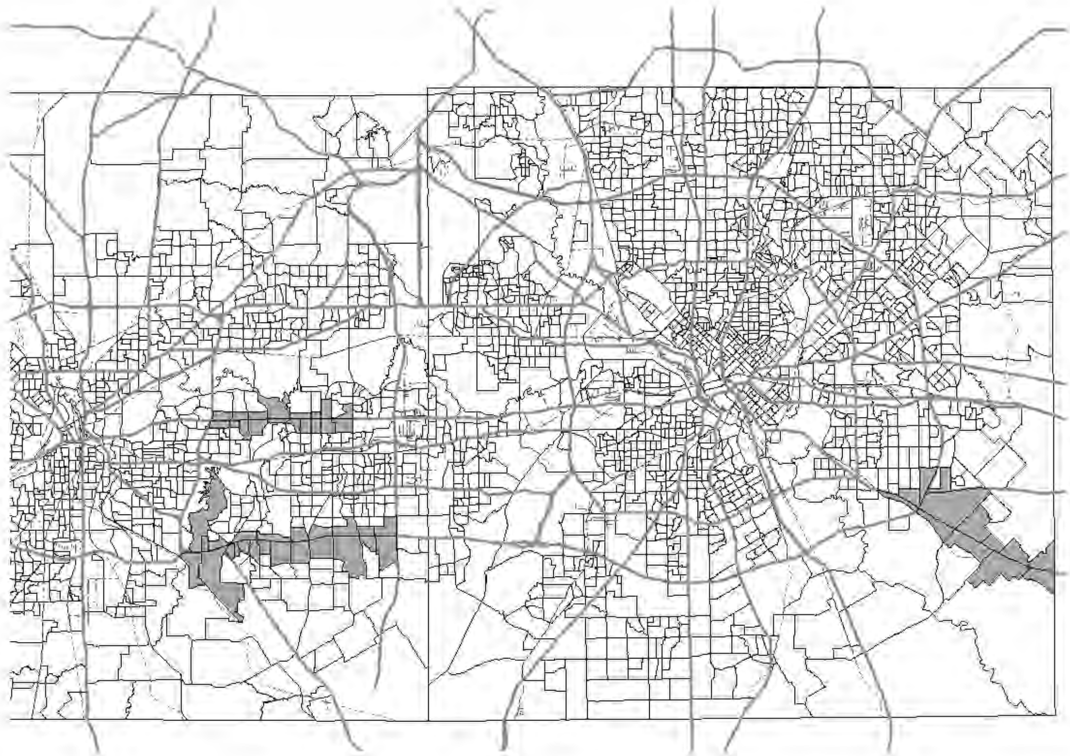

Figure 5.1 Dallas-Fort Worth Regional Map with Selected Block Groups

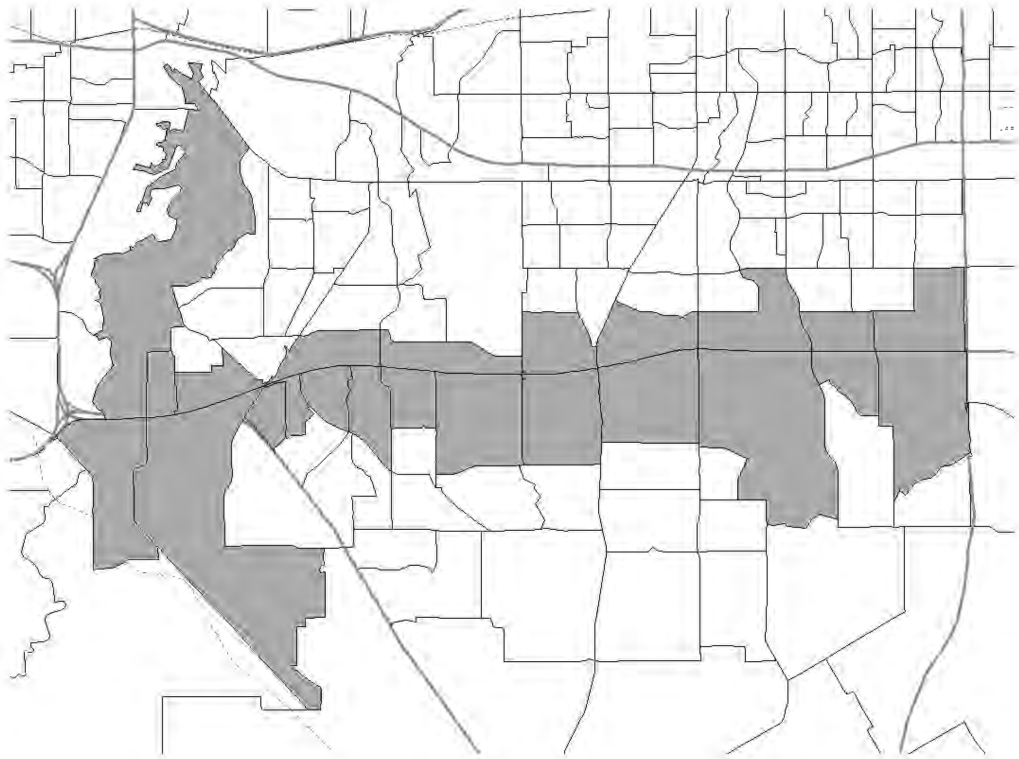

Figure 5.2 Detail of Selected Block Groups in Corridor 1a

This is a frontage road corridor along I-20 from I-820 to Texas 360 in Fort Worth and Arlington.

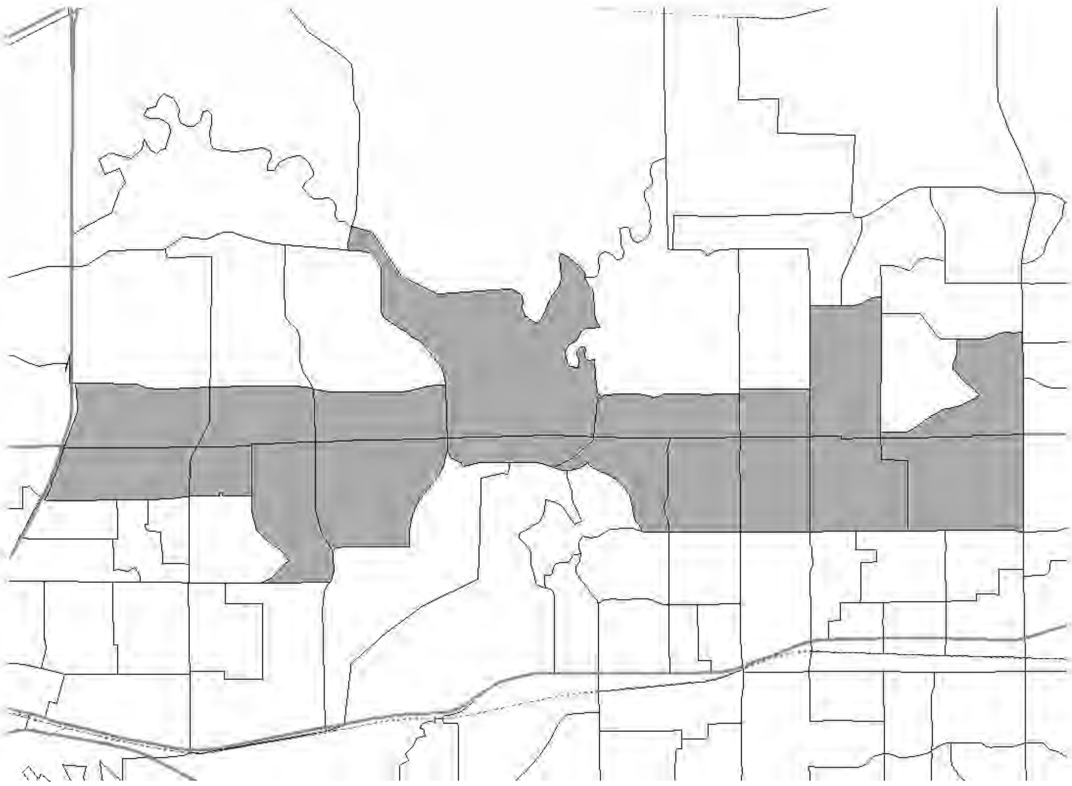

Figure 5.3 Detail of Selected Block Groups in Corridor 1b

This is a non-frontage road corridor along I-30 from I-820 to Route 157 (Collins Road) in Arlington.

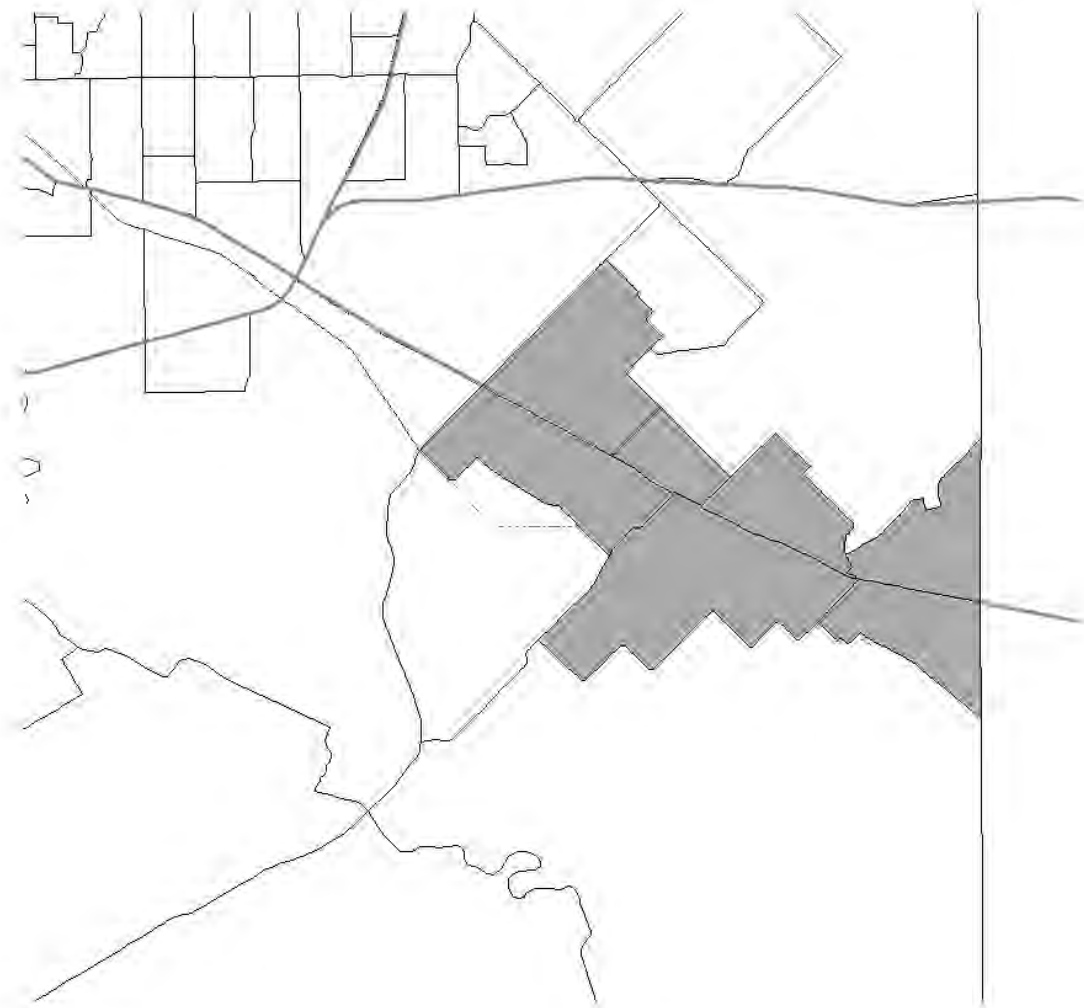

Figure 5.4 Detail of Selected Block Groups in Corridor 1b

This is a frontage road corridor along US 175 from the Route 12 interchange to the Seagoville city limits. The block group boundaries lie within the cities of Dallas and Seagoville.

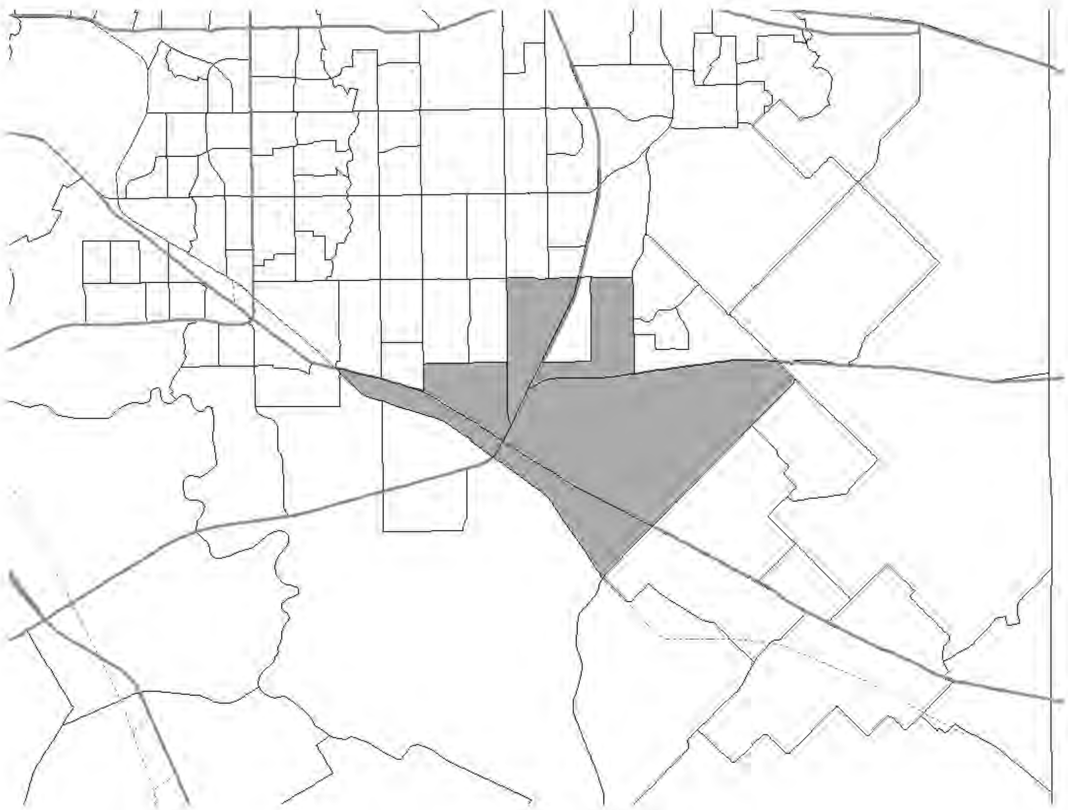

Figure 5.5 Detail of Selected Block Groups in Corridor 2b

This is a non-frontage-road corridor along I-20 from the Union Pacific railroad crossing to 0.25 mile before the Seagoville Road ramp. The block-group boundaries cross the city limits of Dallas, Hutchins, and Balch Springs.

Demographic information collected from each census tract included the following: median household income; per capita income; average household size; population density; percentage who drive alone to work; percentage who carpool to work; percentage who take public transit to work; percentage who bike to work; percentage who walk to work; average travel time to work; average private vehicle occupancy to work; percentage of population with a high school education or greater; percentage with a college education or greater unemployment rate; percentage of population below poverty level; average resident-age; average adult-resident age (18+); and percentage of housing units that are multifamily structures. For each corridor, a population-weighted average of every variable was then computed. Differences of these averages between pairs were taken, and the statistical significance of these differences (when compared to no/zero difference) was evaluated (via a standard t-test).

5.3 Analysis of Demographic Trends

Although the small sample size limits statistical significance results, several differences were practically and statistically significant. Based on the differences that were found to be statistically significant at a 15% level (i.e., p-value ≤ 0.15), census tracts near frontage roads appear to be associated with lower household incomes (averaging $3,800 less per household in 1990 dollars), lower population densities (513 fewer persons per square mile), lower percentages of bike trips to work (just 0.38% lower), lower vehicle occupancies for work trips (0.8 persons per vehicle), and higher unemployment rates (2.3% higher)—relative to a similar/equivalent corridor constructed without frontage roads (see Table 5.2). These results suggest that inhabitants of frontage-road corridors are not as well to do and are more automobile dependent than persons in the non-frontage-road pairings. Frontage-road corridors appear to be less desirable (due to an attraction of lower-income households) and less alternate-mode friendly than non-frontage-road corridors.

Though not statistically significant, the results also suggest that residents of frontage-road corridors exhibit somewhat lower per capita incomes, larger household sizes, more single-occupancy vehicle commuting, lower educational levels, greater incidence of poverty, older average age, and lower fractions of multifamily housing units (Overman 2000). With a larger sample size of such paired corridors in the U.S., such results may become statistically significant. Overall, however, the picture provided is incomplete; information on variables such as employment density and land-use patterns also would be helpful.

Table 5.3 Statistically Significant Differences in Demographic Variables between Frontage-Road and No Frontage-Road Corridors

Corridor pair (FR – no FR)	Median household income	Population density (pers./sq. mi.)	Percent bike to work	Average private vehicle occupancy to work	Unemploy-ment rate
1	$13,156	-1376	-0.08%	-0.03	-1.41%
2	-$834	-1203	0.06%	-0.01	-0.44%
3	$8,974	-1959	-1.74%	-0.26	-5.03%
4	-$13,978	1404	-0.18%	-0.91	17.14%
5	-$2,338	869	-0.06%	0.12	4.29%
6	-$21,649	2480	0.05%	0.05	1.30%
7	-$2,261	-1004	0.19%	-0.01	0.13%
8	-$3,987	925	-0.76%	0.00	1.35%
9	-$1,924	-4119	-3.03%	-0.02	6.01%
10	-$4,318	-622	1.52%	-0.13	-1.30%
11	-$1,003	-1059	-0.78%	-0.01	1.75%
12	-$17,983	-982	0.04%	0.07	4.71%
13	-$1,916	-29	-0.12%	0.02	1.46%
Averages:	**-$3,851**	**-513.4**	**-0.38%**	**-0.08**	**2.30%**
Variance	9.19×10^{7}	2.83×10^{6}	1.16×10^{-4}	7.07×10^{-2}	2.83×10^{-3}
SE of Mean Difference	2.66×10^{3}	4.66×10^{2}	2.99×10^{-3}	7.37×10^{-2}	1.47×10^{-2}
T statistic	-1.449**	-1.101*	-1.260*	-1.150*	1.562**
p-values	0.087	0.146	0.116	0.136	0.072

* significant at 15% level
** significant at 10% level

Table 5.4 Differences in Demographic Variables between Frontage Road and No-Frontage Road Corridors with Low Statistical Significance

Corridor pair	Per capita income, 1989	Average household size	Percent SOV to work	Percent carpool to work	Percent public transit to work	Percent walk to work	Average travel time to work (min)	Percent high school education or greater	Percent college education or greater	Percent below poverty level	Average resident age	Average adult resident age (18+)	Percent multifamily housing units
1	$1,393.99	0.512	4.62%	-2.40%	-0.35%	-1.38%	2.44	3.95%	3.98%	-8.07%	-3.38	-0.51	-40.10%
2	$1,321.00	-0.148	2.22%	-0.72%	-1.71%	-0.65%	1.82	1.11%	-0.41%	-2.00%	3.08	1.25	13.10%
3	$10,033.68	-0.377	22.90%	-8.33%	-11.67%	-1.36%	-3.10	15.81%	17.90%	-14.86%	-3.55	-1.69	-32.99%
4	-$1,995.95	0.565	20.74%	-6.34%	8.92%	-22.77%	7.14	-14.77%	-3.14%	3.34%	1.02	0.30	-11.40%
5	-$2,375.77	0.823	-5.42%	5.07%	0.15%	0.21%	2.41	-18.63%	-3.31%	7.62%	3.83	1.19	3.38%
6	$890.74	-0.836	-5.09%	3.32%	1.01%	0.85%	-4.96	-2.45%	-12.60%	4.70%	5.21	11.42	-54.05%
7	$495.87	-0.113	2.91%	-0.34%	-2.88%	-0.16%	-0.36	0.48%	-3.15%	0.42%	-1.91	-0.66	-18.93%
8	-$4,222.85	0.094	-0.13%	1.48%	-0.78%	0.34%	1.41	-1.05%	-6.38%	0.15%	5.56	0.94	33.62%
9	-$591.29	0.151	2.19%	4.10%	-2.07%	1.01%	-1.09	-8.02%	-3.13%	5.39%	-1.87	-3.08	18.41%
10	$970.89	-0.685	-1.82%	-5.22%	2.77%	3.02%	-2.16	7.60%	3.45%	4.22%	-3.24	-2.87	5.75%
11	-$2,453.29	0.139	1.93%	0.14%	-071%	-0.22%	0.86	-5.59%	-6.93%	2.97%	2.15	3.61	-21.00%
12	-$12,066.16	0.499	-7.88%	5.65%	0.41%	0.79%	0.51	-11.60%	-27.57%	13.58%	4.60	2.81	9.78%
13	$2,544.19	-0.097	-3.59%	1.96%	0.34%	1.38%	1.62	0.21%	3.17%	4.84%	-2.61	-1.63	1.31%
Averages:	-$466	0.041	2.58%	-0.13%	-0.51%	-1.46%	0.503	-2.53%	-2.93%	1.71	0.68	0.85	-7.16
SE of Mean Difference	$1.36x10^{3}$	$1.36x10^{-1}$	$2.59x10^{-2}$	$1.23x10^{-2}$	$1.24x10^{-2}$	$1.81x10^{-2}$	$8.34x10^{-1}$	$2.59x10^{-2}$	$2.88x10^{-2}$	1.97	$9.86x10^{-1}$	1.04	$7.01x10^{-2}$
T statistic	-0.342	0.299	0.998	-0.103	-0.410	-0.807	0.604	-0.979	-1.018	0.869	0.693	0.817	-1.022
p-values	0.369	0.385	0.169	0.460	0.345	0.218	0.279	0.173	0.164	0.201	0.251	0.215	0.163

5.4 Using Dallas Fort Worth Regional Geographic Information System and Employment Density Data

Using a Geographic Information System database of the Dallas Fort Worth metropolitan area encompassing two corridor pairs, corridor employment densities were calculated for seventeen different industrial classifications during the years 1990 and 1997. These data are presented in Table 5.4, and they are a strong proxy for land use in these corridors. The employment types evaluated are as follows: agriculture, forestry, and fishing; mining and construction; nondurable manufacturing; durable manufacturing; transportation; commercial and public utilities; wholesale trade; retail trade; finance, insurance, and real estate; business and repair services; personal services; entertainment and recreation; health services; education services; other professional services; and public administration. Data were collected for the years 1990 and 1997, and average corridor employment densities were computed by dividing total employment across all corridor blocks (by industry) by the total block areas in the respective corridors. These results are shown in Table 5.4.

Table 5.5 Computed Average Corridor Employment Density by Employment Type in 1990 and 1997 (Jobs per Square Mile)

	Agriculture, forestry, fishing	Mining	Construction	Manufacturing: non-durable	Manufacturing: durable	Transportation	Utilities	Wolesale trade	Retail trade	Finance, insurance, real estate	Business and repair srvices	Personal services	Entertainment & recreation	Health services	Education services	Other professional services	Public administration
1990 Data																	
1a	11.5	11.8	43.7	61.1	148.2	66.5	33.4	66.5	185.1	84.7	58.2	27.4	16.5	70.5	79.8	65.3	41.3
1b	7.8	4.1	**80.5**	**90.3**	**237.5**	**117.9**	51.3	**113.4**	**355.9**	**141**	**106.2**	**68.5**	37.1	**126.1**	**125.2**	**115.3**	**72.7**
2a	2.6	6	34.4	22.9	56.4	19.4	17.3	25.9	55.4	27.7	22.2	5.7	2.5	24.7	23	12.3	20
2b	4.4	**60.5**	23.9	49.3	27	23	31	**82.7**	37	25.5	12	6.3	18.4	23.8	16.1	9.8	44.5
1997 Data																	
1a	15.9	14.8	65.8	76.3	183.7	84.7	37.6	84.7	249	111	84.9	39.1	21.5	102.4	109.2	95.7	53.6
1b	11.2	4.5	**98.8**	**98.1**	**257.8**	**130.2**	51.3	**123.4**	**408.3**	**161.3**	**134**	**80.1**	41	**161.4**	**149**	**146.8**	**82.9**
2a	3.1	5.6	37.4	23.2	53.5	21.6	16.6	28.1	60.8	30.8	27.5	7.4	2.8	29.3	25.2	16	20.5
2b	7.2	5.2	**67.6**	26.9	51.5	31.4	24	36.3	**99.3**	45.2	33.9	15	7.9	24.7	29	23	12.6

*Shaded figures represent instances when one corridor clearly "dominates" the other in terms of employment density in important/high-density categories.

5.5 Analysis of Results

The first Dallas Forth Worth corridor pair in Table 5.4 includes I-20, from I-820 to Texas 360 (Corridor 1a, with frontage roads), and I-30, from I-820 to Route 157 (Corridor 1b, without frontage roads). The second pair consists of US 175, from Route 12 to Seagoville's city limits (Corridor 2a, with frontage roads), and I-20 at Union Pacific railroad crossing to a point 0.25 mile from the Seagoville Road ramp (Corridor 2b, without frontage roads). Corridor 1b, the second of these four, did not have frontage roads and clearly dominated the four cases in most of the employment density categories. To a lesser degree, Corridor 2b, the non-frontage-road corridor in the second pair, dominated Corridor 2a in retail, wholesale, and nondurable manufacturing sector densities. In the 1990 data set, however, it was dominated by its frontage-road partner in the durable manufacturing and retail trade sectors. These same two sectors were much higher in both Corridors 1a and 1b. This likely is because Corridor pair 1 is located within the urbanized Mid-Cities area of the Dallas Fort Worth region, while Corridor pair 2 is located at the southeastern edge of the urban fringe.

