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16. Abstract

This research project investigates frontage roads as an element of limited-access highway design. The discussion in this paper reviews legal statutes affecting public access to roadways, summarizes studies on access-right valuation, and considers a variety of operational issues associated with frontage roads. Ongoing, additional investigative efforts regarding policies and practices in other states, construction costs, and design comparisons aim to produce a comprehensive assessment of the benefits and costs entailed by frontage road provision. The ultimate results of this two-year project seek to enable the Texas Department of Transportation 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.

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FRONTAGE ROADS IN TEXAS: LEGAL ISSUES, OPERATIONAL ISSUES, AND LAND USE DISTINCTIONS

by

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

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CHAPTER 1. INTRODUCTION AND PROJECT RESULTS TO DATE

This research project investigates frontage roads as an element of limited-access highway design. The discussion in this paper reviews legal statutes affecting public access to roadways, summarizes studies on access-right valuation, covers policies and attitudes of other state departments of transportation, compares demographic data alongside freeways with and without frontage roads, and considers a variety of operational issues associated with frontage roads. Ongoing, additional investigative efforts regarding construction costs and operational comparisons aim to produce a comprehensive assessment of the benefits and costs entailed by frontage road provision. 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). But the results of this work will enable the Texas Department of Transportation (TxDOT) to more 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 two-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? What design practices should TxDOT consider when frontage roads are built?

Presented in this first-year research report is a summary of the work undertaken and results obtained after one year. In this first year, an extensive literature review was conducted in order to ascertain the current legal attitudes and operational strategies involving frontage roads, not only in Texas, but also in other U.S. states. A survey was distributed to representatives of U.S. state departments of transportation to ascertain their positions on the issue of providing frontage roads, and to see where their policies differ from those of TxDOT. Operation of an initial network was simulated as a first step towards realistic treatment and analysis of such corridors' operations. An analysis of census and land use data along thirteen corridor pairs in Texas and other states in the southwest and midwest was undertaken to determine if there are any significant demographic and land use differences between corridors with frontage roads and those without. This report also includes a summary of additional work to be undertaken before the project is complete, and concludes by reviewing the project results obtained so far.

CHAPTER 2. LITERATURE REVIEW

2.1 INTRODUCTION

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. Planners and engineers wonder if the practice of building this form of access is something TxDOT should continue. The Texas Transportation Commission, a body which oversees the activities of TxDOT, decided that the new I-69 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). Yet TxDOT Director of Transportation Planning and Programming, Al Luedecke, notes that in the past continuous frontage roads were believed to be the cheapest way to provide access to otherwise landlocked properties (Greenberg, 1999). Unfortunately, it may be that such a policy has generated suburban sprawl in rural areas because of ease of access, and added to congestion in urban areas because of short-distance trips loading freeways when access ramps are closely spaced. Safety, cost, route circuity, and the undermining of mass transit modes may be additional reasons other states have avoided frontage road construction (Greenberg, 1999).

This research project investigates frontage roads as an element of limited-access highway design. The discussion in this paper reviews legal statutes affecting public access to roadways, summarizes studies on access-right valuation, and considers a variety of operational issues associated with frontage roads. Ongoing, additional investigative efforts regarding policies and practices in other states, construction costs, and design comparisons — together with this literature review — aim to produce a comprehensive assessment of the benefits and costs entailed by frontage-road provision. Optimal transportation policy will depend significantly on the present land uses alongside freeway corridors, local zoning designations, expectations of future development, public sentiment, presence of utilities in the right of way, and design constraints such as topography and network connections. But the results of this work seek to enable 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 following discussion presents findings from existing studies that help place this research project in its proper context. First, a summary of relevant laws in Texas and nationwide are presented, giving 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 eliminating 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 specific design recommendations from the literature provides some insight into the performance of these systems in different situations.