These results suggest a link between frontage roads and lower overall employment densities, which counters to some extent a perception that frontage- road construction facilitates economic development along freeway corridors. However, land development is much more complex than this four-case study can illuminate. A source familiar with Case 1a noted that small portions are developing as commercial hot spots, but the area is traditionally zoned residential. Corridor 1b was a toll road until 1978; the area is home to Six Flags and the Ballpark at Arlington and has developed almost exclusively under commercial zoning. Thus, one would expect it to exhibit high job densities.

More research is needed to determine if there is a causal link between frontage-road corridors, demographics, employment densities, and land uses. A greater number of corridors need to be compared, and these probably will come from outside Texas (because so few non-frontage freeway corridors exist within the state). A researcher able to access similar GIS databases to the Dallas/Fort Worth database utilized here may be able to draw more statistically and practically significant conclusions than those presented in this report. Moreover, a panel of cross-sections over time would better identify directions of causality (e.g., frontage roads may follow, rather than precede, lower-income, lower-density locations).

CHAPTER 6: OPERATIONAL ANALYSIS

6.1 Introduction

This research investigated the effectiveness of frontage roads as an element of controlled-access facilities. Improper implementation of frontage roads reduces their attributed efficiency and may impair traffic flows on both the freeway and the frontage road itself. To understand under what geometric conditions the operation of frontage roads is problematic, an extensive literature review was conducted and a variety of corridor operations were simulated. The traffic-analysis software, CORSIM (FHWA 1999), was used to evaluate the traffic operations of these scenarios.

Frontage roads offer some advantages for freeway operations. For example, they permit clear route-choice flexibility in cases of maintenance activities, crashes, or other emergencies. However, they may promote weaving maneuvers and intense ingress/egress activity from bordering land uses. Investigations by Pinnel (1963), Barnes et al. (1992), Nolin and Parham (1996), and Fitzpatrick et al. (1996) suggest a variety of design policies to enhance frontage-road operations. Barnes et al. (1992) presented a case study on a section of I-610W where freeway flows improved, following the introduction of a collector-distributor system. However, it was found that the congestion *shifted* to loading and unloading points, such as intersections, creating even harsher consequences at several cross-street interchange locations. Based on their observations of various frontage-road operations, Barnes et al. (1992) recommended that sufficient right-of-way should exist, major cross-street spacing be generous, and existing intersection geometries be appropriate. They also recommended that ramps have one entrance lane and two exit lanes, interchange distances equal or exceed 3,000 feet (915 meters), and weaving section lengths (on the frontage roads) be at least 1,000 feet in length. In comparison with many Texas frontage road corridors, these suggested dimensions are quite generous.

When ramps are frequent, the resulting weaving sections negatively impact safety and flow (Fitzpatrick et al. 1996). The Lewis et al. (1999) findings indicated that decisions to locate ramps in order to facilitate land development along roadway frontages (in fourteen Texas case-study locations) could have very negative impacts on traffic flow. In some cases, growth and development along frontage roads created traffic volumes that exceeded the capacities of the ramps, frontage roads, and traffic signals during peak hours. Other cases suggested that dangerous weaving movements are encouraged when motorists wish to access driveways located close to ramps. Where engineers attempted to avoid such movements via geometric designs that created rather circuitous routes (to access certain driveways), motorists developed illegal and dangerous shortcuts in order to access these developments (Lewis et al. 1999).

Fitzpatrick, Nowlin, and Parham (1996) studied one-sided and two-sided weaving maneuvers (where one-sided weaving implies that ingress/egress points are only along the highway side of a frontage road, and two-sided weaving implies that these lie along both sides of the frontage road). Many factors influence traffic operations in such weaving sections; these include traffic volumes and capacities, ramp spacing, number of lanes, and design speeds. In particular, the effects of weaving length become more evident as traffic volumes increase (Fitzpatrick, Nowlin, and Parham 1996). Based on collected field data and NETSIM simulation, Fitzpatrick and Nowlin (1996a) plainly showed that weaving speeds fall as weaving volumes increase. Moreover, weaving sections below 200 meters in length may break down at relatively low traffic volumes, as compared to weaving sections longer than 200 meters. Therefore, based on correlations between weaving speed and weaving lengths, Fitzpatrick and Nowlin (1996a) recommended that minimum weaving distances of 300 meters be provided.

The *Highway Capacity Manual* (2001) only explicitly considers weaving in the context of *freeway* design and operations. As Fitzpatrick, Nowlin, and Parham (1996) recognize, sections of frontage roads that are influenced by weaving maneuvers between a freeway exit ramp and a downstream intersection possess *two-sided* weaving operations. For these sections, traffic exiting the freeway mainlanes must change lanes to access exit points on the far side of a frontage road. Two-sided weaving is a very common and complex maneuver for frontage roads, but it is not specifically addressed in the *Highway Capacity Manual*.

6.2 Research Objectives

This section describes an investigation of the effectiveness of one-way[5] frontage roads using the traffic-analysis software, CORSIM (FHWA 1999). The simulations were run to assess freeway, frontage road, and arterial operations under various design scenarios and land-use intensities. The results of the simulations (such as the distribution profile of delays across traveler categories) and the flow observations permit an assessment of network performance and design options.

The simulations sought to identify design conditions (e.g., interchange spacing and type) for which frontage roads were most effective. This was done via a comparison of several network types, including freeway corridors with and without frontage roads. Land use intensities and interchange spacings were also varied. Cases where one scenario performed better than others were identified.

This chapter describes the assumptions used and results obtained in modeling the operation of freeway networks. Both X-type[6] and diamond interchanges were examined, because these are the most common types of interchanges when frontage roads are present. An evaluation of the two scenarios permits one to establish the design conditions (e.g. driveway spacings) under which these networks perform best and to compare them. These networks were built progressively to insure that all operational features were evaluated separately – including weaving length, provision of deceleration lanes, signal timing and signal phasing – and to determine the impact of each of those features on the performance of each network. Madi's thesis (2001) describes various tests of pieces of the network, before full-network simulations were run.

The traffic-analysis software CORSIM was used to code several scenarios of land-use intensities (mainly residential and commercial developments), driveway spacings, ramp-to-interchange spacings, and interchange types. The results of the CORSIM simulation outputs were analyzed to assess the performance of the networks. Speed and control delay[7] were the main threshold factors against which operational performance was evaluated.

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[5] AASHTO recommends the use of one-way rather than two-way frontage roads. Two-way frontage roads have serious safety concerns associated with them, both for pedestrians and vehicles at ramp intersections.
[6] X interchanges are those where on-ramps precede the interchange and off-ramps follow the interchange.
[7] Control delay is the delay incurred "between the travel time actually experienced and the reference travel time that would result during ideal conditions: in the absence of traffic control, geometric delay, and incidents, and when there are no other vehicles on the road" (HCM 1997, 9-7).

6.3 Software Simulation Tool

The traffic simulation software CORSIM was used in this study to evaluate the operational level of freeways, frontage roads and secondary arterials.

The first step in defining a dataset for CORSIM is describing the geometrics of the network. CORSIM uses the concept of links and nodes to define the roadway networks. Links are unidirectional segments when coding for freeways and could be used for both directions when coding arterials or secondary roads. Nodes are usually the intersection of two or more links. CORSIM is subdivided into two sections: FREESIM and NETSIM. The freeway network is coded using FREESIM. Arterials and secondary roads are coded using NETSIM. The data record types allow the user to specify the link names and description, traffic parameters, sign and signal controls, intersection simulation, traffic volumes and vehicle occupancy, and traffic assignment. The software offers additional record types that could be used whenever needed.

6.4. Variables Studied in Network Simulations

The input variables were examined over several scenarios, which differed by interchange spacings and traffic-volume intensities for a freeway with one-way frontage roads, secondary arterials and X-type interchanges; a freeway with one-way frontage roads, secondary arterials and diamond interchanges; and a freeway corridor without frontage roads but with secondary arterials. In each scenario, driveway and interchange spacings were varied, as was land-use intensity.

The Texas Department of Transportation recognizes three types of driveways: private, commercial, and public access (where the latter includes all approaches from city/county-maintained roads to public places) (TxDOT 1996). The spacings of such driveways mainly depend on the sizes of connecting parcels. For the final networks, which are described here, only one set of driveway spacings was used. These averaged every 400 feet on each side of two-sided arterials (or every 200 feet when both sides are perceived in tandem) and every 200 feet on the developed sides of frontage roads. Coding of additional driveways across the network exceeded the maximum number of network links permitted by CORSIM. Thus, the full networks had to be relatively coarse in terms of driveway interactions. For tests and results related to finer driveway spacing on simplified networks, please refer to Madi (2001).

Three major interchange spacings were also investigated; these were set to 0.5, 1.0, and 2.0 miles, which span the typical range of spacings, particularly for urban and suburban areas.

Several scenarios of land-use development, from strictly residential to highly commercial, were investigated. The estimated input volume into CORSIM was based on the ITE *Trip Generation Manual* (ITE 1997). Each of the independent variables (i.e., interchange spacing and land-use intensities) was tested separately, keeping all other input variables fixed. Approximately seventy-two scenarios were coded and tested. This number results from three geometrically different networks (no frontage roads, frontage roads with diamond interchanges, frontage roads with X interchanges); three interchange spacings; two land development types; and four different circumstances for land-use intensities. Three replicate simulation runs were developed for each scenario, and variability across replicates was examined as a means of determining the need for additional replicates. Variability across simulation runs was generally small, therefore, only in rare cases were additional replicates required.

To understand when and why frontage roads made good sense, an evaluation of several output variables—including traffic delay and speed—is crucial. These factors reflect the performance level of both the local traffic (loading an arterial/collector network, both with and without frontage roads) and the freeway main lanes. The use of "CORSIM" was particularly handy in determining these output factors (FHWA 1999). Performance levels were evaluated on a link-by-link basis, as well as the network as a whole (freeway and arterial networks).

6.5 Network Design

Three network cases were evaluated: a freeway with frontage roads and diamond interchanges, a freeway with frontage roads and X-type interchanges, and a freeway with diamond interchanges but no frontage roads. Cases One (Figure 6.1) and Two (Figure 6.2) are similar, except for interchange type. (Under X-type interchanges, freeway weaving between traffic entering and exiting the mainlanes can become problematic, and interchanges should be relatively frequent to avoid circuitry in local access via the mainlanes.) These two cases use a six-lane freeway supplemented on both sides by one-way, three-lane frontage roads and six-lane secondary arterials located roughly one-half mile away (and parallel to the corridor). Six-lane cross-arterials connect the nonfreeway subnetworks on both sides. Each network area was subdivided into roughly eighteen different zones. CORSIM traffic volumes (including turn movements) were determined based on an origin-destination trip matrix among these zones, with the volumes attracted to and produced by every zone loaded on appropriate links. In order to ensure a fair comparison, aggregate network traffic volumes were the same for each of the three network cases. Access privileges alongside the freeway corridor are not permitted in Case Three (Figure 6.3) due to an absence of frontage roads. Instead, all related access demand has been shifted to driveways along the cross-streets and parallel arterials.

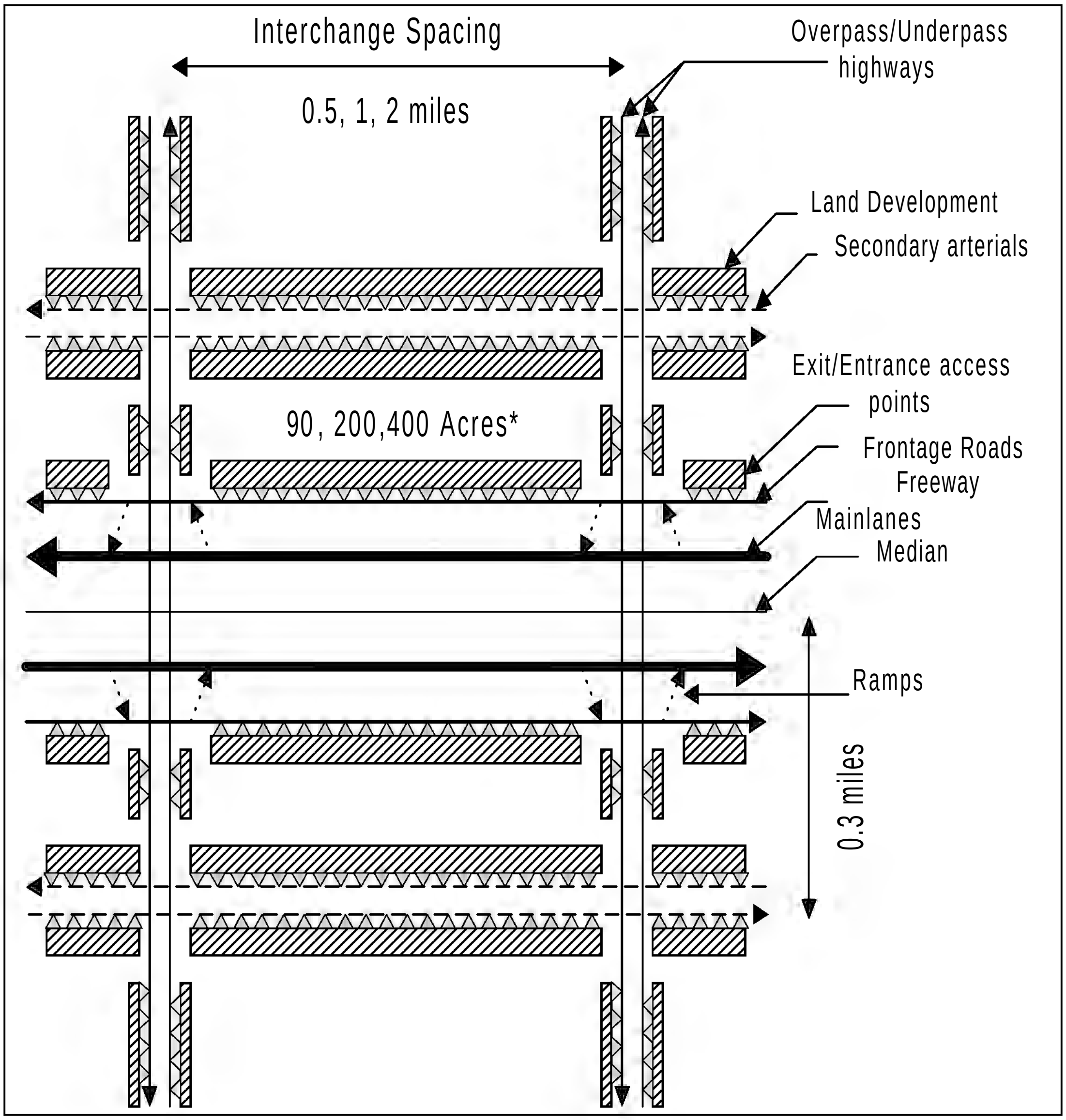

Figure 6.1 Case One: Freeway with Frontage Roads and Diamond Interchanges
**Reflects the total developed area for 0.5-, 1-, and 2- mile interchange spacing, respectively.*

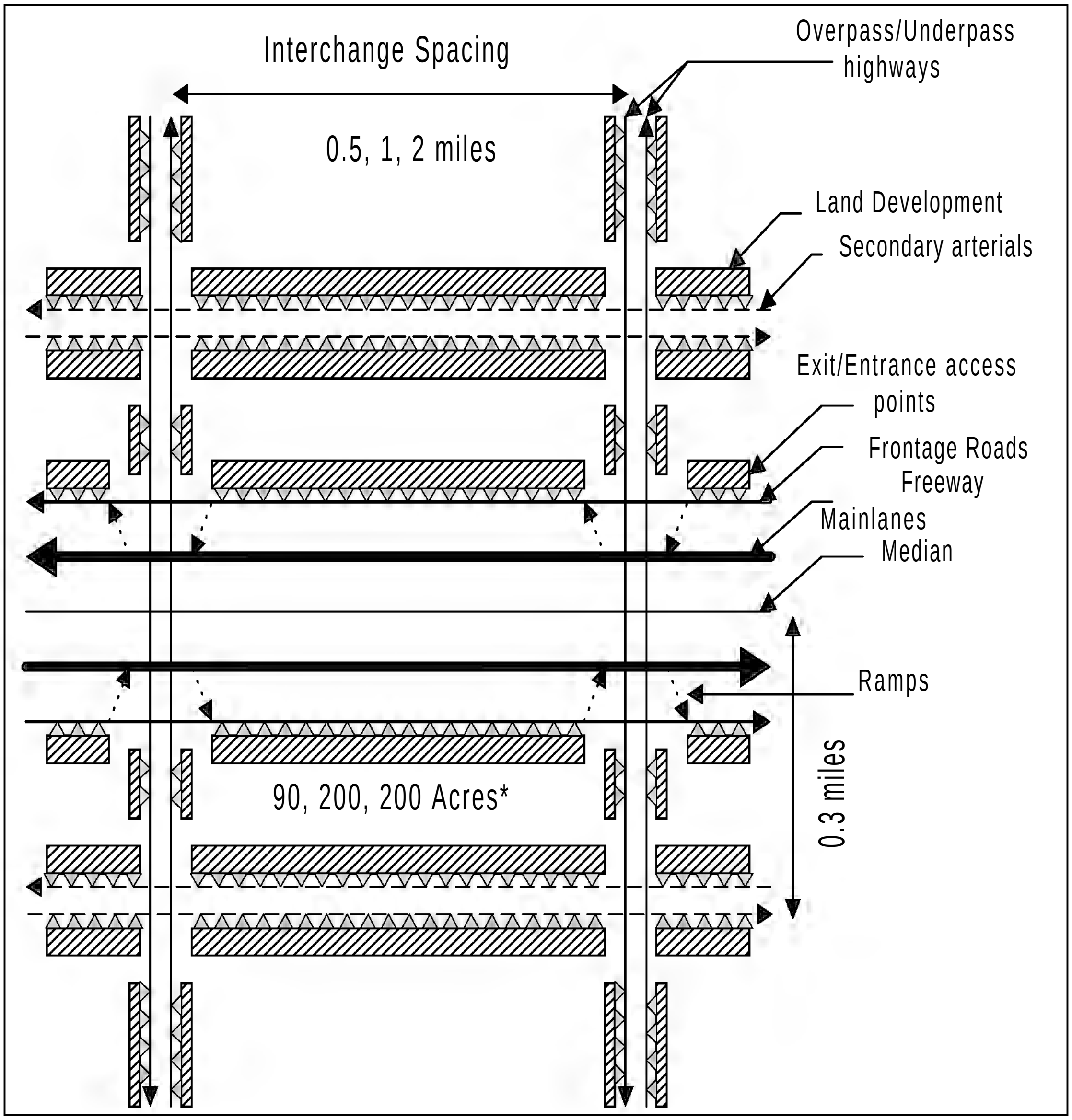

Figure 6.2 Case Two: Freeway with Frontage Roads and X Interchanges
**Reflects the total developed area for 0.5-, 1- and 2- mile interchange spacing, respectively.*

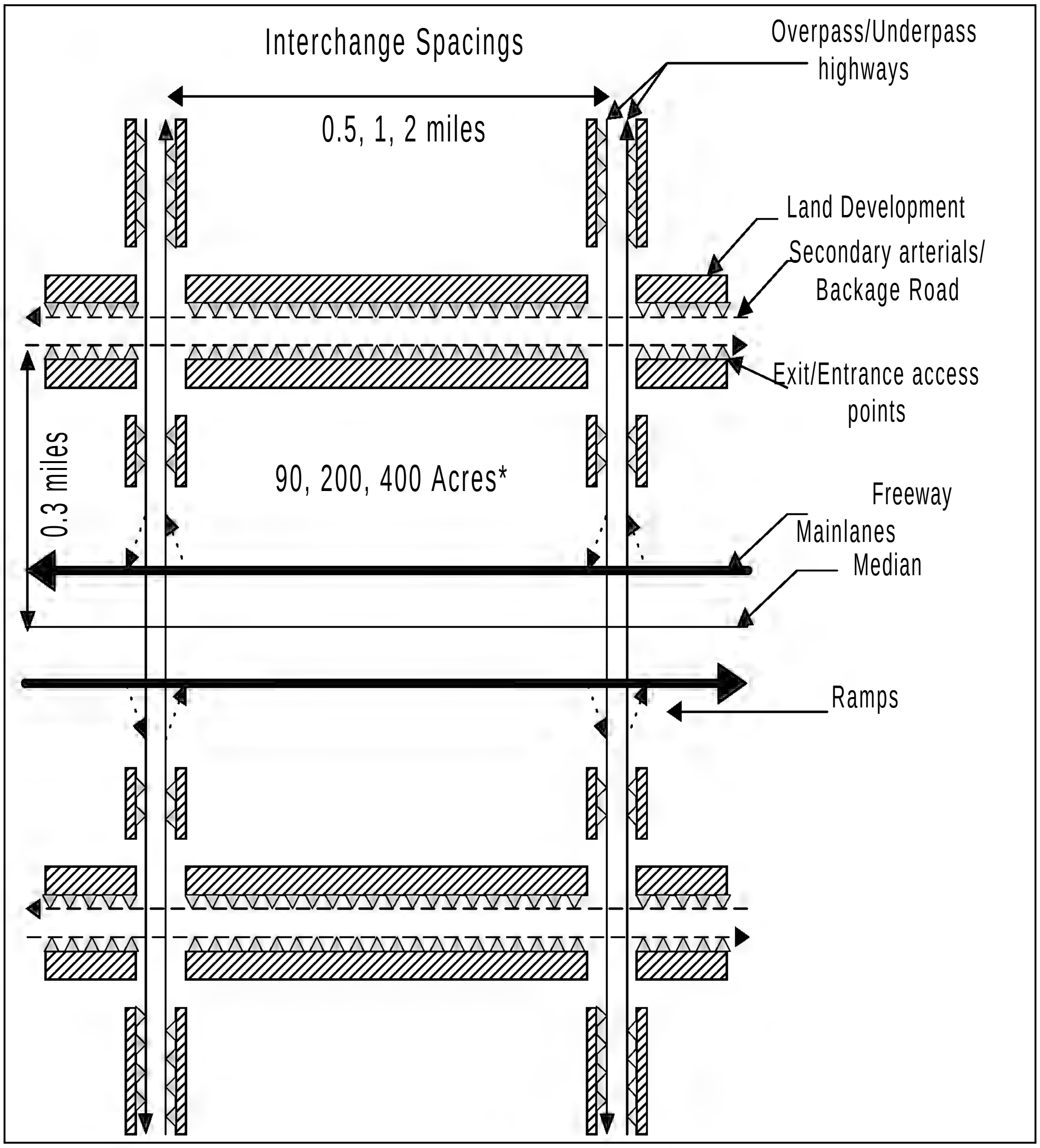

Figure 6.3 Case Three: Freeway with Diamond Interchanges and Secondary Arterials but No Frontage Roads
**Reflects the total developed area for 0.5-, 1- and 2- mile interchange spacing, respectively.*

The study objectives were to assess the performance of each network case for several input variations (basic corridor geometry, interchange spacing, and land-use intensities) and to determine the impact of each input variable on each network. A comparison of the three case studies determined the conditions under which one case performs better than others (e.g., with lower average delays and higher speeds). The simulation focused primarily on total/travel delay[8] and speed. These investigative efforts produced a quantitative assessment of when and where frontage-road provision is advisable. Moreover, the results of the simulations (such as the distribution profile of delays across traveler categories) and the flow observations permitted assessment of network performance and design options.

6.6 Network Simulation

6.6.1 Procedures

The three scenarios studied here represent the most common types of freeway corridor networks. In Scenario One, where no frontage roads are provided, secondary arterials are assumed to be located roughly 1,500 feet from the freeway median. This distance is far enough from freeway lanes to be realistic and permit significant land development—but close enough that the secondary arterials may be considered alternatives to frontage roads. Direct access to ramps and thus to the freeway is not possible for local traffic. In addition to the features presented in Scenario One, Scenario Two illustrates a network where frontage roads are provided. Frontage roads in this case are connected to the freeways via diamond interchanges, as compared to Scenario Three, where X interchanges are used. Figures 6.1, 6.2, and 6.3 illustrate the three scenarios. In each scenario, interchange spacing and land-use intensities (high/commercial and low/residential) were varied to record the impact of each of those variables on network performance. In addition, a comparison among the three networks will establish which scenario performs best under the test conditions.

6.6.2 Assumptions

There were several assumptions that had to be made for the simulations. First, the study assumed that all scenarios were analyzed for peak-hour conditions. Although scenarios were built for peak hours, traffic demands were chosen to preclude heavy congestion. If network elements became heavily congested, measures of effectiveness such as delay would become close-to-linear functions of time (relative to simulation start time) instead of random

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[8] Control delay is specially defined in the *2000 HCM* for intersection analysis, but CORSIM produces total delay as an output, which also applies well to freeways. Papacostas and Prevedouros (2000, p. 187) define *travel delay* as the difference between the time a vehicle passes a point downstream of the intersection or bottleneck where it has regained normal speed and the time it would have passed that point had it been able to continue at a free-flow approach speed.*Stopped delay* “is the time duration of ‘substantially standing still’” (2000, p.187) while waiting in queue at a signalized intersection approach. Substantially standing still is usually

variables. This would limit the nature and type of post simulation analyses. Second, three interchange spacings were used: 0.5, 1, and 2 miles. These reflect the range of general practice for urban areas.

Third, a 200 ft driveway spacing was used throughout the analysis along the developed sides of the frontage roads; a 400-foot spacing was used along the arterials (in order not to exceed CORSIM's maximum link permissions). Tighter driveway spacings would have provided interesting case studies, but link restrictions and other CORSIM operational issues (e.g., assumptions of driver behavior in lane choice for driveway access) prevented their testing at the full network scale. Madi (2001) examines finer driveway spacings, but for more limited networks.

Fourth, two land-use intensities (at peak hour) were analyzed: all residential (0.5 trips/occupied dwelling unit) and all commercial (4.9 trips/1,000 ft^2) (ITE 1997). For the case of residential development, it was assumed that each dwelling unit represents a 2,000 ft^2 area, parking and buildings each covered 50% of the land, and the buildings were three stories high. For the commercial development case, 50% of the land was given to parking and development was one-story high. In both cases, volume intensities were converted to trips per acre. These assumptions produced ten trips per acre for residential use and thirty-six trips per acre for commercial use.

Fifth, the user equilibrium traffic assignment process was adopted to determine the path used by travelers from origin to destination. It is to be noted that NETSIM (the nonfreeway code of CORSIM) uses this assignment method. Hence, among several paths between a specific origin and destination, it assumes drivers select the route with the lowest travel time. This avoids unreasonable path choices sometimes associated with all-or-nothing assignment processes.

Sixth, origin-destination matrices were derived to control intersection traffic demands. Turn movements at each intersection were first chosen by recognizing that each intersection should perform close to, but below, capacity (reflecting peak conditions); then, using the intersection data, the calculation process moved backwards to determine the flows generated and received by each source-sink node. Based on the turn-movement assumptions,

taken to be 3 mi/h or less. And empirical results suggest that division of total delay by 1.3 results in the stopped delay.

it was decided that at a maximum 450 vehicles per hour per lane (vphpl) could travel straight through each intersection approach, 322 vphpl could turn right (using a right-turn factor of 1.4), and 267 vphpl could turn left (using a left-turn factor of 1.7).

In building the origin-destination matrices for all scenarios, several assumptions were required for traffic allocation. These are presented in Table 6.1, which indicates that freeway traffic mainly travels *through* the corridor with only 20% (for residential development) and 36% (for commercial development) exiting at ramps. In addition, it is assumed that no trips are allocated between two driveways; the totality of driveway-generated trips is destined for the freeway (60%) or arterial streets (40%). It is to be noted that these percentages were chosen using judgment driven by the need to avoid intersection oversaturation.

Table 6.1. Origin-Destination Traffic Splits for All Scenarios

Origin				Destination		
				Freeway Sections	Major Arterials	Driveways
Freeway Generated Traffic			R	80%	5%	15%
			C	64%	4%	32%
Arterial Generated Traffic (non-driveway)	Interchange Spacings (miles)	0.5	R	40%	10%	50%
			C	12%	1%	87%
		1	R	32%	1%	67%
			C	8%	--	92%
		2	R	17%	--	83%
			C	5%		95%
Driveway-Generated Traffic				60%	40%	--

R = Residential Land Development
C = Commercial Land Development

6.7 Land-Use Development Case Studies

Four land-use circumstances or case studies were analyzed, but only the first is shown in this chapter. The other two are presented in Madi (2001) for interested researchers. The intent of these case studies was to cover a range of possible development layouts that may occur along freeways for both frontage-road and non-frontage road scenarios. Land-use Case 1 assumes that development densities remain constant per developable acre. Thus, as the interchange spacing increases and, therefore, the size of the corridor coded here increases, total site-generated trips increase proportionally. In significant contrast, Case study 3 assumes that development densities fall with interchange spacing, so that the total number of site-generated trips remained the same under all interchange-spacing/corridor-size scenarios. This second case is intended to illustrate how reduced access may reduce land development; for example, development may occur in simple proportion to interchange access, rather than land availability. This is not a highly realistic case, but it provides a boundary scenario for purposes of illustration. Finally, Case 4 was run under an assumption that frontage roads stimulate development along freeway corridors by providing roughly 50% more locally generated trips in the frontage road networks—relative to the non-frontage-road networks. While a common assumption of many developers, policymakers, and planners, this also is not likely to be a realistic scenario given that our paired-corridor comparisons (described in Chapter 5 and in the Appendix) did not find evidence of added land-use intensity when frontage roads were provided. Thus, only Case 1 is examined here, but Cases 2 and 3 can be found in Madi (2001).

6.7.1 Case 1: Constant Site-Generated Trips per Acre

In order to ensure a fair comparison for all scenarios, land-use Case 1 assumed that the number of trips per acre was held constant across all scenarios and all interchange spacings. Hence, total site-generated traffic increased with increased interchange spacings. The results for local and through traffic for residential and commercial development are presented in Table 6.2.

As can be seen from Table 6.2, through traffic was assumed constant for all scenarios and both land development types. In addition, local traffic (which reflects the volume generated (or received) at all driveways) increased with the increase of interchange spacing.

Table 6.2 Site-Oriented and Through Traffic (Constant Site-Oriented Traffic/Acre across Frontage Roads Versus No Frontage Road Scenario)

Hourly Vehicle Trips Entering Test Networks		
Interchange Spacing (miles)	Land Development Scenario	
	Residential	Commercial
0.5	3,952	15,776
1.0	6,256	26,528
2.0	13,168	50,720

Moreover, although total traffic was maintained constant for every land- use type and scenario, roadway layout differed between frontage-road and non-frontage road scenarios. Hence, parcel-point intensities (i.e., driveway volumes) differed from frontage road to non-frontage-road scenarios. Table 6.3 illustrates the site-generated traffic per driveway for all scenarios. The provision of frontage roads increases the availability of roadspace for driveways; so, to keep traffic constant across frontage-road versus non-frontage road scenarios, driveway intensities were varied accordingly (reduced driveway intensity for frontage-road scenarios).

Table 6.3 Driveway Intensities for All Scenarios, Interchange Spacing and Development Types (Case 1)

Interchange Spacing	No Frontage Roads		With Frontage Roads	
	Residential	Commercial	Residential	Commercial
	Hourly Trips Entering/Leaving Each Driveway			
0.5 miles	32 in 64 out	264 in 192 out	16 in 32 out	128 in 96 out
1 miles	32 in 64 out	264 in 192 out	16 in 32 out	128 in 96 out
2 miles	32 in 64 out	264 in 192 out	16 in 32 out	128 in 96 out

6.8 Case 1: Frontage Roads versus No Frontage Roads for Constant Site-Generated Trips/Acre

As was mentioned in Section 6.7.1, Case 1 assumes constant development intensities across scenarios for specific interchange spacings. The total site-generated traffic increases proportionally with the increase in interchange spacings. Speed and delay for freeway sections are presented for the three networks. Tables 6.4 through 6.9 present these findings for all interchange spacings and land-use types. Performance was evaluated for freeway mainlanes, ramps, and arterials.

6.8.1 Freeways

Delay and speed reductions on freeways within the simulated network are primarily caused by speed changes associated with exiting and entering traffic. Most traffic exiting any of the four exit ramps must pass through an at-grade intersection after leaving the freeway mainlanes. If the intersection becomes saturated, indicating demand exceeding capacity, a standing queue will develop and can grow from the intersection back through the exit ramp, onto the freeway. This activity, which is a common sight on many real urban freeways, is the primary cause for delay and speed reduction on the simulated freeways.

The three interchange spacings presented in Tables 6.4 and 6.5 represent three very different traffic-demand scenarios. Because this case includes essentially constant numbers of trips per developable acre of land, as interchange spacings increase from 0.5 to 1.0 to 2.0 miles, developable land acreage and therefore, total number of trips, increase. Thus, as indicated in Table 6.2, the greatest spacing is associated with the largest traffic demand. The left halves of Tables 6.4 and 6.5 present the "mainly residential" or less intensive land development and traffic-demand scenarios, while the right halves labeled "mainly commercial" represent the more intense traffic demands (see Table 6.2).

Examining the less intense "mainly residential" part of Tables 6.4 and 6.5, freeways in the non-frontage road configuration and all three interchange spacings (or demand conditions) experienced very small traffic delays with speeds approaching 60 mph, indicating level of service A or B conditions. The frontage road with X-ramp configuration also was able to accommodate the three traffic-demand or spacing schemes with little or no delay and high speeds again indicating levels of service in the A or B range. However, the frontage road with the diamond interchange configuration seemed to have been forced to—or beyond—its capacity threshold with the largest spacing and demand scheme. Weighted average speeds were approximately 10 mph lower for the diamond configuration compared to the other two configurations for this high-demand situation and delays were roughly three times those of the others. Reasons for this freeway effect are, as described in the first paragraph of this section, the at-grade intersections at the ends of the freeway exit ramps became saturated and standing queues backed onto the freeway mainlanes. The reason this configuration performed more poorly than the non-frontage road configuration was due to the presence of the frontage road itself. The failed at-grade intersections were forced to serve through traffic on the frontage road in addition to traffic exiting the freeway. With no frontage road, the only traffic demand that can reach the corresponding at-grade intersection approach is from the freeway exit.

Examining the right sides of Tables 6.4 and 6.5, larger traffic demands associated with these commercial land development scenarios consistently produced greater delays and lower freeway speeds. All three configurations were pushed past their respective failure thresholds as successively higher demands were placed upon them across the three interchange spacings or traffic-demand intensities. For all three demand intensities, the non-frontage road configuration produced freeway speeds and delays indicative of at-grade intersection failure causing exit ramp queues to clog freeway mainlanes. The frontage-road diamond configuration seemed to reach its failure threshold with traffic demands for the 1-mile interchange spacing and the frontage road with X interchanges only reached failure conditions under traffic demands of the 2-mile interchange spacing. This observation can be explained by the fact that, given the high traffic demands of these development scenarios, the frontage-road configurations provide significantly more network that more effectively distributes traffic.

Based upon the observed freeway performance for all eighteen cells of Tables 6.4 and 6.5, the frontage-road X configuration seems most capable of handling the range of simulated conditions. However, for the moderate traffic demands of the simulated "mainly residential" development scenario, the non-frontage-road configuration produced the best freeway operations.

Table 6.4 Freeway Performance (Speed)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Average Speed (miles per hour)					
0.5	58.4	57.4	58.2	26.6	52.4	54.0
1	56.1	55.8	57.8	20.8	27.9	46.0
2	58.0	47.7	57.7	11.0	17.9	7.1

Note: Shaded cells identify significant congestion, conceptual level of Service F.

Table 6.5 Freeway Performance (Delay)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Travel Delay Per Vehicle Mile (sec/veh. mile)					
0.5	6.1	7.1	6.3	80.1	13.4	11.1
1	8.6	8.9	6.8	120.6	73.5	22.8
2	6.5	20.0	7.0	271.4	148.1	450.1

Note: Shaded cells identify significant congestion, conceptual level of Service F.

6.8.2 Ramp Performance

Ramp delay and speed statistics clearly are affected by a geometric fact of life that differentiates non-frontage-road and frontage-road configurations. If there is no frontage road, freeway exit ramps lead directly to at-grade intersections with crossing arterial streets. The exit ramps themselves become the geometric element to which intersection-based delay must be charged. If frontage roads are present, exit ramps end where they connect to the frontage road and delays associated with the downstream at-grade intersection can be charged to the frontage road instead of the exit ramp. This fact explains why ramp delays and speeds for non-frontage-road configurations in Tables 6.6 and 6.7 seem to consistently indicate poorer performance than the frontage-road configurations. The explanation of failure thresholds for freeway performance across the configurations and traffic-demand scenarios can be repeated for the ramp speeds and delays. Generally, the frontage-road X configuration seems most robust at being able to best handle all traffic demands; however, the ramp statistics should not be interpreted as negating the previous conclusion regarding excellent performance of the non-frontage-road configuration under moderate traffic demands.

Table 6.6 Ramp Performance (Speed)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Average Speed (miles per hour)					
0.5	16.1	33.8	30.5	4.1	11.4	27.7
1	8.3	33.1	28.8	3.8	2.9	23.5
2	9.0	6.6	29.0	3.6	2.5	24.7

Note: Shaded cells identify significant congestion, conceptual level of Service F.

Table 6.7 Ramp Performance (Delay)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Travel Delay Per Vehicle Mile (sec/veh. mile)					
0.5	143.4	27.3	20.9	799.9	271.7	31.3
1	372.1	28.6	26.3	938.2	1167.2	94.8
2	320.1	478.2	25.9	933.8	1363.9	46.7

Note: Shaded cells identify significant congestion, conceptual level of Service F.

6.8.3 Arterial Street Performance

The weighted average delay and speed statistics of Tables 6.8 and 6.9 include signalized intersections where traffic control reduces speed and increases delay relative to nonintersection links where speeds are greater and delays are much less. The weighted averages provide single values representing the whole arterial system, however, primary delays and speed reductions originate with the intersection links.

Beginning with the lighter traffic demands of the left halves of Tables 6.8 and 6.9, the speeds and delays for the non-frontage road, and both frontage-road configurations, indicate traffic demands were less than capacity (level of service D or E) under the 0.5 and 1.0 mile interchange spacings. As explained previously, the 2-mile spacing scenario represented the greatest traffic demand and under this traffic loading the non-frontage road and the frontage-road diamond configurations produced speed and delay statistics indicative of traffic demands exceeding capacity at signalized intersections. Signal timings were optimized and intersection approach channelization measures were implemented to maximize flows; however, numbers of vehicles arriving during red signal indications could not be cleared through intersections during green times causing standing queues to increase from signal cycle to signal cycle. Because of the manner in which the frontage-road X configuration shunts vehicles to the freeway instead of through the frontage-road intersections, that configuration was able to handle the heavy demands of the 2-mile spacing indicating demands did not exceed intersection capacities (levels of service E).

The right half of Tables 6.8 and 6.9 presents arterial operating statistics under the heavier commercial traffic demands. All nine cells of the table matrix contain speeds and delays descriptive of demands exceeding arterial street intersection capacities. All cases indicate demands exceeded capacity thresholds and no significant differences can be noted between the frontage-road or non-frontage-road configurations. Because the quantity of site traffic generated under the commercial scenario may represent something approximating a worst-case condition, the data show that all three configurations are susceptible to arterial street intersection failure.

Table 6.8 Arterial Performance (Speed)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Average Speed (miles per hour)					
0.5	18.7	20.1	21.2	5.0	6.9	7.3
1	18.6	20.1	21.8	4.4	5.0	3.7
2	11.6	9.4	16.7	4.7	5.2	4.2

Note: Shaded cells identify significant congestion, conceptual level of Service F.

Table 6.9 Arterial Performance (Delay)

Interchange Spacing (miles)	Land-Use Type					
	Mainly Residential			Mainly Commercial		
	No FR	FR D.	FR X.	No FR	FR D.	FR X.
	Travel Delay Per Vehicle Mile (sec/veh. mile)					
0.5	113.0	99.1	89.9	649.5	442.0	417.7
1	114.5	99.6	85.2	743.7	641.0	889.5
2	244.2	306.0	135.8	685.3	623.9	776.8

Note: Shaded cells identify significant congestion, conceptual level of Service F.

6.9 Conclusions

The operational statistics of Tables 6.4 through 6.9 indicate the non-frontage-road configuration performs as well as or better than the frontage-road configurations if traffic demands do not saturate signalized intersections to which freeway exit ramps lead.

Intersection failure creates standing exit ramp queues, which potentially grow back to freeway mainlanes. Recognizing this potential, “non-frontage-road” configurations should be designed to maximize the queue storage area from the freeway ramp gore to the downstream signalized intersection, and as an additional safeguard, freeway auxiliary deceleration lanes always should be provided upstream from the exit ramp.

The frontage-road X configuration was shown to be the most robust operational concept. Because X-ramp configurations divert freeway-entering traffic from signalized intersections, they effectively reduce traffic demands for frontage-road intersections, reducing the likelihood of intersection and network failure. One potential danger associated with the X pattern is freeway mainlane speed reductions caused by weaving between entry and exit ramps. Weaving effects can be minimized by maximizing the distance between X pattern entry-exit ramp pairs. According to the *Highway Capacity Manual* (TRB 1997), if this distance is greater than 1,500 feet, weaving effects will be minimal.

CHAPTER 7: COSTS OF FRONTAGE-ROAD AND NON-FRONTAGE-ROAD FACILITIES

7.1 Introduction

To determine the relative costs of providing freeway facilities with and without frontage roads, total corridor costs were assembled here by construction, land, and access costs. Cost information from a number of sources was used to analyze a series of distinct scenarios, both with and without frontage roads. Frontage-road provision requires additional construction expense, as well as additional expense associated with right-of-way costs. However, freeways with frontage roads avoid the significant cost of access acquisition. This work allowed estimation of the level of access costs at which the provision of frontage roads would become less costly, as well as determination of the relative costs of providing or excluding frontage-road configurations in new-location facilities.

7.2 Construction Cost Computations

Construction costs were determined using data made available by the Texas Department of Transportation (TxDOT) regarding various recent construction projects, specifically, recent projects on US 59, IH-45, US 83, and Spur 330. TxDOT's 5-year averages of construction costs were also taken into consideration during this phase of the research. Monetary costs of construction projects were divided into costs associated with mainlanes and costs associated with frontage roads.

Road construction typically consists of both fixed and variable costs. Variable costs would be those associated with the width, length, and configuration of the facility. Fixed costs are those that do not change based upon the number of lanes, though they may change depending upon topography, soil type, or other geographic or geologic variations. The fixed costs in this study were those associated with guardrails, shoulders, signage, and other reasonably constant features. These costs needed to be distributed evenly among all lanes of the facility when determining the cost per lane of each facility. In order to accomplish this, the total construction costs were divided by the total *equivalent lane miles*, a term that encompasses both usable lanes and additional paved surfaces (i.e., shoulders). This figure was multiplied by the total equivalent lane miles of mainlanes and frontage lanes, while excluding the costs associated with bridge construction. These two values were subsequently divided by the *new usable lane miles* (which exclude shoulders) both for mainlanes and frontage-road lanes, separately. It was important to distinguish between equivalent and usable lane miles. Equivalent lane miles include shoulders, while usable lane miles include only that part of the facility that is intended for travel. The aforementioned calculations served to distribute the costs of building shoulders among all usable lanes in the facility. Lane construction costs were then calculated based upon this methodology as applied to the various TxDOT construction projects located at the beginning of Appendix E1. The lowest cost per new usable lane is used throughout this project as the low-cost assumption, while the highest per new usable lane-mile cost is used as the high assumption.

The initial calculation of construction costs based upon the aforementioned projects did not include the costs of moving utilities or drainage associated with freeway construction projects. Personal interviews with Doug Woodall, TxDOT field coordination section director, Design Division (Woodall 2001b) yielded much of the information used in calculating utility costs associated with construction. Based upon that discussion, it was determined that the costs of moving utilities would equal approximately 6% of the total cost of utilities and construction costs.

According to Woodall (2001b), drainage costs can be assumed to equal from 25% to 40% of the total cost of construction and utilities. These costs, like utility costs, are also highly variable. In this work, drainage costs were assumed to be equal to 30% of the total construction plus utilities cost.

Costs associated with ramp construction were not included in the original study of construction costs. Those cost assumptions were obtained through further conversations with Woodall (Woodall 2001a) and were taken to be $25,000 to $75,000 each, or $100,000 to $300,000 per interchange.

7.3 Land Cost Calculations

Interviews with Paul Hornsby, a private assessor frequently contracted by TxDOT (Hornsby 2000), revealed that rural land values likely vary from $0.15 to $0.30 per square foot, and that urban land values may fall anywhere between $5.00 and $20.00. These assumptions were verified by a study of appraised land values in the Austin area as provided by the Travis County Appraisal District (TCAD 2001). The land costs were then used to calculate the total cost of purchasing right-of-way for the facility. New location facilities without frontage roads also involve the additional cost of paying damages (or purchasing remainders) of properties divided by the new facility, where one part of the parcel would be left without access. This was estimated to add approximately 10% to the cost of land acquisition on such projects (Toner 2001).

Right-of-way purchase can be a significant cost on most projects. That cost is a product of both the cost of land in the area and the width required for the facility. For long-range, full build-out scenarios the TxDOT Austin District Standard Right-of-Way Width (2000) was used to calculate most rights-of-way, although some of the configurations studied for the sake of comparison were not specified in the document. In such cases, extrapolations were made in order to calculate the right-of-way. While TxDOT initially always would prefer to purchase wide rights-of-way, and then sell any unused portions after the facility has been fully built out, often this is not possible and urban freeways in particular often are built on rights-of-way that are less than ideal. Right-of-way assumptions used in this study appear in Table 7.1.

Table 7.1: Total Right-of-Way for Long-Range, Full Build-Out Scenarios

Mainlanes	Frontage Roads	Total ROW(urban/rural)
4	0	150/220 ft
4	4	280/400 ft
6	0	200/250 ft
6	4	400/400 ft
6	6	400/400 ft
8	0	300/400 ft
8	4	400/400 ft
8	6	400/400 ft
10	0	350/400 ft
10	6	400/400 ft

Determining the necessary right-of-way for facility expansion/upgrade scenarios is difficult due to the fact that the width of the facility prior to expansion is not known. For this reason, the assumptions shown in Table 7.2 were used in the analysis.

Table 7.2: Additional Right-of-Way for Facility Expansion/Upgrade Scenarios

Mainlanes	Frontage Roads	Additional ROW
2	0	0 ft
4	0	60 ft
0	4	80 ft
2	4	80 ft
4	4	140 ft
4	6	160 ft

7.4 Access Cost Estimation

Access costs were calculated using the data from Westerfield's (1993) and Gallego's (1996) studies of access costs along US 183 in central Texas. The data in their studies suggest that costs may vary widely. Costs per linear foot of access taken were as low as $0 and as high as $2,421. (Note: All costs expressed here are in 2001 dollars.) The mean access cost per linear foot was $496.80, with a standard deviation of $715.19, or 1.44 times the mean cost. Further discussions with TxDOT's Austin District Right-of-Way Director Bob Harwood revealed that such a variation is common, and that there really is no standard access valuation (Harwood 2001). The difficulty associated with modeling access costs is compounded by the fact that such costs are not only related to physical location, but also to existing zoning and/or subdivision of the land.

In calculating the cost estimates, highs and lows for both urban and rural scenarios were used. In the rural scenarios, the 25th percentile ($11.47 per linear foot of access) was used as the low value, while the mean ($496.80) was taken to be the high value. While these two costs may seem high for rural locations, they are expected and intended to encompass some of the fringe suburban and ex-urban areas that are not classifiable as urban, per se. In the urban scenarios, the mean ($496.80 per linear foot of access) was taken to be the low value, and the 75th percentile ($799.04) as the high value. Observed access costs for *individual* parcels may exceed these averages considerably, but averages over a 0.25 or longer stretch of road would likely be within these observed parameters.

Access costs were applied only in those scenarios that did not include frontage roads and where previously those lot owners had access to the facility (i.e., existing/old-location freeways). Access costs per centerline mile were obtained by multiplying the linear-foot costs by 10,560 feet (which assumes that access is purchased for every linear foot on both sides of an upgraded facility). Threshold access costs were also back-calculated from the various scenarios to determine the critical or "threshold" cost that would determine the low-cost alternative (i.e., frontage roads or no frontage roads) in an upgrade project.

7.5 Scenarios for Comparison

Three general project cases were considered: Provision of mainlanes only (Type A), mainlanes plus frontage roads (Type B), and a lower number of mainlanes plus frontage roads (Type C). Examples of these three configurations are provided in Figures 7.1 through 7.3.