2.2 ACCESS RIGHT LAW

Laws and statutes associated with landowners' rights of access to public property are of central importance to the investigation of the impact of Texas frontage roads. Abutters' rights of access to public highways date back to English common law (FHWA, 1976). The system of interstate and defense highways appears to be the first system in the United States to limit access to private property abutting the public 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). As our nation's leaders began planning the Interstate system, they realized highways tended to encourage development to the point that the highway's capacity was reduced below its design or expected capacity (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 Public Roads Administration and 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 right-of-ways 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).

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 an 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 been controlled or limited. In these situations, it was deemed that abutting landowners were entitled to access rights. States had several choices for providing these rights of 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 (full depth), thus removing the property owner's right of access (AASHO, 1961). This second solution was used most often in urban and suburban areas, since 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 using these streets or alleys as frontage roads (AASHO, 1961).

Frontage roads have been used as a method of *alternate access* to the public property of highways when the highways are brought up to limited-access standards. In a 1944 California court case, *People v. Ricciardi*, 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, p. 53). However, in 1952 the California Supreme Court ruled in *Schnider v. State* that an abutter does not have right of access to a new right-of-way and its accompanying roadway.

In some instances in Texas, right-of-ways 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 frequent ramps (Lee, 2000, and 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. This research is investigating these impacts.

TxDOT design policy formally states that "(f)rontage roads may be included in the planning state … 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). The application of this policy will be under review by the research team during the coming year, for additional information on the costs and benefits of frontage road use.

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 as it fit within their budgets. In Texas, the state's Department of Highways 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).

Access to highways in new locations is also controversial. When construction of a highway divides a piece of property, leaving a small portion, that portion is called a remnant or remainder. For such cases, 1950s guidelines allowed a state to choose one of the following remedies: (1) build frontage roads to connect remainders to public highways, (2) provide continuity in a system of existing roads, or (3) reestablish connection between two portions of a property severed by the interstate highway (AASHO, 1961). Although courts have ruled that "no rights of access exist with respect to highways constructed as controlled-access facilities on entirely new locations," they often have sided with the property owners in cases where there was a combination of old and new right-of-ways used (Netherton, 1963).

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 eventually does connect to the new highway (*Teacher's Insurance and Annuity Association of America v. City of Wichita*, 221 Kan. 325, 559 P.2d 347). However, what is reasonable — in terms of distance or generalized cost to access the mainlanes — remains an issue.

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. 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 NM'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). Cases involving intermediate distances (between 0.25 and 1 mile) are somewhat evenly divided in their determinations of reasonable and unreasonable access (Vance, 1988). However, placing interchanges at separations of less than 1 mile is quite frequent, even for urban areas; some payment of access-related damages may be legally necessary for interchange separations that make operational sense — even in the presence of frontage roads.

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). Damages due to 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 taken into consideration 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 six-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," states that property owners hold an absolute right to cross the boundary line between their property and the highway at every point. In his 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 any time 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* (144 P.2d 799, 803, 1943) clearly defined that access was a property right, but it does 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 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.

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 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, so 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 benefit of property appreciation does not accrue to the state or, necessarily, its travelers, but it is a driving force in terms of landowner expectations and objectives (Woodall, 2000).

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 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.

Rather interestingly, when all access-related land-value changes are taken into account, some highway construction can create an overall economic loss to some types of land uses. For example, an Australian study of the South East Freeway in Brisbane determined that losses to homeowners due to impaired access and noise, vibration, and pollution of $10.1 million greatly exceeded the increase in property values owing to improved highway access of $2.3 million, for a net loss of 8.8 percent of the total residential property value of nearby properties (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 chances of facility upgrades producing benefit-to-cost ratios over 1.0 are probably much higher when nonresidential or low-density residential uses border a corridor.

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. Researchers also have found a marked decrease in property values adjacent to freeways under construction. Values tended to rise to preconstruction levels approximately five years after construction, and land values in some cities (especially those with strong controls on land use) kept rising past their preconstruction levels. 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 were generally positively correlated with the level of accessibility provided to the facility (Lewis et al., 1997). However, Lewis et al.'s work did not control for the presence or lack of frontage roads along the highway corridors.