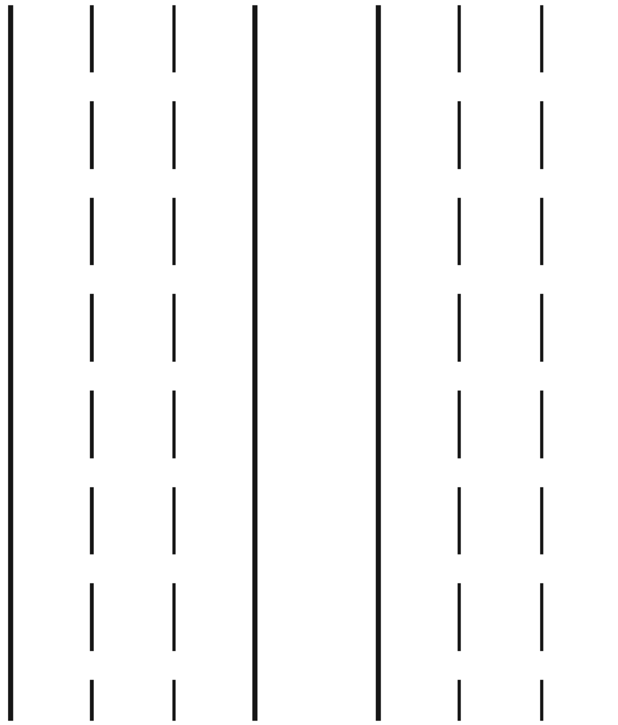

Figure 7.1: Type A Example (shown with six mainlanes and no frontage lanes)

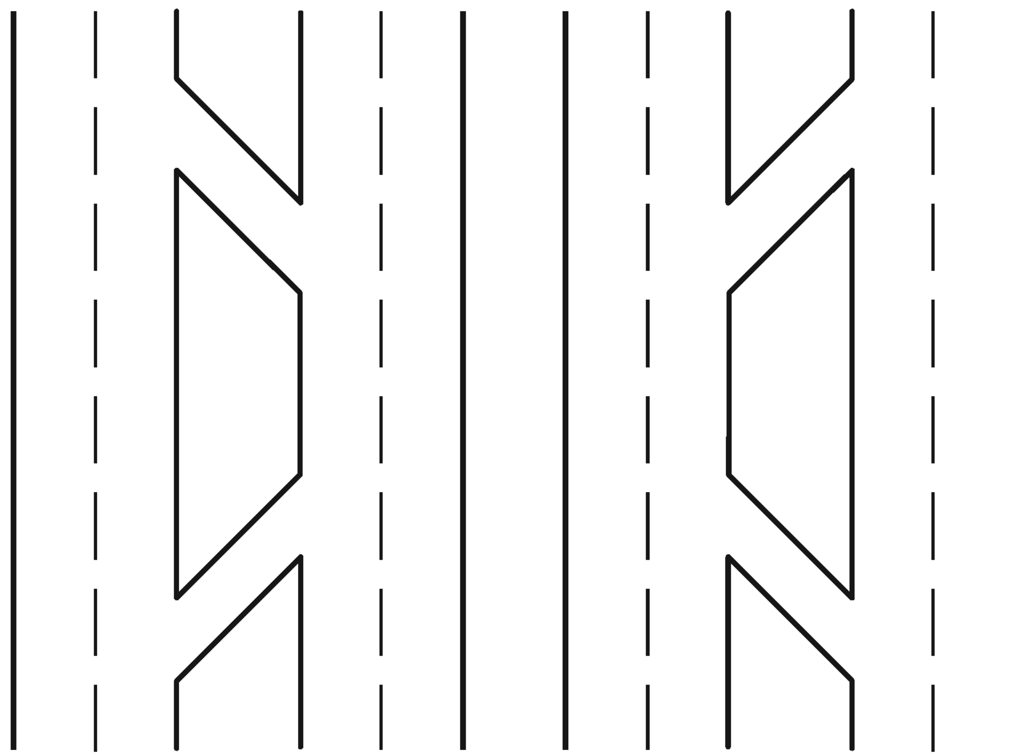

Figure 7.2: Type C Example (shown with six mainlanes and four frontage lanes, with X interchanges)

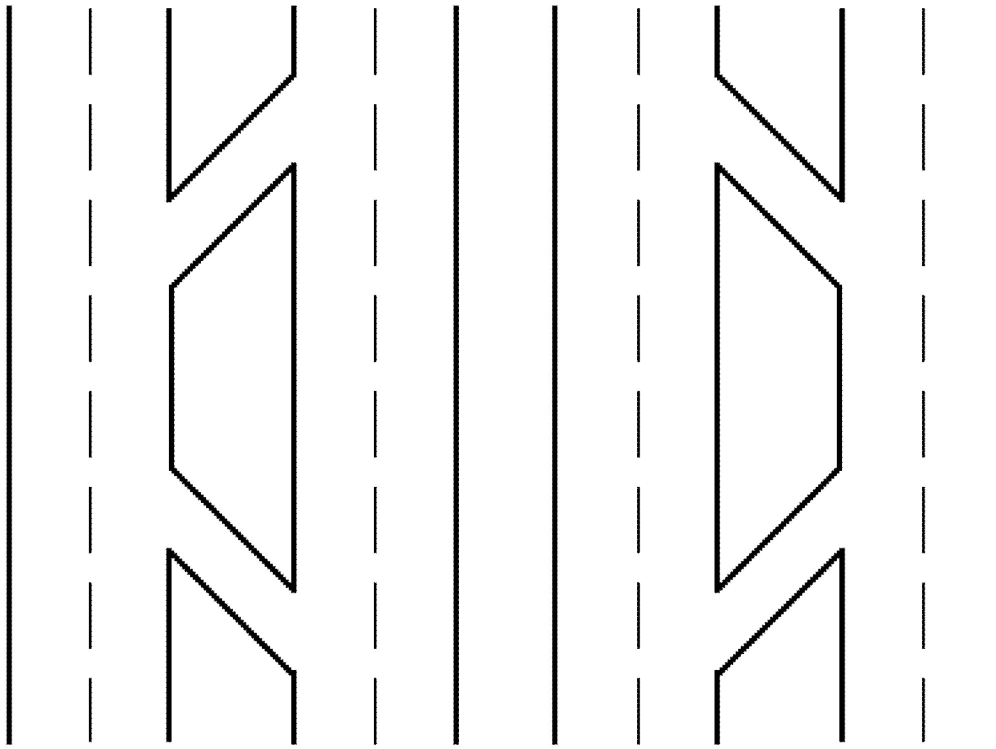

Figure 7.3: Type C Example (shown with four mainlanes and four frontage lanes, with X interchanges)

Types A and B were compared on the basis of the same number of mainlanes. Type A clearly enjoyed lower construction and land acquisition costs (but necessitated access costs). In Type B, it is assumed that frontage roads are provided only for access to abutting properties; that is, the number of mainlanes provided is equal to the number provided in Type A. The number of mainlanes is fixed between Types A and B, and these are assumed to be responsible solely for providing capacity. Type C included fewer mainlanes, holding corridor capacity fixed while assuming that frontage roads contribute to that capacity (and two mainlanes were assumed to have equal capacity to four frontage-road lanes). Three improvement/upgrade scenarios and five new-location/ full build-out scenarios were considered for each of these three cases. Moreover, interchange spacings were varied from 0.5 to 1.0 to 2.0 miles, and land values and access cost assumptions (both high and low) were distinguished by rural versus urban settings.[9] Construction cost assumptions were either high or low. Cost assumptions are shown in Table 7.3.

Table 7.3 Cost Assumptions (2001 dollars)

Item	***Low Estimate***	***High Estimate***
Mainlane, per usable lane mile	\$477,500	\$1,096,500
Frontage, per usable lane mile	\$339,500	\$507,000
ROW acquisition, per square ft, rural	\$0.15	\$0.30
ROW acquisition, per square ft, urban	\$5.00	\$20.00
Rural access purchase, per linear foot	\$11.50	\$497.00
Urban access purchase, per linear foot	\$497.00	\$799.00
Interchange cost	\$100,000	\$300,000

For the new-location, long-range, full build-out scenarios, cost ratios were computed between scenarios of Type A and Type B, and then between those of Type A and Type C. As expected, corridors without frontage roads reduced total project costs significantly, because access-rights costs did not require consideration/inclusion. In urban areas, cost-ratio estimates started at \$0.58, for moderate-size, low-unit-cost project comparisons of Case One to Case Two; these rose to \$0.99 for large-size, high-unit-cost project comparisons of the first and third cases. In rural areas, ratios ranged from \$0.65 to \$1.12, and these two ratio extremes involved the same project types/sizes. Here, the project type of “moderate size” means addition of six mainlanes under Case 1, six mainlanes and six frontage-road lanes under Case 2, and four and four under Case 3. The “large-size” project type involves ten, ten and six, and eight and four mainlanes and frontage-road lanes under the three cases, respectively.

Access costs are a pivotal issue for agencies when considering the provision of limited-access highways (i.e., freeways). When this issue arises, it is because a public travelway with unlimited access already exists in the corridor. Road providers have the choice to upgrade the highway to the status of a limited-access freeway with or without

[9] Note that unlikely situations have been removed from the analysis; these include case-scenario-design-cost combinations that were rural and had 0.5-mile interchange spacings or rural combinations with high access and/or high land costs. and/or high land costs.

frontage roads. Provision of frontage roads avoids the issue of purchasing access costs, but adds significant right-of-way and construction costs. Cost comparisons of this fundamental choice have been distinguished below by considering typical "upgrade" (Table 7.4) scenarios, as well as typical "long-run, full build-out" (Table 7.5) scenarios. Long-run, full build-out scenarios represent those projects in new locations.

Table 7.4. Improvement/Upgrade Comparisons

	Mainlanes Only		Mainlanes with Frontage Roads			
	Type A Scenario		Type B Scenario		Type C Scenario	
Scenario #	#MLs Added	#FR Lanes	#MLs Added	#FR Lanes	#MLs Added	#FR Lanes
1	2	0	2	4	0	4
2	4	0	4	4	2	4
3	4	0	4	6	2	4

Table 7.5. Long-Run, Full Build-Out Facility Comparisons

	Mainlanes Only		Mainlanes with Frontage Roads			
	Case Type A		Case Type B		Case Type C	
Scenario #	#MLs	#FR Lanes	#MLs	#FR Lanes	#MLs	#FR Lanes
1	4	0	4	4	n/a	n/a
2	6	0	6	4	4	4
3*	6	0	6	6	4	4
4	8	0	8	6	6	4
5	10	0	10	6	8	4

* Note that Case Types A and B of long-term Scenario 3 represent the situation for which the operations simulation (using CORSIM) has been run.

For almost all of these eight scenarios (across each of three types), the model varies some of the inputs. Interchange spacings of 0.5, 1.0, and 2.0 miles are considered separately. Land-value assumptions vary by rural and urban locations, and construction costs and access costs are classified as either high or low. (Note: To keep the number of scenario comparisons reasonable, the analysis assumes high land costs when construction and access costs are high.) These high and low values establish values between which most actual costs should fall, providing a reasonable margin of error to account for differences in land value, soil type, bedrock, and grade that may result in higher construction costs.

In general, the systematic variation of these various inputs produces multiple *situations* while each scenario offers a trio of cases. The table of assumptions for the various inputs is shown below. The various sources referenced for these costs and the methods used for their final computation are shown in Appendix E1. Generally, these come from the TxDOT Design Division tabulations of completed project costs, Travis County Appraisal District records, and conversations with TxDOT design engineers with many years of experience in construction cost estimation.

7.6 Estimation of Threshold/Critical Access Costs

The use of both high- and low-cost scenarios was intended to provide parameters between which costs likely would fall. For most projects of any substantial length, the costs likely would fall somewhere close to the middle. The effect of such averaging would be that the threshold access costs also likely would lie in between those costs listed in Table 7.6. For example, in the "facility upgrade/expansion" in urban locations, the threshold for Type A: Type B comparisons for Scenarios One and Two might be closer to $660 per linear foot of access taken (average of 329 and 992). Similarly, the threshold when comparing Type A and Type C in rural locations (Scenario One) might be closer to $20 than to either of the parameters listed ($20 being the average of $44 and $-4).

One objective of this cost study was to determine how access costs might inform decisions regarding the construction of frontage roads. For purposes of analysis in the long-range, full build-out scenarios, cost ratios were computed between Type A and Type B, and then between Type A and Type C. In the case of the facility upgrade/expansion scenarios, it was necessary to determine the level of access cost beneath which it would be favorable to purchase access rather than construct frontage roads. These figures were obtained by subtracting the cost of access purchase from the Type A alternative to obtain the total cost less access cost. This figure was then subtracted from the total cost of the paired comparison (either Type B or Type C). The difference was then divided by the total number of linear feet of access purchased (in this case 10,560). This figure then represents the "access cost threshold," above which access costs would render it necessary to construct frontage roads.

Table 7.6. Cost Results

Long-Run, Full Build-Out, Urban

Scenario	Cost Ratio Type A: Type B		Cost Ratio Type A: Type C	
	Low Cost	High Cost	Low Cost	High Cost
1	0.608	0.620	N/A	N/A
2	0.608	0.600	0.841	0.848
3	0.581	0.589	0.841	0.848
4	0.788	0.824	0.874	0.876
5	0.888	0.938	0.980	0.994

Long-Run, Full Build-Out, Rural

Scenario	Cost Ratio Type A: Type B		Cost Ratio Type A: Type C	
	Low Cost	High Cost	Low Cost	High Cost
1	0.646	0.747	N/A	N/A
2	0.746	0.835	0.942	1.089
3	0.650	0.753	0.942	1.089
4	0.740	0.834	1.004	1.119
5	0.784	0.869	1.020	1.116

Facility Upgrade/Expansion, Urban

Scenario	Access Cost Threshold, A:B		Access Cost Threshold, A:C	
	Low Cost	High Cost	Low Cost	High Cost
1	$329	$992	$238	$784
2	$329	$992	$88	$184
3	$443	$1,288	$88	$184

Facility Upgrade/Expansion, Rural

Scenario	Access Cost Threshold, A:B		Access Cost Threshold, A:C	
	Low Cost	High Cost	Low Cost	High Cost
1	$135	$204	$44	($4)
2	$135	$204	$40	($13)
3	$200	$303	$40	($13)

Note: Above calculations made assuming 0.5 interchanges per mile, or an interchange spacing of 2 miles. Calculations for other interchange spacings may vary slightly. Access costs expressed in terms of year 2001 dollars per linear foot of access taken.

7.7 Results

Results of the cost analysis are shown in Table 7.6. The analysis clearly indicates that in the case of long-run, full build-out scenarios, facilities without frontage roads are far cheaper than those facilities with frontage roads. This is largely a result of the assumption that in such cases access would not need to be purchased because none existed previously (i.e., there was no previous facility). The additional cost associated with constructing frontage roads is largely a result of the cost of additional construction and of the added right-of-way requirements that may result from the provision of frontage roads.

When frontage roads may be intended to provide additional capacity to the facility for local traffic (as in Type C), the costs are closer. In fact, in rural settings the cost ratios between Type A and Type C are nearly one to one and in some instances the costs for non-frontage-road facilities (Type A) exceed their counterparts with frontage roads. This clearly would indicate that in rural and ex-urban areas with considerable local traffic, the lower cost of frontage-road construction might make the construction of such lanes beneficial, though it is difficult to imagine a situation in which such levels of local rural traffic would exist.

In the facility upgrade/expansion scenarios, a different method of comparison was used as previously was described. The access-cost thresholds vary considerably between the low and high cost situations, and as has been previously stated, access costs themselves vary considerably. However, it is possible to draw some conclusions from these figures. First, as in the full build-out comparisons, it frequently may be the case that frontage roads may be cheaper alternatives to mainlanes in rural settings as a means to provide additional capacity to the facility. Second, it can be concluded that in urban settings the provision of frontage roads may not necessarily be less expensive than would be the purchase of access from abutting landowners. However, in areas such as central Austin where land values are frequently astronomical, the cost of purchasing access may often render it economically beneficial to provide frontage roads.

7.8 Conclusions

Access costs, along with safety and level of service, are an important factor in the decision to include or exclude frontage-road configurations in the construction of new freeways as well as the expansion of existing freeways. As part of this investigation, the levels of access costs that would make the inclusion of frontage roads more cost-effective than their exclusion were estimated.

The project found that where frontage roads were not constructed to provide additional capacity, but merely to provide access to abutting properties, the provision of access might be economical in areas with extremely high land values. However, the thresholds of access costs were near, or even well above, the mean costs of access, indicating that over a long stretch of road the cost of purchasing access would likely not exceed the foregone cost of frontage-road construction. In rural locations this threshold was—in some cases—many times greater than the expected land values in those areas, meaning that the costs associated with constructing frontage roads would exceed the cost of purchasing access.

If one assumes that frontage roads provide additional capacity to the facility, then such comparisons would be unfair. Therefore, a second set of comparisons was made between configurations with and without frontage roads. In these comparisons, facilities that include frontage roads fared better than they fared in the previous comparisons. In particular, large urban facilities might benefit from the construction of frontage roads to provide capacity. However, where frontage roads are intended to provide additional capacity, it is quite possible that local governments will build less arterial capacity on parallel roadways. Therefore, it is not possible to say with certainty whether frontage roads add capacity or merely shift some expense related to providing capacity from the local government to the department of transportation.

The obvious benefit of not having to pay access costs is compounded in this scenario by the relatively lower cost per usable lane mile of frontage roads in comparison to mainlanes. This comparison test also found that frontage roads intended to provide capacity relief in rural areas almost always would be cheaper than those facilities intended to provide relief in rural areas without frontage roads. However, it is difficult to imagine a situation in which enough local traffic would exist in a rural environment to make the use of frontage roads as a means to provide capacity truly worthwhile. Perhaps such a situation might exist in an ex-urban or suburban location with extremely high land values where little residual value would remain after the right of access was removed.

To make such comparisons in the case of new facilities (the full build-out comparisons) would be difficult due to the fact that presumably no access would be purchased. In such cases, even if one assumes that part of the role of the frontage-road facility is that of added capacity, frontage-road scenarios were as expensive as, if not more expensive than, those facilities that did not include frontage roads. This was largely a result of the added right-of-way purchase necessary to house the frontage-road facility.

Finally, it should be noted that this study of costs was only a study of direct financial costs associated with construction. The study did not take into account the potential economic costs of traffic accidents, the possible economic benefits of intense commercial development along frontage-road corridors, or the potential user-cost savings associated with frontage road use during freeway incident management.

CHAPTER 8: SUMMARY AND CONCLUSIONS

This extensive project on frontage roads was intended to provide the Texas Department of Transportation with the necessary information to make decisions regarding the continued use of frontage roads as a means to provide access. The review of legal, planning, policy, and other literature, case studies, corridor pair analyses, operational analyses, and cost analyses together should allow TxDOT and other state departments of transportation to make more informed decisions regarding the use of frontage roads as an aspect of controlled-access facilities. All together, the efforts represented in this report aimed to produce a comprehensive assessment of the benefits and costs entailed in frontage-road provision — as well as to suggest optimal design strategies.

TxDOT recently has affirmed its desire to limit frontage-road construction on new projects. As mentioned in Chapter 2 of this report, an August 2001 Texas Transportation Commission Minute Order #108544 (shown in Appendix F) declared that "New controlled access highways are to be developed without frontage roads whenever feasible." The document continues by stating that the need to construct frontage roads must be "fully justified" by existing laws, and that a frontage road may be constructed "when it is the only feasible alternative after all other alternatives have been considered" (Texas Transportation Commission 2001). An August 20, 2001, memo by then-elect TxDOT Executive Director Behrens, echoes this by stating that new controlled access facilities are to be built without frontage roads "except where engineering studies and economic analyses of access rights versus right-of-way and construction costs indicates otherwise." (Behrens 2001) Such statements represent a significant shift in state policy towards access issues.

The review of literature related to frontage roads considered a variety of issues, including access-right valuation, access policies, and operations. It also highlighted issues of reasonable access, alternatives to frontage roads, corridor preservation, ramp location and spacing, merge lengths, and access-point densities. Overall, it suggests that a wide variety of options are available to TxDOT for limiting access to and improving flow and safety along freeway corridors.

The survey of state departments of transportation indicates that a state's tendency to build frontage roads depends both on past access policies within the state, which tend to depend heavily on legislation, and formal policy guidelines that specify the provisions under which a frontage road will be provided. Moreover, the roadway geometry associated with frontage roads in other states was in many cases quite different from typical Texas designs. Frontage roads where development was allowed to occur on both sides of the roadway was a design characteristic shared by several states, generous ramp-to-signal distances were required by several policy guidelines, and development adjacent to the ramp-frontage-road interface to prevent dangerous weaving maneuvers was generally much more restricted than in Texas. While not every strategy given by a state DOT will apply to Texas, new and rehabilitated roadways within Texas may achieve significant operational and safety advantages by utilizing some of the techniques proven successful in other areas of the United States.

Thirteen corridor pairs were selected for a corridor pair analysis based on their proximity to one another within an urbanized area; in each of these pairs, one corridor provides frontage roads along its entire length and the other does not. One of the project objectives was to determine whether there are any fundamental differences in land uses or resident demographics along corridors with frontage roads versus freeway corridors without frontage roads. The results suggested that census tracts near frontage roads are associated with lower household incomes, lower population densities, lower percentages of bike trips to work, lower vehicle occupancies for work trips, and higher unemployment rates — relative to an equivalent corridor constructed without frontage roads. Though not statistically significant, the results also suggested somewhat lower per capita incomes, larger household sizes, more single occupancy vehicle commuting, lower educational levels, and more poverty in corridors utilizing frontage roads. An examination of two Dallas Ft. Worth corridor pairs with employment data across seventeen industry types at the census block-group level suggested that jobs densities are not necessarily higher along frontage-road corridors; zoning is very important and may lead to higher levels of commercial and industrial activity along non-frontage-road corridors.

The case studies of Austin-area frontage roads should provide TxDOT with useful information regarding frontage-road design should TxDOT choose to continue its long-standing practice of constructing frontage roads. Both increased access density and increased speed variation were estimated to exhibit strong positive effects on frontage-road accident and injury incidence. This conclusion was reached through the development of multivariate regression models on data collected at twelve case-study sites in the Austin metropolitan region. These findings clearly suggest that reducing the density of access and speed variation along frontage-road corridors is a judicious goal for TxDOT to pursue when developing access control policies for existing frontage roads.

The operational analysis of freeway systems with and without frontage roads under heavy/peak use demonstrated that while frontage roads may improve the operation of the mainlanes in intensely developed areas, non-frontage-road facilities may function better than their frontage-road counterparts in moderately developed areas (even though they provide less overall corridor "capacity," as measured by area of pavement). While high-intensity, land-use-area frontage roads may improve the operation of the mainlanes, the resulting weaving movements associated with frequent driveway spacings might create additional operational and safety considerations that need be addressed.

The financial costs associated with frontage-road facilities were found to be considerably higher than those associated with non-frontage-road facilities. Such comparisons favored non-frontage-road facilities both when frontage roads were considered to provide only access and when it was assumed that their purpose was also to provide additional capacity. In some scenarios where land values were assumed to be extremely high, the cost of purchasing access may result in construction cost savings (associated with narrower rights-of-way and lower total construction costs). However, such savings likely would only be evident only on very short projects bisecting very high land-value areas.

The analyses presented here represent avenues of study not previously attempted. The momentum of frontage-road construction in the state of Texas dates back to before construction of the interstate highway system, and many may argue that it gave rise to undesirable roadway operations and land development within the state. It is hoped that these results, in addition to efforts by other researchers, will assist in constructing a solid, formal policy for Texas to follow in providing access along its new and existing freeways in the decades to come.

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APPENDIX A
Responses to DOT Survey Questions

Appendix A. Responses to DOT Survey Questions

Question 1: What is your overall impression of frontage roads (i.e. too expensive, too land consumptive, good buffer for residential uses, etc.)?

"In general, Caltrans would prefer not to construct frontage roads as part of our projects simply due to the additional Environmental Impacts and added cost. Frontage roads are often necessary on Freeway and Expressway where access control is established. The practice of using frontage roads on conventional highways (such as city street situations) is not a standard practice. However, when frontage roads are warranted the following applies.

Frontage Roads are considered on a case-by-case basis to:

To control access to the through lanes, thus increasing safety for traffic.

To provide access to abutting land ownerships.

Restore continuity of the local street or road systems.

Provide for non-motorized traffic that might otherwise desire to use the freeway.

Provide continuity even though it did not exist before when unreasonable circuity of travel would be incurred due to freeway construction without a frontage road.

Often, a frontage road is assessed for a cost to benefit ratio when considering what the best alternative is. In terms of economic considerations for abutting landowners, in general, a frontage road is justified on freeways and expressways if the costs of constructing the frontage road are less than the costs of providing access by other means. Right of way considerations often are a determining factor. Thus, a frontage road would be justified if the investment in construction and extra right of way is less than either the severance damages or the costs of acquiring the affected property in its entirety. Frontage roads may be required to connect parts of a severed property or to serve a landlocked parcel resulting from right of way acquisition. Additionally, Caltrans requires as a mandatory standard for new construction or major reconstruction of interchanges, the minimum distance between ramp intersections and local road intersections shall be 125 m. The preferred minimum distance should be 160 m." (California: Engstrom)

"Sometimes necessary, but not a desirable solution to providing local circulation and access. They are undesirable because they add to highway maintenance and ownership costs, require snow plowing that takes time away from plowing the mainline, they are basically serving a local street (collector) function so they are not really state highways, the continuing need (costs) to maintain the ditch or fence between the frontage road and the mainline to prevent crossovers.

Proximity problems: their proximity to the main highway can cause problems. People crossing over the separator median directly to the highway. A big problem is where the frontage road ties to the cross street. Colorado has spent many millions of dollars to pull the frontage road connection to the cross street back to 500 feet or up to 1500 feet back from the highway.

Signal progression and capacity is poor to impossible if the frontage road connections need traffic signals as well as the main highway. Frontage roads create lasting (long term or forever) problems.

Frontage Roads should be a last resort. First effort should be to improve the local street system to provide proper layout of local and collector streets. Rearage streets, easements. The frequent need for "frontage roads" is just an indication of poor land use and transportation planning. Proper transportation and street planning should provide the necessary local access and circulation patterns, not frontage roads.

Design frontage roads like local streets. The big problem is where they connect to the cross street and then to the main highway. This is frequently a traffic operation and safety nightmare as the area traffic increases. Although usually not a problem in rural areas." (Colorado: Demosthenes)

"Frontage roads, though they exist throughout Florida, are not common access management features along state highways. The decision to use frontage roads, which as you know can have many design and right of way expense issues attached with them, is made on a case-by-case basis by the Department when reviewing traffic, right of way, extent of current access." (Florida: Sokolow)

"Our Department is currently re-writing our Access Management policy which includes the consideration of frontage roads in those area where growth is expected. The Department feels that the Frontage Road, although more expensive in initial investment, will save money in the future when the need for R/W acquisition is reduced. As traffic volumes increase businesses will find that easy access to their properties via a frontage road will actually entice consumers to frequent their businesses. This is the opposite effect that a series of congested approaches has on the customer when they have a hard time gaining access to properties." (Idaho: Holland)

"Overall, frontage roads (we often refer to them as access roads) are only used in Kansas to restore access to existing properties. Otherwise, we do not build them.

Frontage roads are expensive to construct, especially when upgrading to access controlled facilities on or near existing, because there is often developed properties in that way. We generally give these to local units of government to maintain, even though they may not want them. We prefer to let local developers construct their own internal circulation plans in undeveloped areas. Frontage roads often cause major traffic problems and high "cost to cure" if they are not located away from ramp terminals." (KS: Brewer)

“Good alternative for providing unlimited access to the facility while minimizing or eliminating driveways on the main-line, improves safety.” (MA: Wood)

“Valuable transportation asset, valuable land use asset, used by local traffic to relieve the freeway of frequent interchanges and short trips, used by local traffic in lieu of Mile Road bridges across freeway, used by freeway traffic during accident, maintenance, reconstruction, not required along all freeways, not necessarily required along full length of freeways.” (MI: Stebbins)

“Frontage roads are good options for making connections between major roadway connections on access controlled or limited access roadways. In order to maintain mobility on the higher speed, regional routes, the frontage road provides access for the shorter local trips where access to the regional route is made at controlled intersections. We also consider the use of "backage" roads. These roadways serve the same purpose of the frontage road but have the ability of serving properties on both sides of the roadway and usually are located further away from the mainline. This is a benefit to both Mn/DOT and the local government.” (Minnesota: Narusiewicz)

Montana uses frontage roads in the following ways: (1) two-way frontage roads along most of its Interstate/full-access-control facilities, and (2) (one-way) frontage roads alongside many limited-access arterials where too many access points impede the functioning of the main facility. The first type of facility represents the conversion of an existing ~45-mph travelway to frontage road status when the high-speed/high-design Interstates were built along the same corridors. These frontage roads' ramps are stop-controlled (at the end of off ramps) - rather than yield-controlled two-way frontage roads where vehicles in the opposing direction were asked to yield to vehicles coming off the facility, which is what Texas used to have before the safety issues led to construction of only one-way frontage roads & conversion of remaining two-way frontage roads.

The 2nd type of FR facility is usually rather short and may be required of the developer or purchased as public ROW. It is becoming more common as Montana's 1M population swells in certain areas. To achieve this kind of limitation, Montana DOT must first get the state's Transportation Commission to designate the road as a limited-access facility; they then work with the developers and the often-overwhelmed/understaffed county transportation departments to develop the facility with limited access. (Montana: Olberg)

“We consider them a good tool to address property access issues along controlled access freeways.” (North Carolina: Sykes)

“Necessary to provide access to existing facilities while purchasing control of access.” (Nebraska: Poppe)

“Yes to all of these.” (New Mexico: Bracher)

“Frontage roads can be an effective access management and congestion management tool. However in urban and suburban areas that are already developed, they can be difficult and costly to implement due to the amount of right of way required. Since major guide signs for the same destinations are erected on both the freeway and the parallel frontage roads, we have found that this signing, if the design concept is new to the area, may initially confuse motorists.” (Pennsylvania: King)

“The benefit of separating the local traffic with the through is very good. They also provide an alternative route for mainline emergencies.” (South Carolina: Davis)

“They have their uses depending on the access needs and associated costs if the access wasn't provided. We don't have too many here in South Dakota. We'd rather have the local government establish a good street system.” (South Dakota: Bjorneberg)

“The benefit is that you can preserve the functionality of a major arterial and maximize operational efficiency of through movement while providing circulation of local traffic. The weaknesses are the substantial impacts to the urban areas. We should provide sufficient separation between the frontage road and main roadway to have working intersections with side streets. Best used in areas that is semi -developed and there are large tracts of vacant land along the roadway.” (Virginia: Mirshahi)

“Frontage roads often times provide more favorable access for commercial and residential development; Helps preserve safety and capacity on the main line roadways; Continuous frontage roads constructed along high speed arterial streets & freeways with at grade intersection may experience ingress & egress problems if constructed too close to main line; we have found that service roads function better from a traffic operation standpoint if constructed a block or so away from main line; service roads are a necessity along full control access facilities, such as Interstates, to serve land lot properties; VDOT has, over the years, removed service roads in urban areas where round the block circulation could not be provided, these type service roads were located & running parallel to the main line with as little as a 20' to 40' median separating the facilities and these frontage roads operated poorly.” (Virginia: Orcutt)

“A good idea in areas where undeveloped land exists for their use. Frontage roads can help maintain service levels on the primary route, limit turning movements, and thus improve safety.” (Vermont: Shattuck)

"An excellent method of minimizing the number of access points on the main line, while providing maximum land access to parcels along the highway. However, they are very 'land-hungry' and the design of the intersections at the crossroads is critical." (West Virginia: Lewis)

Question 2: Does your state have a written policy on frontage roads? (If so, could you tell us where to get a copy?)

"You can access our policies for Frontage Roads online at the following Internet site: http://www.dot.ca.gov/hq/oppd/. You can look at both the Project Development Procedures Manual (Chapter 11, 17, 22, 24, 25, 27) and the Highway Design Manual (Topic 104, 105, 202. 209, 302.1, 309, 310, 504, 902) at this site." (California: Engstrom)

"There is no written policy on Frontage roads at Colorado DOT. These opinions are unofficial, based on my years of experience." (Colorado: Demosthenes)

"We have no written policy on frontage roads." (Florida: Sokolow)

"Our new Access Management Policy is due out in 2001 after Legislative approval in spring of 2001." (Idaho: Holland)

"We do not have a written policy. We only use them to provide access to existing properties." (Kansas: Brewer)

"MN/DOT has written design policy included in the Road Design Manual - Design Policy and Criteria. The section lays out design controls when frontage roads are considered for grade separated interchanges. (Page number: 6-4.02) The manual can be obtained from: MN/DOT Manual Sales, Mail Stop 260, 395 John Ireland Blvd., St. Paul, MN 55155. If you are only interested in the few pages relating to frontage roads, I can fax those to you. Please respond with a fax number." (Minnesota: Narusiewicz)

"A basic interpretation of our policy regarding the use of new or proposed service roads is that we do the cheapest of the three basic options; build the frontage/service road, buy the affected properties or buy the properties' access. We perform 'service road studies' to determine the cost of these three options." (North Carolina: Sykes)

"This is in reply to your request concerning 'Service Road Studies'. I have asked our project engineers to search their files for a respectable 'Service Road Study', (SRS). I will send one as it becomes available. However, I feel I should explain them a bit further. A SRS is more of a procedure rather than a document. Frequently, there may be only sufficient documentation to support the resulting decision. We undertake a SRS to determine the most economical of the two basic option: use construction funds to build a service road or use right of way funds to pay for property damages caused by lack of said service road. Simply put, a SRS will compare the service road construction cost to the Right of Way (R/W) cost estimate without said service road. Normally this will entail a preliminary design of the potential service road and the associated construction cost estimate. It will also include an estimate of Right of Way costs without said service road. The service road design and construction cost estimate are done in house while the R/W cost estimate is requested from our R/W Branch. Nonetheless, I will search for a respectable SRS and send when available. As a note, along partial controlled arterials, certain cities and we have recently been encouraging commercial developers to build back door frontage roads as part of their development. By back door frontage roads I mean frontage roads that are located behind the first row of restaurants, banks etc. and provide access at the back of that first row. The property owner gets visibility along the major road and access is provided through the service road rather than driveway after driveway. It serves to maintain the traffic moving ability of the road. Should you be interested, our unit's web site is http://www.doh.dot.state.nc.us/preconstruct/highway/roadway/default.htm." (North Carolina: Sykes)

"Yes. We call them service roads instead of frontage roads. Our Policy and Procedure Manual addresses them in Chapter 26, Miscellaneous Roads, Construction and Paving of Service Roads, Roadway Policy Two. A copy will be mailed to you. However, future copies can be requested from: Mr. Frankie Draper, Special Services Squad Leader, Design Services Unit, North Carolina Department of Transportation, PO Box 25201, Raleigh, NC 27611, 919 250-4128, fdraper@dot.state.nc.us." (North Carolina: Tasaico)

"At the present time, Pennsylvania does not have a written policy on frontage roads." (Pennsylvania: King)

"We do not have a written policy on "when and where" to use frontage roads." (South Carolina: Davis)

"No. – We are working on an access management policy. This issue is very controversial/ political and most probably requires legislation action." (Virginia: Mirshahi)

"AASHTO - A policy on Geometric design of highways and streets; VDOT – Road Design Manual" (Virginia: Orcutt)

"Minimal. Vermont Statues, Title 19, Section 1111(f) reads: The Board (meaning the Transportation Board) may, as development occurs on land abutting the highway, provide as a condition of any permit for the elimination of access previously permitted and require the construction of a common frontage road." (Vermont: Shattuck)

Question 3: How does your state generally provide access to land parcels abutting roadways when they are converted to limited access freeways?

"The state of California requires all Freeways to have access control. However, an expressway may have access to the through lanes of a facility as long as there is only one access point per parcel, there are no more than three access points within 500 meters on one side, and access is not available by any other means. In the event that Caltrans must provide access, the project proposing the change in access will construct a Caltrans standard connection." (California: Engstrom)

"We provide access service as necessary to make sure each remaining parcel has reasonable access. Sometimes this requires frontage roads, sometimes service roads in other configurations (like rearage access) and sometimes we work to complete a local street system to improve circulation. Sometimes we buy the parcel rather than face the large long-term costs of frontage road maintenance and tort liability. Sometimes we buy the right of way in the name of the local government so it becomes a local street after construction rather than a state highway frontage road." (Colorado: Demosthenes)

"Generally, we do not convert arterial roads to freeways. If this is considered in the future, I imagine what we would do is try to negotiate reasonable side street access with major landowners along the corridor in order to allow subdivision of properties and development by multiple landowners with unified access to these side streets." (Florida: Sokolow)

"Access to abutting properties on limited access freeways is only provided by frontage roads via interchanges. No other access is allowed." (Idaho: Holland)

"Generally by using access roads. However, we are required to provide "reasonable access" or acquire the property. Often times reasonable access can be attained by connecting to existing local streets or roads." (Kansas: Brewer)

"Case-by-case, usually try to provide indirect access i.e.: through a cross street." (Massachusetts: Wood)

"Full-length frontage roads were most recently built along 80 km (50 miles) on I-69 around Lansing built in early 1990's, when the 1950's free-access 4-lane Blvd in 45 meters (150') ROW running on a diagonal alignment primarily with rural homes and businesses alongside was converted to Interstate by buying 150' additional LA ROW on one side or the other (determined by least impact). The location-design kept and resurfaced one Blvd roadway as the 2-way frontage road, and established new LA ROW in the 'Blvd Median'. All four lanes of traffic were maintained during freeway construction by building the new Fwy roadway in the new LA ROW, then shifting the Blvd roadway onto the new Fwy roadway and remove the Blvd and build the opposite Fwy roadway and establish the LA Fence line.

MDOT seems to be taking a different approach on a 25 km (16-mile) free-access US-27 Blvd north of Lansing that is scheduled to be converted to Freeway, due to cost and speed limit considerations. In 2000 discussion on converting a north-south 1950's free-access 4-lane Blvd in the same ROW width primarily with rural adjacent farms alongside to a freeway with one frontage road, it has been decided to cost out initially purchasing LA ROW along both sides in lieu of having one blvd roadway serve current adjacent land development. The driving factor now is lack of construction funds, so there is a desire to quickly convert the existing blvd to Freeway so the speed limit can be raised to 70 mph. This segment is a 16 mile free-access gap in a 200 mile freeway route, and current financial plans say it won't get its eventual freeway built for another 20 years at least.” (Michigan: Stebbins)

“Typically frontage roads are incorporated into the plans or provisions are made for connections to the local street systems when applicable.” (Minnesota: Narusiewicz)

“Montana constructed frontage roads along the entire length of fully access controlled facilities, like Texas, when these corridors already in use were converted to Interstate highway standards and design speeds. They mostly use ‘button hook’ ramp geometry.” (Montana: Olberg)

“Generally speaking, we provide service roads unless it is cheaper to purchase the affected properties or their access. If the land parcel has access via other roads, the issue is not as straightforward. We perform ‘service road studies’ to help resolve this and other situations.” (North Carolina: Sykes)

“One of the following: construct a frontage road, pay damage to the remainder if other access is available, purchase the property if landlocked.” (Nebraska: Poppe)

“Frontage roads or via access management plan.” (New Mexico: Bracher)

“Pennsylvania has not converted conventional roads to freeways in the recent past. Access issues would be resolved on a case-by-case basis.” (Pennsylvania: King)

“I cannot recall a non-access control road that was converted to a limited access freeway. Most of our roads that have some type of control access began as access control facility.” (South Carolina: Davis)

“Normally, however sometimes it is better just to pay damages to the property owners and let them work with the local government to construct the road how they want it. Depends on the situation.” (South Dakota: Bjorneberg)

“Access will be provided through the side roadways. Sometimes this means extending a public roadway or constructing long driveways. These issues are part of our Right of Way negotiation/activities. If we totally landlock a parcel and there is not a viable access point, it might be cheaper to purchase the property and resale it to a neighbor that has access to a side roadway.” (Virginia: Mirshahi)

“There has been limited use of frontage roads in this situation, however Virginia has not converted a great deal of roadways to limited access freeways. In fact most of our Interstate and other new limited access roadways have been on generally new location. In those cases we used service roads where land lot properties were involved.” (Virginia: Orcutt)

“Either buy the land as ‘loss of access’ or find or build a new access.” (Vermont: Shattuck)

“This has to be determined on a project-by-project basis. In West Virginia, just about every highway, along with the terrain and environment, is different.” (West Virginia: Lewis)

Question 4: In purchasing access rights, how do you decide what to pay landowners whose access to a roadway is removed?

“Parcels are appraised for the fair market value of the parcel with access control and without access control. The difference of these two appraisals is the amount paid to the land owner.” (California: Engstrom)

“We refer to it as acquiring access rights. "Purchase" is not always necessary. Since we control access to state highways by access regulations, (Texas doesn't have this) we frequently do not pay or pay very little for access rights. If the property retains reasonable access to the general street system, then we normally do not pay for loss of access to the main highway. If the loss of access to the whole parcel rises to the level of "substantial impairment' then we pay for the access rights or buy the property. We acquire access rights at many levels of highway function and type, not just freeways and expressways. Anywhere it is determined to need long term access control, like major intersection corners - all four legs.” (Colorado: Demosthenes)

“The purchasing of access rights in Florida is handled by the standards set out in federal policy.” (Florida: Sokolow)

“Access removal is based upon an appraisal of the property value with and without the access.” (Idaho: Holland)

“Our baseline requirement is that we must provide “reasonable access” or acquire the property. There have been a few instances where the property owner requests to retain a landlocked property. In such cases, depending on specific circumstances, we may appraise and negotiate a payment of damages, and let the property owner retain the landlocked property.” (Kansas: Brewer)

“Fair market value by policy.” (Massachusetts: Wood)

“Appraisal value for any land area taken, plus.... Appraisal value for loss of access to the removed road, Sometimes buying LA ROW or access rights requires purchasing Total Takes, Sometimes we stop the LA ROW or access rights line 15 m (50') short of the full property frontage so the property has enough for a driveway opening and thus residual value to Owner or upon Resale by MDOT. (This can substantially reduce the ROW cost of large parcels.)” (Michigan: Stebbins)

“There is an appraisal process that is followed to determine how removal will affect value of property, and to determine severance damages.” (Minnesota: Narusiewicz)

Ivan says that as of June 1999 Montana formally has "gotten out of the business of buying and selling access rights." He will be sending us a copy of this document, passed by the Transportation Commission, which essentially allows limitation of access rights based on police powers. They still try to provide "reasonable access," which is assessed qualitatively and determined as part of their negotiation process. There are no rules regarding circuity and access distances. And in practice, residential use circuity of access is less important than that of business use, due to the number of associated trips being made. (Montana: Olberg)

“We do not account specifically for loss of access but rather account for it in our overall Right of Way appraisal process. Appraisals of the effected properties are done of the ‘before’ and ‘after’ conditions. We appraise the value of the property in its ‘before’ or current condition absent the proposed highway impacts. We appraise the value of the property in its ‘after’ condition considering the proposed highway impacts; loss of land to right of way, loss of access etc. The difference in the ‘before’ and ‘after’ appraisals is what we consider just compensation. This process should account for damages to the remaining property due to such things.” (North Carolina: Sykes)

"Appraisal of the properties worth before and after the taking of the access." (Nebraska: Poppe)

"A before and after appraisal is done, the difference if any is the amount of compensation." (New Mexico: Bracher)

"At the present time, Pennsylvania does not have a formal policy for purchasing access rights from landowners. However, this is an important issue for our state and efforts are underway to monitor access management activities from around the nation for future implementation in Pennsylvania." (Pennsylvania: King)

"We would have an appraisal of the before and after, then compensate the owner on the difference." (South Carolina: Davis)

"It is appraised on its before and after value. Sometimes it is best to purchase the entire property and sell off the excess after construction (only if a willing seller). Damages can include what associated costs would be incurred to construct their own access road. Normally, a jury decides though." (South Dakota: Bjorneberg)

"We usually compensate the property owners for a fair market value of the damage. The damage figure is the difference between the value of the residue immediately before and immediately after the taking. A cost benefit analysis will be conducted to determine the cost of a whole take or a partial take (adding the cost of appropriate access roadways)." (Virginia: Mirshahi)

"Formal appraisal taking loss of access and best use of land into account." (Vermont: Shattuck)

"We don't have to pay if the parcel is not touched. If they have an alternative access, they are paid for property taken plus damage to the value of the residual. If they don't have an alternative access and one can't be provided, the parcel is usually bought for the appraised value." (West Virginia: Lewis)

Question 5: Is there anyone else you recommend we contact regarding such design issues?

"Terry Abbott, Chief, Office of Geometric Standards. (916) 653-0253." (California: Engstrom)

"For issues of right of way purchasing I would recommend you get in touch with Ken Towcimak, Director of the Office of Right of Way, whose phone number is (850) 414-4545. For issues of frontage roads and the conversion of regular arterials into arterials served by frontage roads, as well as conversion of intersections into interchanges, I would contact the District Seven Design Engineer in the Tampa office. His name is Sam Messick, the District Roadway Engineer. That district has done extensive construction and design of frontage roads and conversion of at-grade intersections into urban style interchanges on US 19 in Pinellas County. His phone number is (813) 975-7725." (Florida: Sokolow)

"Greg Laragan, PE Bill Smith, Design Engineer Right-of-way Agent (208) 334-8488 (208) 334-8521" (Idaho: Holland)

"Bonnie Towslee, Bay Region Real Estate Agent, towsleeb@mdot.state.mi.us

Tom Jay, Metro Region Real Estate Agent, jayt@mdot.state.mi.us" (Michigan: Stebbins)

"Regarding the appraisal process please contact: Keith Slater, Keith.Slater@dot.state.mn.us" (Minnesota: Narusiewicz)

"Regarding the R/W appraisal process, contact:Mr. Fred J. Barkley, Appraiser, Right of Way Branch, North Carolina Department of Transportation, PO Box 25201, Raleigh, NC 27611, 919 733-7932x358, fbarkley@dot.state.nc.us

"Regarding design issues, contact: Ms. Deborah Barbour, PE, State Design Engineer, North Carolina Department of Transportation, PO Box 25201, Raleigh, NC 27611, 919 250-4001, dbarbour@dot.state.nc.us." (North Carolina: Sykes)

"Chris Vigil, R/W Manager, NMSH&TD" (New Mexico: Bracher)

"Ken Lantz, PE VDOT State Transportation Planning Engineer (804) 786-2964." (Virginia: Mirshahi)

"Mr. Stuart A. Waymack is VDOT's R/W & Utilities Division Administrator - His office would be able to assist you with the above question. His email address: waymack_sa@vdot.state.va.us" (Virginia: Orcutt)

“Our Right-of-Way unit (Allan Blake - al.blake@state.Vermont.us) can provide more detail regarding #4.” (Vermont: Shattuck)

APPENDIX B
DOT Survey Respondents by State

Appendix B. DOT Survey Respondents by State

California

Paul M. Engstrom

Design Reviewer

State of California

Department of Transportation, Design and Local Programs, P.O. Box 942874, MS 29, Sacramento, CA 94274-0001

Phone: 916-653-3263

Email: Paul_Engstrom@dot.ca.gov

Colorado

Philip Demosthenes

Access Program Administrator, Safety and Traffic Engineering Branch

Colorado DOT, 4201 East Arkansas Ave. EP 770, Denver, CO 80222-3400

Phone 303-757-9844, FAX 303 757 9219

mailto:phil.demosthenes@dot.state.co.us

Colorado Access Mgmt Web page

http://www.dot.state.co.us/business/accessmgt/

Florida

Gary Sokolow

Public Transportation Manager

Florida DOT, 605 Suwannee Street, MS 19, Tallahassee, FL 32399-0450

Phone: 850 414-4912

Email: gary.sokolow@dot.state.fl.us

Kansas

James O. Brewer, P.E.

Engineering Manager – State Road Office

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Phone: 785 296-3901
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Idaho
Steve C. Holland, TSEA
Idaho Transportation Dept., P.O. Box 7129, Boise, Idaho 83709
Phone (208) 334-8565
Email: SHolland@itd.state.id.us

Massachusetts
Stanley W. Wood, PE
Highway Design Engineer
Mass Highway Department, 10 Park Plaza, Boston, MA 02116
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Michigan
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Engineer of Project Coordination
Design Division, Mich Dept Transportation, PO Box 30050, Lansing MI 48909
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Minnesota
Sherry Narusiewicz
Principal Transportation Planner, Local Government Liaison Section
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Email: sherry.narusiewicz@dot.state.mn.us

Montana
Ivan Olberg
Phone: 406-444-9458
Responses taken by Dr. Kockelman via phone conversation, April 7, 2000

Nebraska

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Roadway Design Engineer
Nebraska Department of Roads, P.O. Box 94759, Lincoln, NE 68509
402-488-2243
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North Carolina

Burt Tasaico
NCDOT - Planning and Programming
Phone 919-733-2031, fax 919-733-9428
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Dewayne Sykes, PE
Assistant State Roadway Design Engineer
North Carolina Department of Transportation, P.O. Box 25201, Raleigh, NC 27611
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New Mexico

Robert B. Bracher
Traffic Technical Support Engineer
P.O. Box 1149, 1120 Cerrillos Rd. Santa Fe, NM 87504-1149
Phone: 505-827-5473

Pennsylvania

Larry M. King
Deputy Secretary for Planning
Pennsylvania DOT, 555 Walnut St., 9th Floor, Forum Place, Harrisburg, PA 17101
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South Carolina

E. Warren Davis, Jr.
Preliminary Design Manager
SCDOT, PO 191, Columbia, SC 29202
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South Dakota

Tim Bjorneberg
Chief Road Design Engineer, 700 E Broadway, Pierre, SD 57501
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Vermont

Robert F. Shattuck
Roadway & Traffic Design Engineer
Vermont Agency of Transportation, National Life Building, Drawer 33,
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Virginia

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APPENDIX C
Frontage Road Policy by State

Appendix C. Frontage Road Policy by State

CALIFORNIA

Project Development Procedures Manual, Chapter 24, Freeway Agreements, Article 3, Freeway Agreement Format

"Joint Participation

The freeway project may involve work that is to be financed by the local agency. Such work should be shown on the Freeway Agreement exhibit map. The financial obligation is shown on the exhibit map by symbol or by adding a note. Symbols indicating financial obligation are not used for freeway lanes or interchange connections. These are shown with the solid filled-in freeway symbol.

In the instance where the cost of ramps or freeway lanes is to be paid for by others, a note indicating the financial obligation should be placed on the exhibit map. Financial obligation for frontage roads and other roads that is to be paid for by others is shown on the exhibit map by standard symbol or a note."

Project Development Procedures Manual, Chapter 27, New Public Road Connections, Article 2, Policy

"Public Road

The definitions in Article 1 are used for purposes of implementing new public road policy. A local agency "public road" must clearly serve a public purpose, exceed 0.4 km in length, and should function as part of the local circulation element providing access to General Plan land uses.

The connection of the new public road must also meet freeway Design Standards for interchange spacing, as described in HDM Index 501.3, or it must have an approved exception. The proposal should conform to Caltrans Access Control Policy in HDM Topic 104 and Index 205.1.

Better local service may be provided by frontage road, local public road or public street."

"Access Control Policy

In the following paragraphs, access control policy from several sources is summarized.

On freeways, direct access from private property is prohibited without exception, see HDM Index 104.1. Abutting private property ownerships served by frontage roads or streets connected to interchanges. All connections to freeways are by interchanges, see HDM Index 501.2. (When an original Freeway Agreement is executed to cover the route adoption, staged construction with an interim at-grade intersection is permissible until high traffic volumes, safety, or other factors justify construction of the interchange. However, for a proposed connection of a new public road to a full freeway, an interchange is required).

On expressways (which require a controlled access highway agreement as opposed to a Freeway Agreement), access from private property is permitted (HDM Index 205.1), but the size and number of openings are held to a minimum. Parcels that have access to another public road or street, as well as frontage on the expressway, are not allowed access to the expressway, see HDM Index 104.2.

If future conversion of an expressway to full freeway is possible, the freeway Advisory Design Standard for interchange spacing (see HDM Index 501.2) is implied for the spacing between public road at-grade intersections.

Frontage roads on freeways and expressways are justified if investment in construction and extra right of way is less than either severance damages or the cost of acquiring the affected property in its entirety. When more than 3 private access openings are located within the distance specified in HDM Index 104.3, a frontage road should be considered."