Some researchers have created models to estimate the value of access rights. Westerfield (1993) estimated appraised value per square foot 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 offers an extension of Westerfield's work by adding an average vehicle trip ends variable obtained from ITE's *Trip Generation Manual* (Gallego, 1996). This new variable plus the land use variable predicted over 83 percent of the variability in the compensation paid for access rights (Gallego, 1996).

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.

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 Texas Highway Commission may do for access control but mentions that this "does not relieve the commission of their responsibility to justly compensate persons under other laws of the state for damages caused by the exercise of the commission's powers."

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 these 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. (1996) suggest some regulatory techniques supportive of access management; these are shown in Table 2.1.

Table 2.1 Regulatory techniques supporting access management

• Regulate driveway spacing, sight distance, and corner clearance
• Restrict number of driveways per existing parcel on developing corridors
• Increase minimum lot frontage along thoroughfares
• Encourage joint access and parking lot cross access
• Review lot splits to prevent access problems
• Regulate flat lots and lot width-to-depth
• Minimize commercial strip zoning and promote mixed use and flexible zoning
• Regulate private roads and require maintenance agreements
• Establish reverse frontage requirements for subdivision and residential lots
• Require measurement of building setbacks from future right-of-way line
• Promote unified circulation and parking plan

Source: Williams et al. (1996).

Highways with properly managed access and signalization have been found to carry up to 30 percent 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 due to 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.

In §203.052(b) (9), the Texas Transportation 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 Texas Transportation Commission may wish to acquire additional right-of-ways to shield the corridor from intense development or limit subdivision and driveway spacings so as to facilitate frontage road flows while enhancing safety.

AASHTO-listed techniques for corridor preservation include governmental 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 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, and (7) cooperation from local jurisdictions and the private sector can be obtained in protecting a corridor (AASHTO, 1990).

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 DOT (Stokes, 1995).

The 73rd Texas Legislature Committee on Transportation (1992) reviewed two polices related to right-of-way acquisition; these are the *enhanced value* deduction and the *early take* procedure; and both may assist in corridor preservation. An enhanced-value policy subtracts any value *added* to the remaining portion of a parcel due to highway construction from any amount awarded for the actual takings on the parcel. 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 the 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.

Bass et al. examined the feasibility of corridor preservation strategies in Texas in 1996. Their report indicated that, at that time thirty-eight U.S. states operated programs identifying corridors for protection or preservation, 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, negotiated agreements, protective buying, eminent domain, and donations. 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).

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. Below, a very different issue area for frontage roads is discussed; this concerns corridor operations and includes traffic safety and congestion.

2.5 FRONTAGE ROAD OPERATIONS

In analyzing freeway operations, a major issue for smooth flow is demand exceeding capacity. One alternative to expanding freeway capacity is use of frontage roads; such a design is also known as a *collector-distributor system*. Depending on the ramp sequence (e.g., off-ramps lying just upstream of on-ramps), such a system can substantially buffer freeway mainlanes from weaving maneuvers by moving such maneuvers to surface streets. However, it is not always the case that collector-distributor facilities present a solution for operational problems on freeways, and implementing them haphazardly (e.g., with too many ramps, too many intersections, too many driveways, insufficient right-of-way) can produce serious safety and flow problems on the frontage roads and mainlanes. In order to consider the application of a collector-distributor system, Barnes et al. (1992) recommend that sufficient right-of-ways exist, major cross-street spacing be generous, and existing intersection geometries be appropriate. Moreover, to ensure effective collector-distributor design, they also recommend that ramps have one entrance lane and two exit lanes, distances of 3,000 feet (915 meters) be provided between interchanges, and weaving section lengths on the frontage roads be at least 1,000 feet (305 meters) in length. In comparison with many Texas frontage-road corridors, these dimensions are sizable, which suggests the need for design changes — although these must be balanced by the expense of removing reasonable access.