"<u>Existing Road as Frontage Road</u>

If a new local road or street is to be connected to an existing highway that is clearly to remain as a frontage road after construction of the freeway, the connection does not need CTC approval. The connection will be handled by the usual encroachment permit process. The permit should note the same points and conditions noted for theoretical connections as described in Article 3."

"Violations of Private Access Openings to Expressways

Existing private access openings to expressways are sometimes misused. This usually occurs when land uses change from agricultural to urban or suburban. An opening that originally served one owner now serves several owners due to parcel splits.

In such an instance, residential, commercial, and industrial development may have occurred that impairs the safety and operational capacity of the private connection. More often than not, the owners have widened the driveways to widths greater than the legal opening (without permits) and the driveways become de facto public streets. Once in place and allowed to stay a number of years, it is questionable whether the Department would be successful in litigating removal of the unauthorized driveway improvements.

The districts, particularly through their maintenance superintendents, must take all reasonable measures necessary to protect the integrity of access control. An alternative, where the "driveway" extends some distance from the expressway, is to encourage the affected local agency to work with the property owners to develop a bona fide public road under the jurisdiction of the local agency with new connection approval by the CTC. This alternative must be compatible with future improvement plans for the expressway. Another alternative may be for the affected local agency to develop a frontage road or a local road network that connects to another public road."

"<u>Consider Future Land Use in Initial Design</u>

To avoid the access violation problem described above, the initial expressway could be designed to accommodate the most probable future land-use changes with planned access openings and frontage road provisions, after thorough evaluation of the most likely development adjacent to the facility. An option that can be considered is to acquire frontage road right of way (or a wide main line right of way) but permit interim private access directly to the expressway to avoid excessive severance damages and frontage road costs. When development does come, the rights of way for the solution will be available."

Highway Design Manual, Chapter 100, Basic Design Policies, Topic 104, Frontage Roads

"104.1 General Policy

Control of access is achieved by acquiring rights of access to the highway from abutting property owners and by permitting ingress and egress only at locations determined by the State.

On freeways, direct access from private property to the highway is prohibited without exception. Abutting ownerships are served by frontage roads or streets connected to interchanges.

104.2 Access Openings

The number of access openings on highways with access control should be held to a minimum. (Private property access openings on freeways are not allowed.) Parcels which have access to another public road or street as well as frontage on the expressway are not allowed access to the expressway. In some instances, parcels fronting only on the expressway may be given access to another public road or street by constructing suitable connections if such access can be provided at reasonable cost.

With the exception of extensive highway frontages, access openings to an expressway are limited to one opening per parcel. Wherever possible, one opening should serve two or more parcels. In the case of a large highway frontage under one ownership, the cost of limiting access to one opening may be prohibitive, or the property may be divided by a natural barrier such as a stream or ridge, making it necessary to provide an additional opening. In the latter case, it may be preferable to connect the physically separated portions with a low-cost structure or road rather than permit two openings.

104.3 Frontage Roads

(1) General Policy.

(a) Purpose--Frontage roads are provided on freeways and expressways:

To control access to the through lanes, thus increasing safety for traffic.

To provide access to abutting land ownerships.

Restore continuity of the local street or road systems.

Provide for nonmotorized traffic that might otherwise desire to use the freeway.

Provide continuity even though it did not exist before when unreasonable circuity of travel would be incurred due to freeway construction without a frontage road.

(b) Economic Considerations--In general, a frontage road is justified on freeways and expressways if the costs of constructing the frontage road are less than the costs of providing access by other means. Right of way considerations often are a determining factor. Thus, a frontage road would be justified if the investment in construction and extra right of way is less than either the severance damages or the costs of acquiring the affected property in its entirety. Frontage roads may be required to connect parts of a severed property or to serve a landlocked parcel resulting from right of way acquisition.

(c) Access Openings--Direct access to the through lanes is allowable on expressways. When the number of access openings on one side of the expressway exceeds three in 500 m, a frontage road should be provided (see Index 104.2).

(2) New Alignment.

Frontage roads generally are not provided on freeways or expressways on new alignment since the abutting property owners never had legal right of access to the new facility. They may be provided, however, on the basis of considerations mentioned in (1) above.

(3) Existing Alignment.

Where a freeway or expressway is developed parallel to an existing highway or local street, all or part of the existing roadway often is retained as a frontage road. In such cases, if access to remainders of land on the side of the freeway or expressway right of way opposite the old road cannot be provided by other means, a frontage road must be constructed to serve the landlocked remainders or the remainders must be purchased outright. The decision whether to provide access or purchase should be based on considerations of cost, right of way impacts, street system continuity and similar factors (see (1) above).

(4) Railroad Crossings.

Frontage roads on one or both sides of a freeway or expressway on new alignment, owing to safety and cost considerations, frequently are terminated at the railroad right of way. Any new railroad grade crossings and grade separations, and any relocations or alterations of existing crossings must be cleared with the railroad and approved by the PUC.

(5) Frontage Roads Financed by Others.

Frontage roads which are not a State responsibility under this policy may be built by the State upon request of a local political subdivision, a private agency, or an individual. Such a project must be covered by an agreement under which the State is reimbursed for all construction, right of way, and engineering costs involved.

Highway Design Manual, Chapter 100, Basic Design Policies, Topic 105, Pedestrian Facilities

105.1 Sidewalks

"The State may assume financial responsibility for the construction of sidewalks under the conditions described below. (See the Project Development Procedures Manual for further discussion of State's responsibility in providing pedestrian facilities.)

…(6) Frontage Roads. Sidewalks may be built along frontage roads connecting local streets that would otherwise dead end at the freeway provided the intersecting streets have sidewalks. Such sidewalks are considered to be replacements of existing facilities. Normally, sidewalks should not be placed on the freeway side of frontage roads except where connections must be made to pedestrian separations."

Highway Design Manual, Chapter 300, Geometric Cross Section, Topic 310, Frontage Roads

310.1 Cross Section

Frontage roads are normally relinquished to local agencies. Index 308.1 gives width criteria for city streets and county roads. These widths are also applicable to frontage roads.

However, the minimum paved cross section for urban frontage roads shall be two 3.6 m lanes with 1.2 m outside shoulders. (See Chapter 1000 for shoulder requirements when bicycles are present.) The minimum paved cross section for rural frontage roads shall be 7.2 m.

310.2 Outer Separation

In urban areas and in mountainous terrain, the width of the outer separation should be a minimum of 8 m from edge of traveled way to edge of traveled way. A greater width may be used where it is obtainable at reasonable additional cost, for example, on an urban highway centered on a city block and paralleling the street grid.

In rural areas, other than mountainous terrain, the outer separation should be a minimum of 12 m wide from edge of traveled way to edge of traveled way. See Figure 307.4 for cross sections of outer separation and frontage road.

310.3 Headlight Glare

Care should be taken in design of new frontage roads to avoid the potential for headlight glare interfering with the vision of motorists traveling in opposite directions on the frontage roads and in the outer freeway lanes. The preferred measures to prevent headlight glare interference on new construction are wider outer separations, revised alignment and raised or lowered profiles."

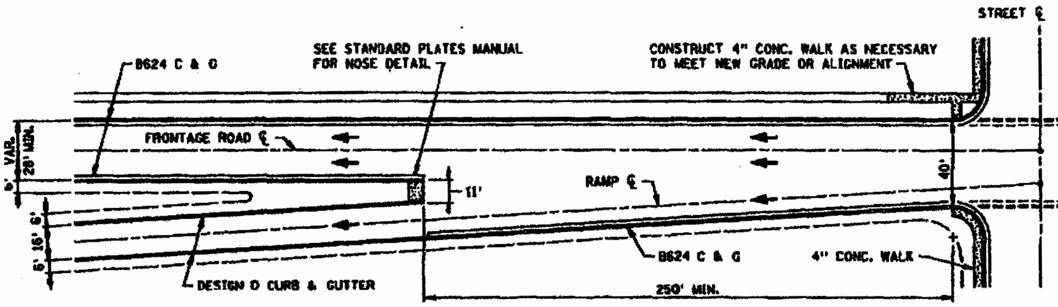
MINNESOTA

Minnesota Road Design Manual, Design Policy and Criteria
6-4.02: Frontage Road Intersections

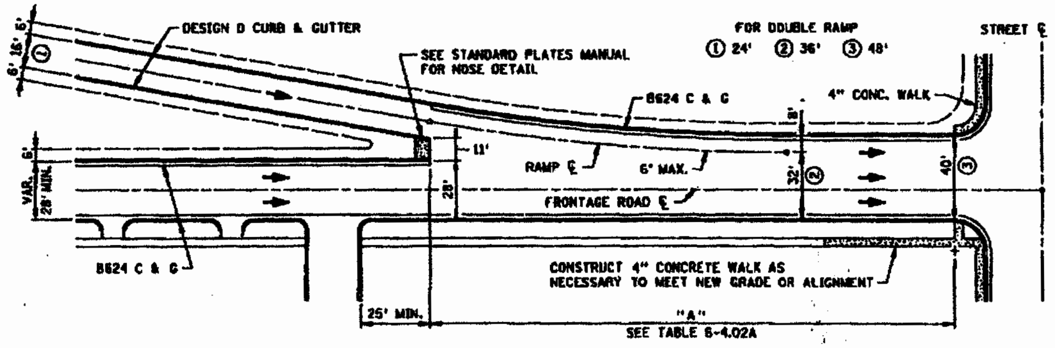
"Where frontage roads are present adjacent to freeways, the ramp/minor road intersection is greatly complicated. If possible, the frontage road should be curved away from the interchange and allowed to intersect the minor road a sufficient distance away from the ramp intersection. This treatment allows the two intersections to operate independently, and it eliminates the operational and signing problems of providing the same point of exit and entrance for the frontage road and freeway ramp.

In urban areas, when due to the R/W constraints, it may not be possible to achieve a separation between the ramp and frontage road adequate enough to develop full turn lanes, a minimum of 300 ft. separation should be provided. When the 300 ft. minimum separation is not available, then the following design applications may be considered:

1) One way frontage roads: figure 6-4.02A provides the basic schematic for the layout, and figure 6-4.02B provides the design details for the merging and diverging operations for the frontage road and ramp. The critical design element is the distance "A" between the ramp/frontage road merge and the minor road. This distance must be sufficient enough to allow traffic weave, vehicle deceleration and stop, and vehicle storage to avoid interference with the merge point. No points of access can be allowed in this section. Table 6-4.02A presents general guidelines, which may be used to estimate this distance during the preliminary design phase. A number of assumptions have been made including weaving volume, operating speeds, and intersection queue distance. Therefore, a detailed design will be necessary to firmly establish the needed distance to properly accommodate traffic volumes and speed, weaving, stopping, and intersection storage.



DIVERGING OF RAMP AND FRONTAGE ROAD



MERGING OF RAMP AND FRONTAGE ROAD

Figures 6.402A and 6.402B

Frontage Road Volume (VPH)[1]	Exit Ramp Volume (VPH)[2]	"A" (ft)		
		Desirable	Minimum	Absolute Minimum
200	140	500	380	260
400	275	560	460	360
600	410	630	500	400
800	550	690	540	430
1000	690	760	590	450
1200	830	870	640	480
1400	960	970	690	500
1600	1100	1070	770	530
1800	1240	1180	860	550
2000	1380	1300	970	580

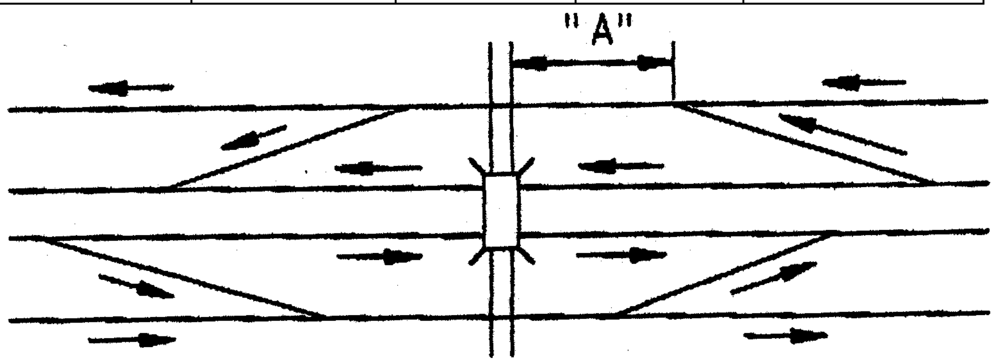


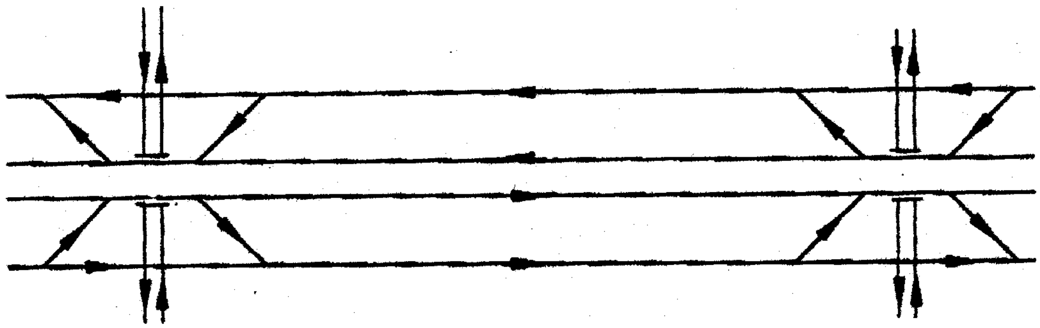
Figure 6-4.02A Distance "A" from Ramp/Frontage Road to Intersection with Minor Road

[1] Total frontage road and exit ramp volume between merge to intersection with minor road.

[2] Assumed to be 69 percent of total volume in first column.

Reference: J. Michael Turner and Carroll J. Messer, "Frontage Road Ramp to Cross-street Distance Requirements in Urban Freeway Design," Texas Transportation Institute, January 1978.

2) When there is a series of cross roads with a need for a number of on and off-ramps along such a corridor, it may be beneficial to consider the use of 'X' pattern ramps at diamond interchanges. With this type of ramp pattern, the entrance occurs prior to the intersection while the exit occurs after the cross street. This configuration can improve traffic flow characteristics for the through roadways around diamond interchanges. The only drawback is that the driver expectancy may be altered slightly in comparison to a traditional diamond configuration."



"X" Ramp Configuration

NORTH CAROLINA

North Carolina Policy and Procedure Manual: Chapter 26, Miscellaneous Roads, Construction and Paving of Service Roads, Roadway Policy Two.

"Policy statement: A policy for the construction and paving of service roads has been adopted by the Division of Highways. The adopted policy is:

1) Proposed service roads for controlled access project

- If the construction cost (grading, drainage, stabilization) of a proposed service road, plus the right of way damages with the service road in existence are equal to or less than the appraised right of way damages without a service road, the service road shall be constructed.
- If the construction cost of the service road including paving as set forth in "A" is equal to or less than the right of way damages without the service road, and it appears that residential or business development can warrant such paving, the service road will be paved as a part of the construction project.
- If in the opinion of the Division of Highways in the construction of a service road, without paving, it appears that the dust situation created could be hazardous to the main highway, then the service road may be paved as a part of the initial project.

2) Existing service roads on controlled access facilities

    A. Where service roads exist in an unpaved condition on a typical rural project, the paving of said service road shall be constructed as a part of the regular secondary road plans for the county and shall meet the same requirements as other country roads.

    B. Where the unpaved service road is a part of a subdivision, the paving will be handled by "participation paving" as outlined in the subdivision policy of the secondary road plan.

    C. Service roads within the municipality may be paved by participation paving as outlined in the subdivision policy or, if in the judgment of the city and the State, the project is considered of major importance, they may be paved or improved with "urban construction funds."

3) Requests for construction of new service roads along existing controlled access facilities

    A. If an existing fully controlled-access facility has sufficient right of ways available for the construction of service roads on the highway right of way, the following procedure shall be employed:
    Property owners may be permitted to request the Division of Highways to construct a service road along the highway right of ways at the expense of the property owners in the same manner as "participation paving;" this

participation in the initial construction and paving to be based upon the fact that there is a need for such a service road. If it is determined that such a need exists, and that the property owners will bear the entire cost for construction, the Division of Highways will then accept the roads for maintenance. The Division of Highways reserves the right to obliterate the service road in the event that a planned development is abandoned or reduced to such an extent that a service road is not needed.

4) Construction of service roads along partially controlled-access facilities with temporary access points

    A. Where temporary access points have been permitted and the amount of traffic at the temporary access point and the state of development has increased to make a hazard to the main traveled lane of the highway, then the Division of Highways shall construct a minimum type service road to eliminate the temporary access point unless the Division of Highways can justify the cost of purchasing all access rights at the temporary access point and thus eliminating the access point to make the facility a fully controlled facility. If additional right of ways are needed for the construction of such service roads to eliminate temporary access facilities, the cost of the right of way acquisition shall be borne by the Division of Highways.

    B. The paving of such service roads shall be based upon the same general formulas as previously set forth pertaining to rural, residential, business, and urban development conditions.

5) Planning of service roads for new construction projects

    A. Where feasible, when it has been determined that a service road is needed, such service road shall be constructed away from the main highways to permit development on both sides of the service road. For residential development, the service road should be approximately 200 feet from the highway right of ways. For industrial development, the service road should be approximately 400 feet from the highway right of ways to permit development on both sides of the service road. Where the highest and best use of the land is for farming or pasture, service roads should be constructed adjacent to the highway right of ways for the main project.

6) Improvement of service roads

    Where service roads have been constructed on controlled-access projects, and abutting property owners, cities, towns, or developers desire to improve the service road by additional pavings, widening, construction of curb and gutter, additional drainage, etc., this improvement shall be carried out in accordance with the plans approved by the Division of Highways, and the cost of said improvement shall be borne by the property owners, developer, city, or town.

7) Financing of service roads

    Where it can be determined that service roads can be justified, the financing of this work will be contingent upon available funds; and the Federal Highway Administration shall participate in the cost in the same manner as in the construction cost of the main projects, with such participation by the Federal Highway Administration limited based upon their laws, policies, and regulations.

Background: Approval of the Division of Highways 4/27/61, memorandum from W. A. Wilson, Jr. 4/6/78, general update 4/15/98.

Purpose: To establish procedures for the construction and paving of service roads."

(NC: Policy and Procedure Manual)

WISCONSIN

Wisconsin statutory policy on frontage roads

84.29(4)

"(4) Laying new highways for Interstate system. Upon finding and determination by the department that it is not in the public interest and that it is impractical to establish the route of the Interstate system on or along an existing state trunk highway, the department is authorized and empowered to lay out and establish a new and additional state trunk highway for the Interstate highway. As an Interstate highway may be established, laid out and constructed on a new location as an expressway or freeway which is not on and along an existing public highway, no right of access to the highway shall accrue to or vest in any abutting property owner. As an Interstate highway may be established, laid out and constructed as an expressway or freeway on and along an existing public highway, reasonable provision for public highway traffic service or access to abutting property shall be provided by means of frontage roads as a part of the Interstate highway development, or the right of access to or crossing of the public highway shall be acquired on behalf of the state as a part of the Interstate highway improvement project. The occupation or use of any part of an existing public highway is authorized for the construction of the Interstate system. The action of the department relative to establishment, layout, location or relocation of any part of the Interstate system shall be conclusive.

84.295(5)

(5) Designating highways as freeways or expressways. Where a state trunk highway is established on a new location which is not on or along an existing public highway, and the state trunk highway is designated as a freeway or expressway no right of access to the highway shall accrue to or vest in any abutting property owner. Where a state trunk highway is on or along any highway which is open and used for travel and is designated as a freeway or expressway, reasonable provision for public highway traffic service or access to abutting property shall be provided by means of frontage roads as a part of the freeway or expressway development, or the right of access to or crossing of the public highway shall be acquired on behalf of the state as a part of the freeway or expressway improvement project. The occupation or use of any part of an existing public highway is authorized for the construction of a freeway or expressway. The action of the department relative to designation, layout, location or relocation of any part of a freeway or expressway shall be conclusive."

WISDOT's Official Mapping Authority

84.295(10)(a)

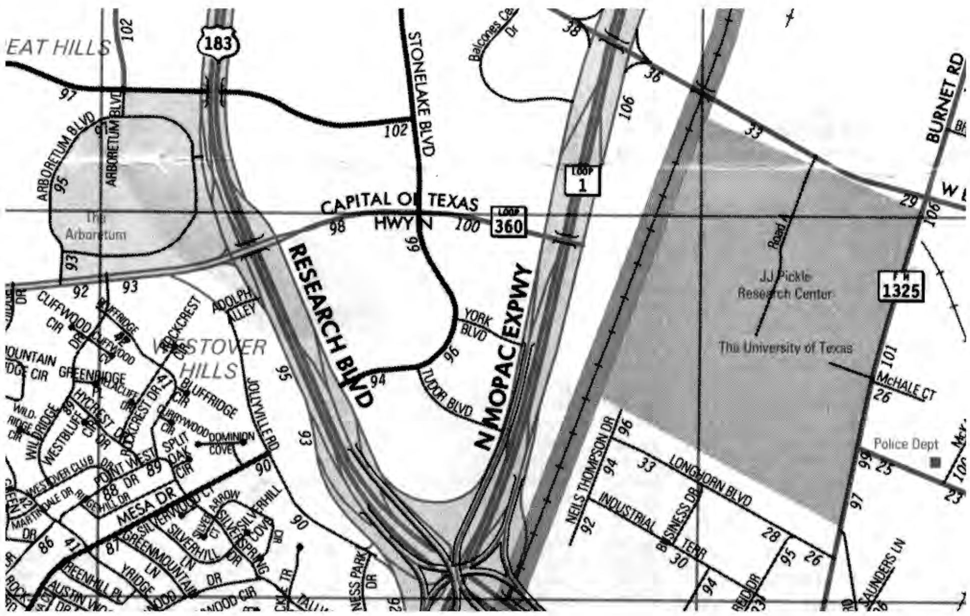
“(a) Where, as the result of its investigations and studies, the department finds that there will be a need in the future for the development and construction of segments of a state trunk highway as a freeway or expressway, and where the department determines that in order to prevent conflicting costly economic development on areas of lands to be available as rights-of-way when needed for such future development, there is need to establish, and to inform the public of, the approximate location and widths of rights-of-way needed, it may proceed to establish such location and the approximate widths of rights-of-way in the following manner. It shall hold a public hearing in the matter in a courthouse or other convenient public place in or near the region to be affected by the proposed change, which public hearing shall be advertised and held as are state trunk highway change hearings. The department shall consider and evaluate the testimony presented at the public hearing. It may make a survey and prepare a map showing the location of the freeway or expressway and the approximate widths of the rights-of-way needed for the freeway or expressway, including the right-of-way needed for traffic interchanges with other highways, grade separations, frontage roads and other incidental facilities and for the alteration or relocation of existing public highways to adjust traffic service to grade separation structures and interchange ramps. The map shall also show the existing highways and the property lines and record owners of lands needed. Upon approval of the map by the department, a notice of such action and the map showing the lands or interests therein needed in any county shall be recorded in the office of the register of deeds of such county. Notice of the action and of the recording shall be published as a class 1 notice, under ch. 985, in such county, and within 60 days after recording, notice of the recording shall be served by registered mail on the owners of record on the date of recording. With like approval, notice and publications, and notice to the affected record owners, the department may from time to time supplement or change the map.”

APPENDIX D
Case Studies

Appendix D. Case Studies

D.1 CASE STUDY AREA MAPS

The maps in this appendix are from Mapsco Metro Traveler Map Series, Austin City Map, 1999.

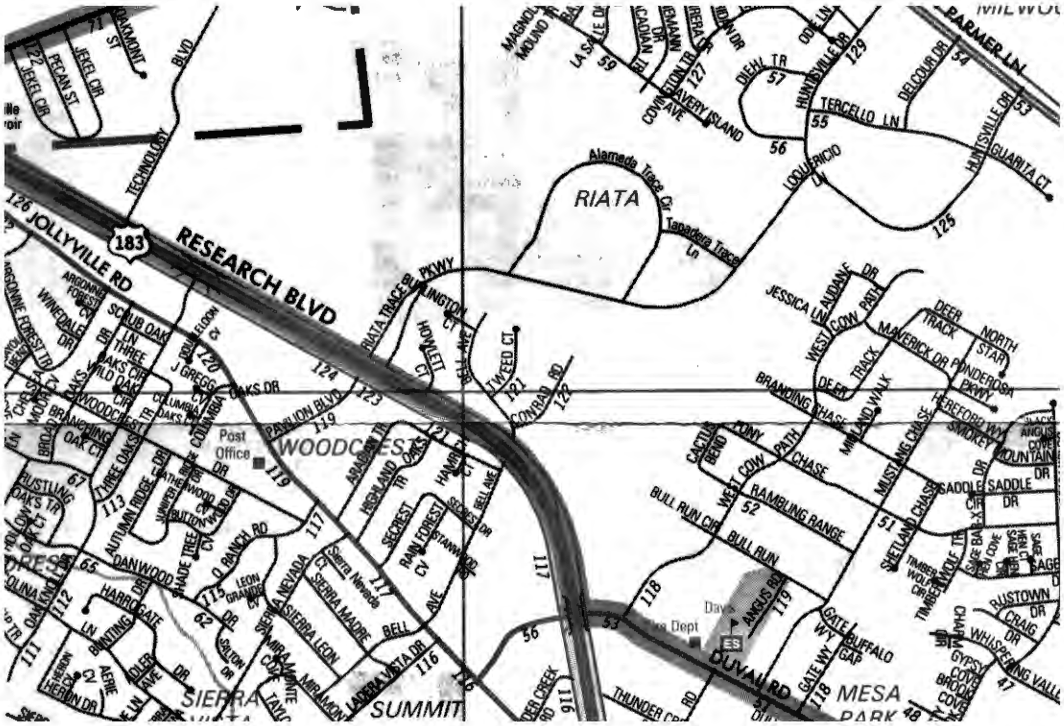


US 183 Northbound at Loop 360/Capital of Texas Highway

This US 183 (also known as Research Boulevard) location is one of the most notorious of all the case studies in terms of the many poor access provisions it exhibits. Located along Gateway Center, a desirable, upscale retail center in Austin's Arboretum area, this location's frontage serves not one but *two* exit ramps from two separate freeways. US 183's exit ramp lies to the south, at the southern end of the study area, and an access ramp from the nearby northbound MoPac interchange merges farther downstream. The intersection with Loop 360/Capital of Texas Highway marks the northern study boundary. The frontage road here has two lanes upstream of the 183 ramp, where it widens to three lanes. Contributing to the access problems here, several driveways are located within close proximity to both the 183 and MoPac ramps, and drivers were seen making dangerous turning movements at high speeds to access these driveways across two or three frontage road lanes. Furthermore, driveways within 70 feet of the signalized intersection interfere with queuing traffic at this high-volume location during even nonpeak hours. The area does provide sidewalks along its length along with a landscaped strip between the frontage roads and adjacent development, though pedestrian connectivity does not exist across the large MoPac/183 interchange area immediately to the south. One positive characteristic of this location is the three southernmost driveways to Gateway Center, which are clearly marked and provide proper channelization for incoming and outgoing vehicles. These driveways also minimize the frontage length consumed by access driveways by consolidating such access points to just three locations over a rather long distance.

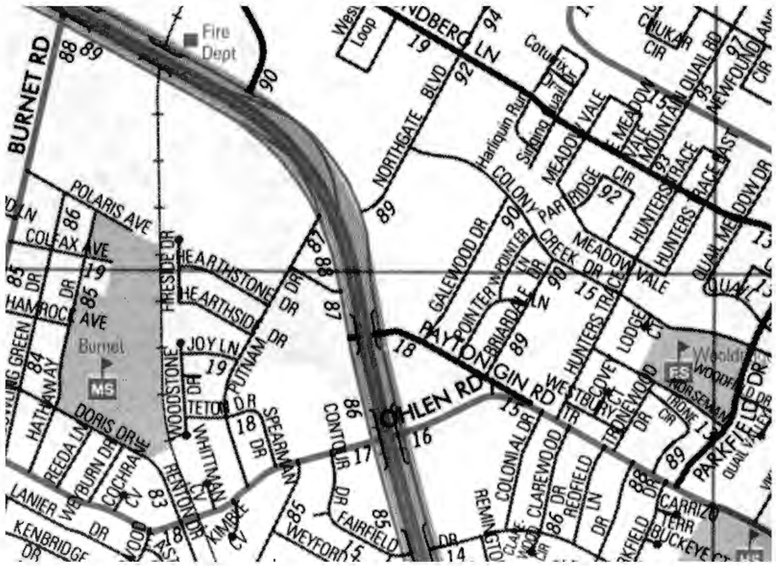
US 183 Northbound at Balcones Woods Drive

The northbound US 183 at Balcones Woods Drive frontage road location is along an elevated section of US 183, and is three lanes wide. The study location begins at the signalized intersection of Balcones Woods Drive and ends where Angus Road meets the frontage road at a T-intersection. Most of its length abuts the Windriver Apartments development, which has two driveways accessing the frontage road. No sidewalks are present, though there is a foot-worn pathway between Balcones Woods Drive and a Capital Metro bus stop near the second downstream driveway. The bus stop is identified only by a small route sign; no other pedestrian treatments or shelter is located here. The frontage road at this location appears to operate well, as there are few access points and no ramp traffic to contend with.



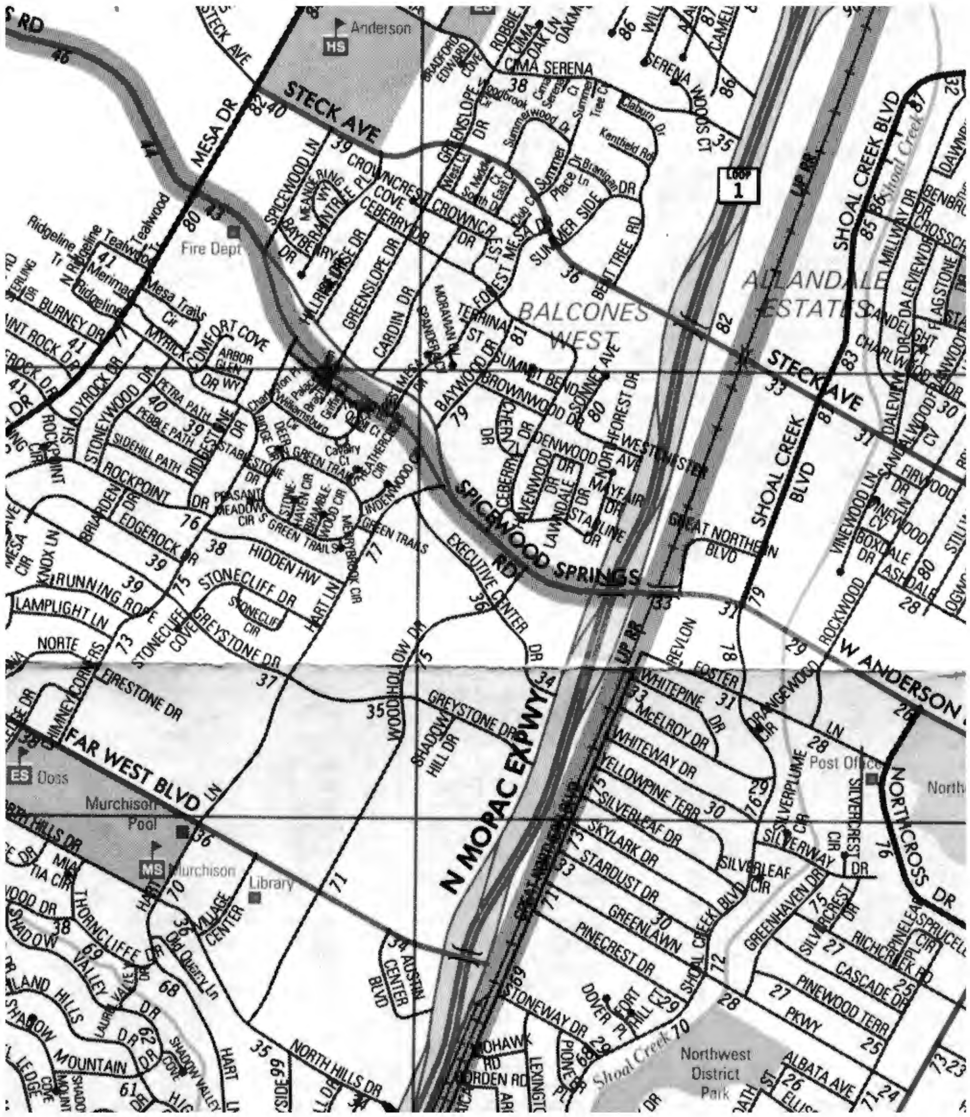
US 183 Northbound at Tweed Court/Riata Trace Parkway

This frontage road also exists alongside an elevated section of US 183. The exiting ramp gore marks the southern boundary of the study location and the entrance ramp gore marks the northern boundary. The frontage road has two lanes south of the exit ramp, and the ramp adds a third lane north of Tweed Court. A notable feature at this study location is the guide poles blocking exiting mainlane traffic from turning right onto Tweed Court, which is entirely within the ramp, gore area. Before the poles were installed, this site had been a persistent safety problem for the Texas Department of Transportation, because a highly limited sight distance around a horizontal curve prevents exiting vehicles from noticing through vehicles on the frontage road, and exiting vehicles desiring a right turn onto Tweed Court must decelerate very quickly while still within the ramp gore area and proceed across two more frontage road lanes. Other than Tweed Court, the only other access point to the frontage road within the study location is Riata Trace Parkway at an unsignalized T intersection. This four-lane roadway exhibits a wide median area separating westbound from eastbound traffic, and accesses a dense multifamily residential development and several high-tech office facilities before terminating at Parmer Lane. Such intense development occurring off the frontage road corridor with access provided by an internal collector-distributor roadway may prove a good example for future development policies and land use controls by TxDOT in conjunction with the governing municipality.



US 183 at Peyton Gin Road

Peyton Gin Road marks the southern boundary of this study location with an entrance ramp to US 183's elevated lanes delineating the northern boundary. Two driveways exist to separate businesses (currently Dell Factory Outlet and Oak Outlet, though both are soon to be vacated), with the second of these located just over 300 feet from the ramp gore area. Vehicles were witnessed exiting the second downstream driveway and accelerating rapidly to gain entry to the entrance ramp. Sidewalks are present along the entire frontage, and residential development is located east of the three-lane frontage road off Peyton Gin Road.



MoPac (Loop 1) Southbound at Capital of Texas Highway

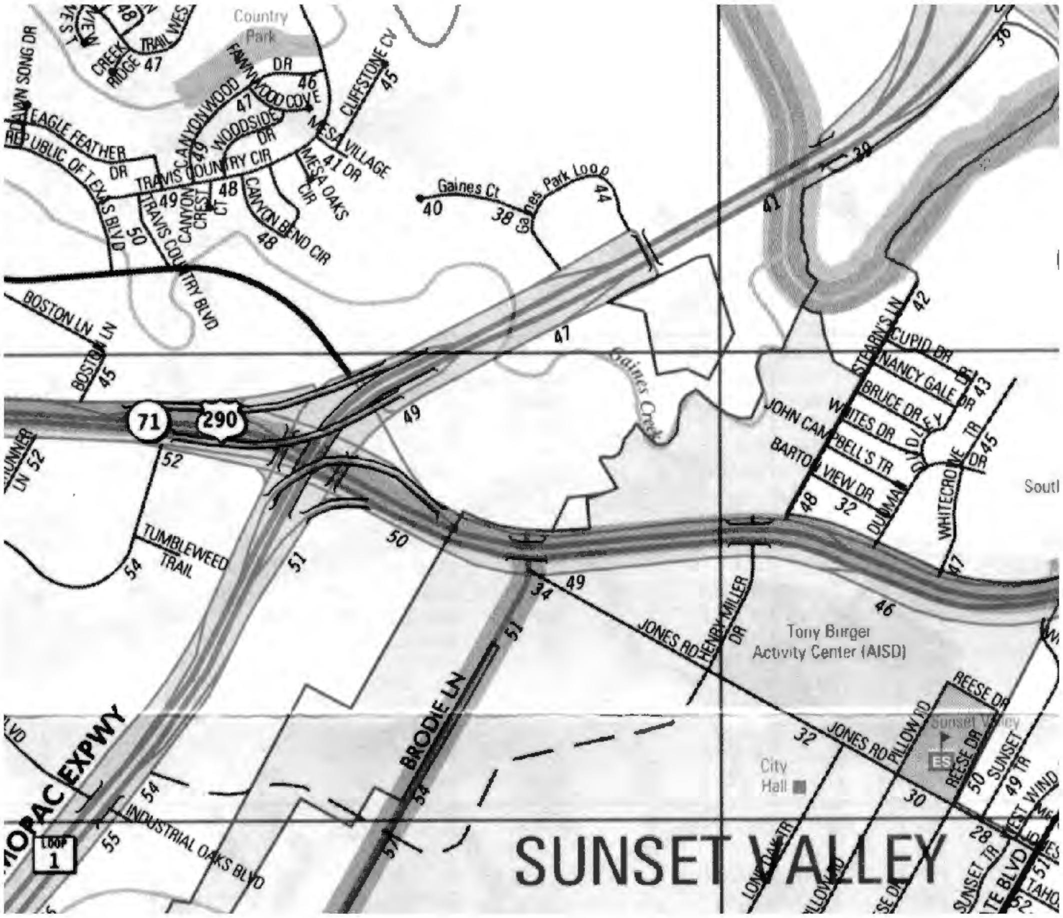
This section of MoPac exhibits depressed mainlanes with frontage roads on both sides at a higher elevation. The study location is bounded by the exiting ramp gore to the north and the entrance ramp gore to the south. No driveways provide access along the two- to three-lane frontage road length; it exists only to allow traffic northbound on MoPac to access Capital of Texas Highway. This unique situation is not because of any special access restrictions on abutting properties, but is created by the thin strip of land abutting the frontage road buffering it from adjacent developments. The University of Texas'Pickle Research Center is opposite the study location across the MoPac mainlanes, and the university owns this ribbon of property along the entire roadway frontage, forcing adjacent property owners to provide access via Capital of Texas Highway rather than the MoPac frontage road directly. Intense development exists off Capital of Texas Highway, where two hotels (Marriott Towne Place Suites and Extended Stay America) and an apartment complex occupy land near the MoPac intersection, and the Arboretum shopping center and several restaurants lie nearby, to the west. While the access restrictions at this location were most likely not intentional, it is another example (like Riata Trace Parkway) of successful development occurring not along the main freeway frontage but along an intersecting arterial.

MoPac (Loop 1) Southbound at Steck Avenue

Similar to the previous MoPac location with its depressed mainlanes, this study area is bounded on its southern end by MoPac's intersection with Steck Avenue and on the north by the entrance ramp gore to MoPac mainlanes. A potential safety problem is present here, because only 55 feet separate eastbound Steck's right turning lane from a driveway to Luby's Cafeteria. Vehicles traveling through the Steck intersection in the rightmost frontage road lane conflict with vehicles accessing the Luby's driveway. The Westpark office complex is located south of Luby's and accesses the three-lane frontage road via a single median-separated driveway. This particular study location provides yet another opportunity to exhibit an alternative access strategy: a roadway at the rear of the properties could provide access to each, because they are of similar depth from the MoPac right-of-way. This roadway, if it existed, would remove the need for a frontage road next to the mainlanes and vehicles could access either property by turning onto Steck Avenue (to the north) or Spicewood Springs (to the south).

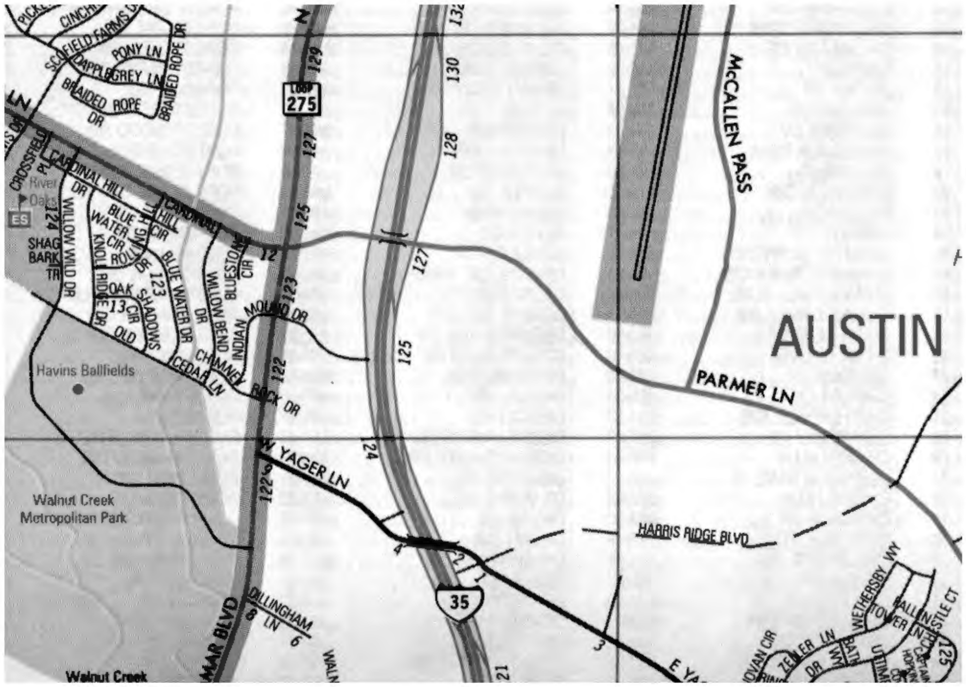
MoPac (Loop 1) Southbound at Anderson Lane/Spicewood Springs/Far West

Just south of the previous study location is this study area, which is bounded by the exiting ramp gore to the south and an entrance ramp gore to the north before an intersection with Far West Boulevard. In marked contrast to the previous example, however, this location includes nine driveways or roadways intersecting the frontage road, and two separate office complex properties each having driveways that provide access. Along with a restaurant and a gas station, this section of three-lane frontage road represents a more typical Texas location and a strip-type development pattern. Of note here are mitigation strategies that make the location more easily walkable and more attractive than other locations with similar access patterns. A strip of landscaping with grass and trees between the frontage road and adjacent development eases the visual impact of development on the corridor, and wide sidewalks and curb cuts within the landscaped region allow good pedestrian access to the residential areas along Far West Boulevard.



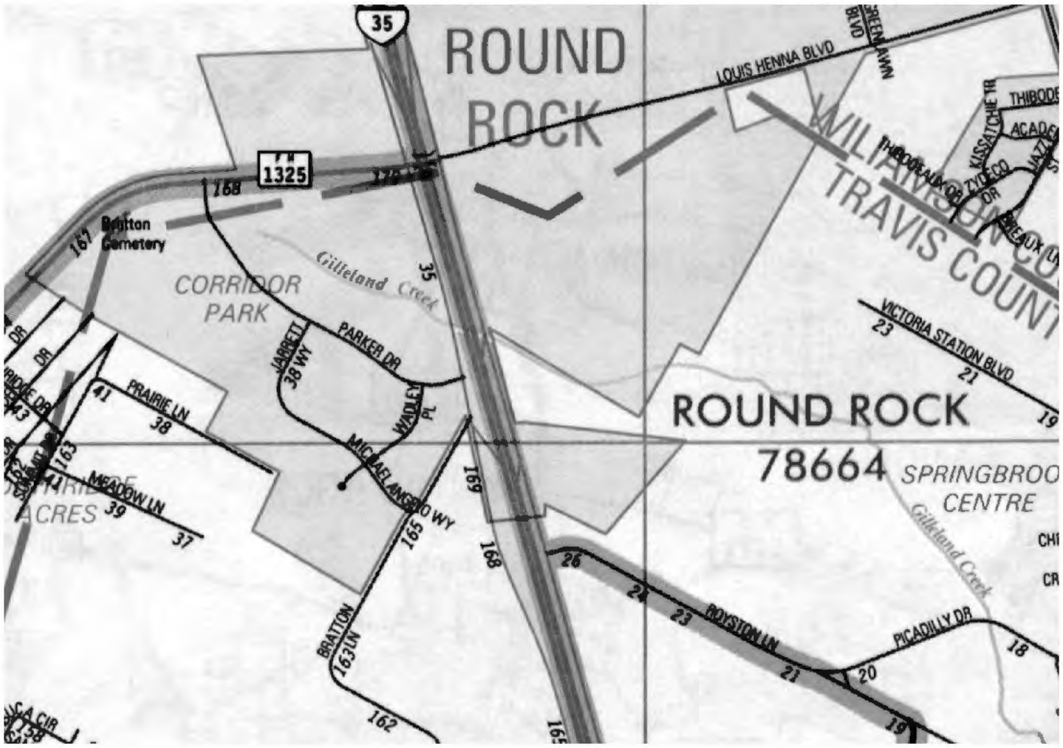
MoPac (Loop 1) Southbound at Gaines Ranch

This site was not included in the analysis, owing to lack of accident data, but it represents an interesting and unique example of frontage road provision. Unlike Austin freeways US 183 and I-35, MoPac does not utilize continuous frontage roads along a substantial portion of its length. Gaines Ranch is located in one of these non-frontage road sections south of Town Lake. The property owner actually reimbursed TxDOT for the entire construction cost of one exit ramp and a connecting frontage road to allow advantageous development of his land abutting MoPac. A large La Quinta hotel and an upscale residential development are located off Gaines Loop, a short collector roadway connecting to the frontage road at two points. This location is evidence of the pressure often put on TxDOT to provide access even when it does not make sense from a safety or operational efficiency standpoint.



Interstate 35 Northbound at Parmer Lane

Near the rapidly expanding Samsung Electronics campus in north Austin, this study location provides some interesting and unique properties. First, it is the only location of the twelve that does not have any access points along the frontage road between the study boundaries of the exit ramp and the intersection with Parmer. Off-roadway signage indicates a planned retail development along the frontage called Timberline Square, but a drainage ditch along the entire frontage would prevent direct access to the two- to three-lane frontage road without additional improvements. It is at present unclear whether or not the proposed development will access I-35's frontage road, Parmer Lane, or both. The eighty-fifth percentile speed of 61 mph (the highest measured at any study location) along with long queues at the signalized intersection are factors that may favor barring access to I-35 in this section of frontage.

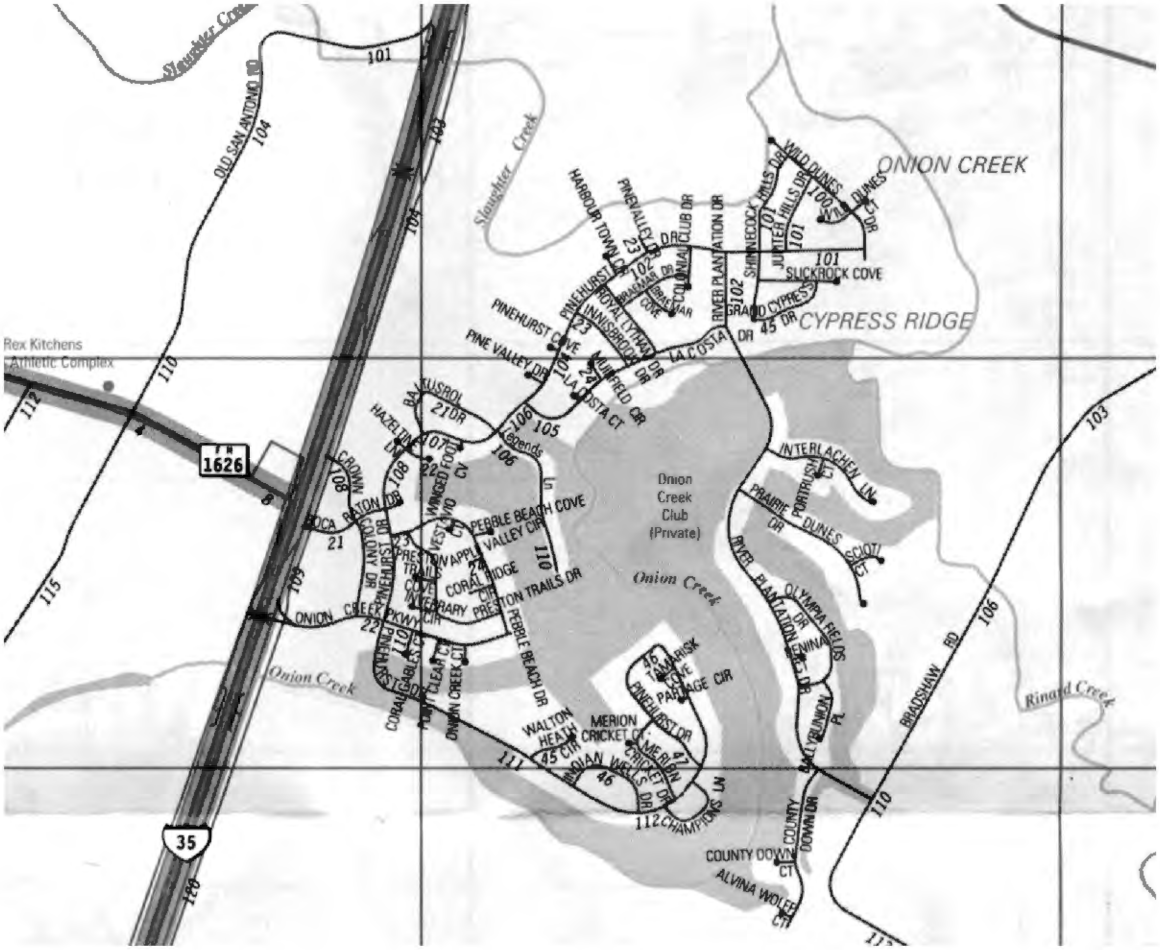


Interstate 35 Northbound at FM 1325

High-access density and limited delineation of driveway locations characterize this poorly access-controlled site in Round Rock, Austin's northern suburban neighbor. Reliable speed data could not be collected at this location, because it was impossible to locate the radar in a position that reflected off only frontage road vehicles and not mainlane traffic. Barely any of the driveways are well defined; a vehicle could literally drive across the dirt strip between the two- to three-lane frontage road and adjacent developments at nearly any point along the frontage. Even with this rather open access pattern, each property paved either one or two "formal" driveways to the frontage road, for a total of thirteen access points. At the study location's southern end, two roadways providing access to new development are located either completely within or very close to the exiting ramp gore location. This results in confusion for drivers who may exit the freeway near the development, but are then required to either make an unsafe turning movement across two frontage road lanes or exit the freeway nearly a mile upstream in order to access the roadways. A solution similar to the barrier poles at US 183 at Tweed Court may be necessary here, but it would have been advantageous to locate either the ramp or roadways elsewhere in order to prevent such a serious safety problem. More safety and congestion issues arise downstream nearer the intersection with FM 1325. Driveways to Applebees Restaurant, a Target store, and Jason's Deli are located so close to the signalized intersection as to interfere substantially with queuing traffic and increase the potential for both accidents and irritated drivers. This location has no real redeeming qualities; it may be a perfect example of what *not* to do when allowing development to access frontage roads.