Barnes et al. (1992) presented a case study on a section of I-610W where freeway flows improved, following introduction of a collector-distributor system, but the congestion *shifted* to loading and unloading points, such as intersections, creating even harsher consequences at several cross-street interchange locations. They recommended that when capacity-adding designs are to be implemented for limited-access highways, every case is unique and should be studied without imposing too many generalized assumptions. Relieving freeway mainlanes of congestion may seem an obvious objective, but simply shifting similar problems to other locations is probably not the solution.

2.5.1 Ramp Spacing and Weaving Maneuvers on Frontage Roads

Frontage roads offer some advantages for freeway operations. For example, they permit clear route-choice flexibility in cases of maintenance activities, accidents, or other emergencies. However, when ramps to the mainlanes are frequent, the resulting weaving sections negatively impact safety and flow (Fitzpatrick et al., 1996). Almost all weaving studies examine freeway operations, but Lewis et al. (1999) focused specifically on frontage roads and how ramp locations influence traffic operations and land development. Their findings indicated that decisions locating ramps in order to facilitate land development along roadway frontages, in fourteen Texas case-study locations, can 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 try to access driveways located close to ramps. In other cases, 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).

Several studies have been conducted to provide information on frontage road level of service and ramp spacing in order to evaluate which situations perform most efficiently. Indeed, many have assumed that frontage roads offer a solution to freeway congestion. In reality, frontage roads may very well contribute to freeway bottlenecking and interchange congestion. And the proper ramp spacing for various weaving operations plays an important role; proper spacing is likely to relieve some congestion on frontage roads, freeways, and their interchanges (Pinnel, 1963).

Fitzpatrick, Nowlin, and Parham (1996) have 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, as illustrated in Figures 2.1 and 2.2. Their work demonstrated that adequate spacing between entry and exit ramps leads to a higher operational efficiency on the frontage roads. Unfortunately, their work offers no comparisons to operations along freeway corridors designed with*out* frontage roads, which should be a long-term option for road authorities.

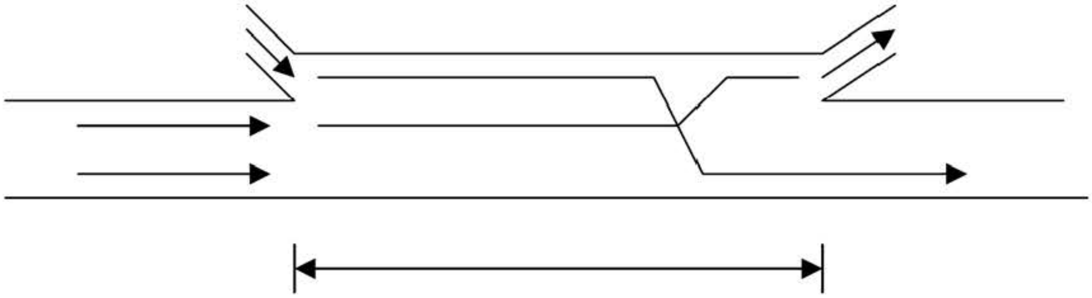

Figure 2.1 One-sided weaving maneuvers on frontage roads

When all weaving maneuvers take place on one side of a roadway, they are referred to as one-sided weaving maneuvers. Fitzpatrick et al. (1996) define frontage road one-sided weaving as occurring "when an exit ramp is followed by an entrance ramp connected by a continuous auxiliary lane" and there are no local land uses requiring direct access on the far side of the frontage road (Fitzpatrick, Nowlin, and Parham, 1996, p. 5).

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) clearly showed that weaving speeds fall as weaving volumes increase. Moreover, weaving sections below 656 feet (200 meters) in length may break down at relatively low traffic volumes, as compared to weaving sections longer than 656 feet (200 meters). Concerning the level of service, Fitzpatrick and Nowlin (1996a) noted that there appear to be specific, critical points at which weaving speeds drop most rapidly. For example, below 2,000 lane changes per hour (Lc/hr), weaving speeds appeared rather stable and levels of service ranged between A and B. Under these conditions, drivers can maneuver quite easily. At 2,000 Lc/hr, speed drops appear to be more significant. Between 2,000 and 4,000 Lc/hr, the simulated traffic appeared rather stable although constrained (because the ability to maneuver was restricted by other traffic), and the level of service was between C and D. At 4,000 Lc/hr, changes are even more pronounced. Beyond this level of weaving, traffic conditions were undesirable and unstable, weaving action was very difficult, and levels of service ranged between E and F.