Interstate 35 Northbound at 38 ½ Street

This location in downtown Austin near The University of Texas campus is another location where planners and designers can study what to avoid when providing access to frontage roads. The interstate mainlanes here are both elevated and depressed with regard to the frontage road, with two northbound lanes below (lower deck) and two northbound lanes above (upper deck). The unnecessarily wide and frequent driveways provide little to no channelization of traffic accessing this section of two- to three-lane frontage, as the driveways consume more than half the entire frontage length. The driveway to Taqueria Los Altos restaurant is located a mere 54 feet from the exiting ramp gore, presenting a safety problem. No sidewalks are present, though bus stop locations are located along the frontage. And the same business, an adult video store, occupies fully four driveways when one clearly would be sufficient.



Interstate 35 Northbound at Onion Creek Parkway

Strip-type development along this study location is similar to that of other sites in Austin's developing suburban fringe. Onion Creek Parkway is the main collector roadway accessing a large, upscale, single-family residential development east of the Interstate, and is the southern boundary of the study area. The entrance ramp gore to I-35 mainlanes forms the northern study boundary. Businesses along the frontage mainly service residents of this neighborhood. Two gas stations, a small strip center with a dry cleaner and realtor, and another dry cleaners are located here, all with separate driveways. In addition, a single-family residence several hundred feet off the frontage road has a driveway here as its sole means of public roadway access, and there are several currently vacant plats of land slated for development. The two-lane frontage road operates without much incident, since the current low-density developments contribute little traffic. But as Austin urbanizes, and the vacant plats of land are developed with a higher intensity than exists currently, this could be another frontage road trouble spot in five to ten years, if current access patterns continue.

D.2 CASE STUDY METHODOLOGY

Access density was calculated by dividing the distance along the frontage road where driveways and roadways were encountered by the total frontage distance within the study boundary. This variable ranged from zero in the case of I-35 at Parmer Lane to 0.52 along I-35 at 38 ½ Street.

Incidence of speeding was estimated by first obtaining an 85th percentile speed from the spot speed measurements collected (Table 4.2), and dividing it by the speed limit posted at each site. Values above 1.0 represent locations where speeding took place regularly, while values below 1.0 represent sites where vehicles typically traveled at speeds below the posted limit.

Variance of speeds was calculated as well, using the well-known variance formula: $\sigma^2_{speed} = \sum_{i=1}^{N} \frac{(speed_i - speed_{avg})}{N-1}$. High variances indicate that observed vehicles traveled at a variety of different speeds, while lower variances indicate that vehicles that traveled closer to the mean corridor speed.

Vehicle miles traveled (VMT) represents an estimate of total vehicle miles traveled through each study section during the 48 hours of vehicular counts. It is calculated by multiplying the vehicle count by the frontage distance in each study area.

Accidents and **Injuries** represent the number of accidents and injuries occurring during the years 1996-1999 within each study area on the frontage roads only. No fatalities occurred in any of the sections studied during this three-year time frame.

APPENDIX E
Cost Computation Methodology

Appendix E: Cost Computation Methodology

E.1 Methodology

Construction Costs were determined by using internal TxDOT documents regarding the costs of various recent freeway projects. Those costs were compiled and averaged, and to those averages were added the costs of utilities and drainage as described in Chapter 7. Following are the costs of construction not including the costs of drainage or utilities, and before costs were distributed among new usable lane miles, as well as the methodology used to obtain those costs.

Items Included in Construction Cost

- Pavement striping (paint and raised buttons)

ITEMS INCLUDED IN MAIN LANE COST ONLY

- Concrete or asphalt quantities corresponding to the depth shown on the typical section
- Metal beam guard fence
- Quad guards

ITEMS INCLUDED IN FRONTAGE ROAD LANE COST ONLY

- Concrete or asphalt quantities corresponding to the depth shown on the typical section
- Turnarounds
- Driveways
- Mailboxes of adjacent landowners
- Curbs

Items Not Included in Any Costs (construction or other)

- Anything related to landscaping, (seeds, fertilizer, vegetation, watering)
- Anything related to signs and supports for signs
- Anything related to signal lights (conduits, conductors, ground boxes, supports)

- Anything related to drainage (culverts, pipes, inlets, manholes)
- Preparation of ROW
- Anything temporary (barricades, detour signs, sediment control fence)
- Detour pavement striping
- Retaining walls

Note: These items were not included in any of the cost figures because they are not attributable to lane construction. **Essentially, anything that could not be counted on a per-mile basis was not considered in costs estimated here.** These non-mile-based contributions were significant: compared to entire project cost, they ranged from 25 - 29%, except for the US 83 project that was 47%. Note that the Spur 330 project required a lot of drainage, signing, barricade, and electrical work (for signals) that was removed.

<u>I-45</u>

Location: North of Houston and just south of Conroe, where the West Folk San Jacinto River crosses I-45
Main lane materials: 15” continuously reinforced concrete pavement (CRCP)
1” asphalt stabilized base (ASB) bond breaker
6” Portland cement treated stabilized base (PCTB)
6” lime treated subgrade (LTS)

Frontage road lane materials: 10” continuously reinforced concrete pavement (CRCP)
1” asphalt stabilized base (ASB) bond breaker
6” Portland cement treated stabilized base (PCTB)
6” lime treated subgrade (LTS)

<u>US 83</u>

Location: South Texas, around McAllen

Main lane materials: 20” flex base

Frontage road lane materials: 14” flex base
12” LTS

<u>Spur 330</u>

Location: Just east of Houston, off of I-10
Main lane materials: 13” CRCP

1” ASB bond breaker

6” PCTB

6” LTS

US 59

Location: Near Houston
Main lane materials: 13” CRCP

1” ASB bond breaker

6” PCTB

6” LTS

County: Montgomery

Project Length: 4.154 miles

Scope: US 59 N -- Widening of a freeway facility.

Adding shoulders and reconstructing 4 main lanes throughout length of project.

No new frontage roads were constructed.

	Miles	No. of Equiv. Lanes	Equivalent Lane-miles	Constructed Lane-miles	Constructed Ratio
Main lanes	4.039	**	13.007	13.007	1.00
Frontage Rd	0.000	0	0.000	0.000	0.00
Bridge	0.115	7	0.805	0.805	---
Total	4.154		13.812	13.812	

		Project	Main lanes	Frontage Road	Bridge
Construction	$	6,980,614.55	6,980,614.55	0.00	2,249,796.08
Other	$	0.00	0.00	0.00	
TOTAL		9,230,410.63	6,980,614.55	0.00	2,249,796.08
% of TOTAL COST			0.76	0.00	0.24
New Usable Lanes Constructed			**	0	4
New Usable Lane-miles			6.90	0	0
COST PER NEW LANE-MILE		**$**	**1,012,405.78**	**---**	**4,890,861.04**

County: Montgomery

Project Length: 1.57 miles

Scope: I-45 -- Widening of a freeway facility from 4 to 8 main lanes and 4 to 6 frontage road lanes

New frontage roads were constructed for 0.38 (of the 1.15) centerline miles.

New main lanes were constructed for the whole project.

	Constructed No. of Miles	No. of Equiv. Lanes	Equivalent Lane-miles	Constructed Lane-miles	Constructed Ratio
Main lanes	1.15	14	16.04	16.04	0.88
Frontage Rd	0.38	6	2.28	2.28	0.12
Bridge	0.43	14	5.96	5.96	---
Total	1.57		24.29	24.29	

		Project	Main lanes	Frontage Road	Bridge
Construction	$	3,030,233.72	2,653,190.89	377,042.83	8,969,693.36
Other	$	1,284,316.00	991,730.00	292,586.00	
TOTAL		13,284,243.08	3,644,920.89	669,628.83	8,969,693.36
% of TOTAL COST			0.27	0.05	0.68
New Usable Lanes Constructed			8.00	6.00	8
New Usable Lane-miles			9.17	2.28	3
COST PER NEW LANE-MILE	**$**		**397,569.90**	**293,696.86**	**2,631,952.28**

County: Hidalgo

Project Length: 5.5 miles

Scope: US 83 -- Widening of freeway facility from 0 (or 2) to 4 frontage road lanes and adding mainlanes or shoulders to mainlanes.

	Miles	No. of Equiv. Lanes	Equivalent Lane-miles	Constructed Lane-miles	Constructed Ratio
Main lanes	5.313	**	34.19	34.2	0.67

Frontage Rd	5.313	**	17.12	17.12	0.33
Bridge	0.187	8	1.50	1.50	---
Total	5.500		52.8	52.80	

		Project	Main lanes	Frontage Road	Bridge
Construction	$	12,627,927.11	8,414,758.25	4,213,168.86	5,997,510.29
Other	$	2,616,300.60	1,943,872.70	672,427.90	
TOTAL		21,241,738.00	10,358,630.95	4,885,596.76	5,997,510.29
% of TOTAL COST			0.49	0.23	0.28
New Usable Lanes Constructed			**	**	6
New Usable Lane-miles			22.62	10.52	1
COST PER NEW LANE-MILE		$	**458,031.75**	**464,423.72**	**5,345,374.59**

County: Harris

Project Length: 0.951 miles

Scope: Spur 330 -- Conversion of a non-freeway facility to a freeway facility.

Adding shoulders and new main lanes throughout length of project.

No new frontage roads were constructed.

	Miles	No. of Equiv. Lanes	Equivalent Lane-miles	Constructed Lane-miles	Constructed Ratio
Main lanes	0.935	**	8.692	8.692	1.00
Frontage Rd	0.000	0	0.000	0.000	0.00
Bridge	0.016	8	0.128	0.128	---
Total	0.951		8.820	8.820	

		Project	Main lanes	Frontage Road	Bridge
Construction	$	2,681,143.80	2,681,143.80	0.00	585,394.99
Other	$	0.00	0.00	0.00	
TOTAL		3,266,538.79	2,681,143.80	0.00	585,394.99
% of TOTAL COST			0.82	0.00	0.18
New Usable Lanes Constructed			**	0	8
New Usable Lane-miles			5.673	0	0.128

COST PER NEW LANE-MILE	$	**472,574.42**	---	**4,573,398.36**

Utility Costs: based on a six percent of total construction costs assumption. Doug Woodall gave us a range of 3-13 percent. Costs are distributed to usable lane miles under the assumption that equiv lane miles affects costs of moving utilities.

Table E1: Construction Costs, subtotals

		Construction+Utility	Construction+Utility+Drainage
I-45	Mainlanes	477,477	620720.10
I-45	Frontage Rd	339,379	441192.70
US 83	Main Lanes	497,453	646688.90
US 83	Frontage Rd	506,868	658928.40
Spur 330	Main Lanes	508,850	661505.00
US 59	Main Lanes	1,096,683	1425687.90

Access costs were determined based upon information obtained from Westerfield (1993) and Galleg (1996). The costs listed in the table below came from the Travis Central Appraisal District, and were then updated to year 2001 dollars.

Table E2: Access Cost Data

CASE #	COMPEN'93	2001 $	FRONT	COST/LIN.FT.
1	26898.82	32547.5722	70	464.97
2	1953.24	2363.4204	78	30.30
3	67658.36	81866.6156	188.26	434.86
4	667.05	807.13	149.95	5.38
5	21770.74	26342.5954	52.98	497.22
6	29216.2	35351.602	372.94	94.79
7	670.89	811.78	904.61	0.90
8	39902.85	48282.4485	52.98	911.33
9	17979.41	21755.0861	52	418.37
10	670.51	811.3171	120	6.76
11	52332.36	63322.1556	229.5	275.91
12	70120.48	84845.7808	182	466.19
13	11389.68	13781.5128	130	106.01
14	342210.9	414075.189	171	2421.49

15	682820.7	826213.047	490	1686.15
16	18014.71	21797.7991	176.44	123.54
17	0	0	678.14	0
18	6797.98	8225.56	154.1	53.38
19	614117.58	743082.2718	349.14	2128.32
20	65768.53	79579.9213	91	874.50
21	0	0	351	0

AVERAGE		2505862.80	5044.04	496.80
STANDARD DEV				715.19

Consumer Price Index

Table E3: Consumer Price Index Data

Year	CPI
1990	130.7
1991	136.2
1992	140.3
1993	144.5
1994	148.2
1995	152.4
1996	156.9
1997	160.5
1998	163.0
1999	166.6
2000	172.2
2001	175.0

The Consumer Price Index (CPI) figures were provided by the Bureau of Labor Statistics. The 2001 figure in the above table represents the CPI as of March 1, 2001. That number has since changed. CPI can be utilized by dividing the index in the current year by the CPI in the year compared. For purposes of this research, the 2001 CPI was divided by the 1993 CPI. This operation yielded the multiplier $1.21—meaning that $1.00 in 1993 is equal to $1.21 in 2001.

E.2 Results

The following assumptions were used for all cost comparisons.

Facility Upgrade Scenarios **Type A**

Scenario 1	Mainlanes	2	2	2	2	2
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	0	0	0	0	0
	Access (linear feet)	10,560	10,560	10,560	10,560	10,560
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$6,251,162	$1,126,077	6301162	1176077	$6,401,162
	Total Cost (hi)	$10,781,228	$7,589,574	$10,931,228	$7,739,574	$11,231,228

Assumptions

All cost figures expressed in 2001 dollars

Lane costs: Include construction, utility, and drainage for at-grade facilities

and are expressed per usable lane mile

	Lo	Hi
Mainlane	$477,477	$1,096,683
Frontage	$339,379	$506,867
ROW acquisition, per square ft, rural	$0.15	$0.30
ROW acquisition, per square ft, urban	$5.00	$20.00
Rural access purchase, per linear foot	$11.47	$496.80
Urban access purchase, per linear foot	$496.80	$799.04
Interchange cost	$100,000	$300,000

Scenario 2	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	316800	316800	316800	316800	316800
	Access (linear feet)	10,560	10,560	10,560	10,560	10,560
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$8,790,116	$2,128,551	$8,840,116	$2,178,551	$8,940,116
	Total Cost (hi)	$19,310,594	$9,877,980	$19,460,594	$10,027,980	$19,760,594

Scenario 3	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	316800	316800	316800	316800	316800
	Access (linear feet)	10,560	10,560	10,560	10,560	10,560
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$8,790,116	$2,128,551	$8,840,116	$2,178,551	$8,940,116
	Total Cost (hi)	$19,310,594	$9,877,980	$19,460,594	$10,027,980	$19,760,594

Facility Upgrade Scenarios		**Type B**				
Scenario 1	Mainlanes	2	2	2	2	2
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	422400	422400	422400	422400	422400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$4,474,470	$2,425,830	4524470	2475830	$4,624,470
	Total Cost (hi)	$12,818,834	$4,497,554	$12,968,834	$4,647,554	$13,268,834
Scenario 2	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	739200	739200	739200	739200	739200
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$7,013,424	$3,428,304	$7,063,424	$3,478,304	$7,163,424
	Total Cost (hi)	$21,348,200	$6,785,960	$21,498,200	$6,935,960	$21,798,200
Scenario 3	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	6	6	6	6	6
	ROW Acquisition (sq ft)	844800	844800	844800	844800	844800
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$8,220,182	$4,122,902	$8,270,182	$4,172,902	$8,370,182
	Total Cost (hi)	$24,473,934	$7,831,374	$24,623,934	$7,981,374	$24,923,934

Facility Upgrade Scenarios **Type C**

Scenario 1	Mainlanes	0	0	0	0	0
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	422400	422400	422400	422400	422400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$3,519,516	$1,470,876	3569516	1520876	$3,669,516
	Total Cost (hi)	$10,625,468	$2,304,188	$10,775,468	$2,454,188	$11,075,468
Scenario 2	Mainlanes	2	2	2	2	2
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	422400	422400	422400	422400	422400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$4,474,470	$2,425,830	$4,524,470	$2,475,830	$4,624,470
	Total Cost (hi)	$12,818,834	$4,497,554	$12,968,834	$4,647,554	$13,268,834
Scenario 3	Mainlanes	2	2	2	2	2
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	422400	422400	422400	422400	422400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$4,474,470	$2,425,830	$4,524,470	$2,475,830	$4,624,470
	Total Cost (hi)	$12,818,834	$4,497,554	$12,968,834	$4,647,554	$13,268,834

Full Build-out Facility Comparisons **Type A**

Scenario 1	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	792000	1161600	792000	1161600	792000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$5,919,908	$2,134,148	5969908	2184148	$6,069,908
	Total Cost (hi)	$20,376,732	$4,885,212	$20,526,732	$5,035,212	$20,826,732
Scenario 2	Mainlanes	6	6	6	6	6
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	1056000	1320000	1056000	1320000	1056000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$8,194,862	$3,112,862	$8,244,862	$3,162,862	$8,344,862
	Total Cost (hi)	$27,850,098	$7,126,098	$28,000,098	$7,276,098	$28,300,098
Scenario 3	Mainlanes	6	6	6	6	6
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	1056000	1320000	1056000	1320000	1056000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$8,194,862	$3,112,862	$8,244,862	$3,162,862	$8,344,862
	Total Cost (hi)	$27,850,098	$7,126,098	$28,000,098	$7,276,098	$28,300,098
Scenario 4	Mainlanes	8	8	8	8	8

	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	1584000	2112000	1584000	2112000	1584000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$11,789,816	$4,186,616	$11,839,816	$4,236,616	$11,939,816
	Total Cost (hi)	$40,603,464	$9,557,064	$40,753,464	$9,707,064	$41,053,464
Scenario 5	Mainlanes	10	10	10	10	10
	Frontage Road Lanes	0	0	0	0	0
	ROW Acquisition (sq ft)	1848000	2112000	1848000	2112000	1848000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$14,064,770	$5,141,570	$14,114,770	$5,191,570	$14,214,770
	Total Cost (hi)	$48,076,830	$11,750,430	$48,226,830	$11,900,430	$48,526,830

Full Build-out Facility Comparisons **Type B**

Scenario 1	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	1478400	2112000	1478400	2112000	1478400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$10,709,424	$3,634,224	10759424	3684224	$10,859,424
	Total Cost (hi)	$36,132,200	$7,197,800	$36,282,200	$7,347,800	$36,582,200
Scenario 2	Mainlanes	6	6	6	6	6
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	2112000	2112000	2112000	2112000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$14,832,378	$4,589,178	$14,882,378	$4,639,178	$14,982,378
	Total Cost (hi)	$50,997,566	$9,391,166	$51,147,566	$9,541,166	$51,447,566
Scenario 3	Mainlanes	6	6	6	6	6
	Frontage Road Lanes	6	6	6	6	6
	ROW Acquisition (sq ft)	2112000	2112000	2112000	2112000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$15,511,136	$5,267,936	$15,561,136	$5,317,936	$15,661,136
	Total Cost (hi)	$52,011,300	$10,404,900	$52,161,300	$10,554,900	$52,461,300
Scenario 4	Mainlanes	8	8	8	8	8

	Frontage Road Lanes	6	6	6	6	6
	ROW Acquisition (sq ft)	2112000	2112000	2112000	2112000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$16,466,090	$6,222,890	$16,516,090	$6,272,890	$16,616,090
	Total Cost (hi)	$54,204,666	$12,598,266	$54,354,666	$12,748,266	$54,654,666
Scenario 5	Mainlanes	10	10	10	10	10
	Frontage Road Lanes	6	6	6	6	6
	ROW Acquisition (sq ft)	2112000	2376000	2112000	2376000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$17,421,044	$7,217,444	$17,471,044	$7,267,444	$17,571,044
	Total Cost (hi)	$56,398,032	$14,870,832	$56,548,032	$15,020,832	$56,848,032

Full Build-out Facility Comparisons **Type C**

Scenario 1 Not applicable

Scenario 2	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	1478400	2112000	1478400	2112000	1478400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$10,709,424	$3,634,224	$10,759,424	$3,684,224	$10,859,424
	Total Cost (hi)	$36,132,200	$7,197,800	$36,282,200	$17,274,200	$36,582,200
Scenario 3	Mainlanes	4	4	4	4	4
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	1478400	2112000	1478400	2112000	1478400
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$10,709,424	$3,634,224	$10,759,424	$3,684,224	$10,859,424
	Total Cost (hi)	$36,132,200	$7,197,800	$36,282,200	$7,347,800	$36,582,200
Scenario 4	Mainlanes	6	6	6	6	6
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	2112000	2112000	2112000	2112000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$14,832,378	$4,589,178	$14,882,378	$4,639,178	$14,982,378
	Total Cost (hi)	$50,997,566	$9,391,166	$51,147,566	$9,541,166	$51,447,566

Scenario 5	Mainlanes	8	8	8	8	8
	Frontage Road Lanes	4	4	4	4	4
	ROW Acquisition (sq ft)	2112000	2112000	2112000	2112000	2112000
	Access (linear feet)	0	0	0	0	0
	Interchanges per mile	0.5	0.5	1	1	2
	Urban/Rural	Urban	Rural	Urban	Rural	Urban
	Total Cost (lo)	$15,787,332	$5,544,132	$15,837,332	$5,594,132	$15,937,332
	Total Cost (hi)	$53,190,932	$11,584,532	$53,340,932	$11,734,532	$53,640,932

APPENDIX F
Recent TxDOT Policy Changes

Appendix F: Recent TxDOT Policy Changes

Minute Order 108544

The Texas Department of Transportation (department) is committed to following its frontage road rules in Title 43 Texas Administrative Code (TAC) §15.54; however, further clarification would aid their full implementation for new controlled access highways.

It is the policy of the department to design new location relief routes to function as conduits through populated areas without adversely impacting the through traffic or local traffic.

Since access points lead to congestion on the main lanes of controlled access highways, sound engineering practices dictate that a controlled access highway, such as a relief route on the Texas Trunk System, should be designed with as few access points as feasible.

The department plans to develop all relief routes designated in the future as full controlled access facilities, to the extent possible.

Interchanges are to be spaced to preserve the capacity on the main lanes and industrial and local development is to be limited to the adjacent on and off-system roadway network.

New controlled access highways are to be developed without frontage roads whenever feasible.

During and after the planning stage, the need for frontage roads must be fully justified in accordance with TAC §15.54 (d), and when it is the only feasible alternative after all other alternatives have been considered.

IT IS THEREFORE ORDERED by the Texas Transportation Commission (commission) that all new location relief routes on the state highway system shall be full controlled access.

IT IS FURTHER ORDERED by the commission that the executive director will minimize the construction of any frontage roads along newly designated controlled access highways in Texas, consistent with sound engineering judgment and with the criteria outlined in 43 TAC §15.54.

IT IS UNDERSTOOD that this order will apply to projects with Long-Range Project Status and, whenever possible, to projects being developed in Priority 2.

IT IS FURTHER ORDERED that the existing rules in §15.54 (d) be reviewed and modified as necessary to better define this policy.

Submitted and reviewed by:	Recommended by:
Director, Transportation Planning and Programming Division	Executive Director

108544	JUN 28 01
Minute Number	Date Passed

Minute Order 108545

Transportation Code, §201.103 empowers the Texas Transportation Commission (commission) to plan and make policies for the location, construction, and maintenance of a comprehensive system of state highways and public roads.

Transportation Code, §203.002 authorizes the commission to lay out, construct, maintain, and operate a modern state highway system, with an emphasis on the construction of controlled access highways.

Transportation Code, §203.052 authorizes the commission to acquire an interest in real property that the commission determines is necessary or convenient to a state highway, including property necessary or convenient to protect a state highway or to accomplish any other purpose related to the location, construction, improvement, maintenance, beautification, preservation, or operation of a state highway.

Transportation Code, §202.021 authorizes the commission to recommend to the governor the sale of any interest in real property, including a highway right of way that was acquired for a highway purpose and is no longer needed for that purpose. The commission is authorized to sell surplus land and improvements to a local government under this section for the fair value of the land and improvements.

Construction of controlled access highways by the Texas Department of Transportation (department) may bisect local roadways, thereby disrupting traffic circulation and negatively affecting mobility on local road systems and on state highways located within the jurisdictional boundaries of the local government. Projects to connect local roadways are then necessary to maintain local circulation and minimize local use of the through highway.

Projects to connect local roadways are also necessary to facilitate the replacement of two-way frontage roads with one-way frontage roads, as traffic that can no longer use the frontage road may not have a nearby alternate route. Construction of these projects would reduce the need to construct and maintain additional interchanges or frontage roads.

The commission finds that it is in the public interest to provide for local traffic circulation that is disrupted by an improvement to the state highway system, and that the acquisition of real property for purposes of constructing projects to restore local traffic circulation is necessary and convenient to provide for the efficient operation and maintenance of state highways.

The commission finds that real property acquired for a project to restore local traffic circulation will be surplus property that is no longer needed for state highway system purposes after the completion of the project, that the improved roadway will be part of the local road system, and that the surplus property should be transferred to the affected local government.

The commission also finds that the local government may provide fair value for the transferred property by assuming responsibility for the costs of operating and maintaining the roadway after completion and by assuming liability for the roadway.

IT IS THEREFORE ORDERED by the commission that the department work with local governments during the development of controlled access highway projects to determine whether the inclusion of projects to connect local roadways is in the best interest of the public, considering the safety and efficiency of the overall design for the state highway system and the need to minimize the disruption to local traffic circulation.

IT IS FURTHER ORDERED that the department obtain project specific commission approval before entering into an agreement to connect local roadways as part of a state highway improvement project.

Submitted and reviewed by: Recommended by:

Director, Transportation Planning and Programming Division

Executive Director

108544	JUN 28 01
Minute Number	Date Passed