Based on correlations between weaving speed and weaving lengths, Fitzpatrick and Nowlin (1996a) therefore recommended that minimum weaving distances of 984 feet (300 meters) be provided. If space is unavailable, then a minimum length of 656 feet (200 meters) should be provided (Fitzpatrick and Nowlin, 1996a).

One thing to be mentioned here is the difference between field data and NETSIM results. In NETSIM, vehicles accessing the entrance ramp did not begin weaving until they reached the weaving link; in contrast, the field data showed that weaving maneuvers actually started earlier (Fitzpatrick, Nowlin, and Parham, 1996). For simplicity and due to NETSIM limitations at the time the paper was written, it was assumed that weaving occurred at the weaving links. Fitzpatrick et al. did not address the safety issue in their work. Such behavior may lead to safer or less safe traffic conditions; it is not clear.

2.5.2 Two-Sided Weaving Maneuvers

The *Highway Capacity Manual* defines weaving as "the crossing of two or more traffic streams traveling in the same general direction along a significant length of highway without the aid of traffic control devices" (HCM, 1996, p. 4-2) — but it 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. This is a very common and complex maneuver for frontage roads, though it is not addressed in the *Highway Capacity Manual*.

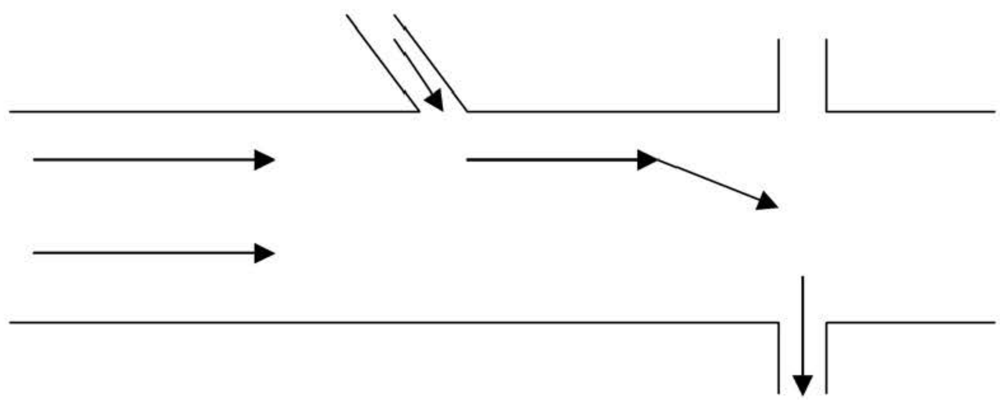

Figure 2.2 Two-sided weaving maneuvers on frontage roads

In studying these two-sided weaving sections, Fitzpatrick et al. (1996) modeled operations and levels of service (LOS) as functions of traffic volumes, turning percentages, ramp-to-intersection spacing, lane number, and design speeds. Based on both field data and simulation results using NETSIM, they concluded that two densities appear critical and correlated to the level of service: below 40 vehicles per lane-kilometer, traffic was unconstrained[1]; between 40 and 100 veh/lane-km, traffic was constrained but LOS was reasonable; and, above 100 veh/lane-km, LOS was undesirable.

Based on their field data, Fitzpatrick et al. (1996) noticed that most drivers required between 196.8 feet (60 meters) and 393.6 feet (120 meters) to weave from an exit ramp to the right-most lane on a two-lane frontage road. The field information also suggested that queues of 295.2 feet (90 meters) or more at the exit ramp had significant effects on drivers attempting to make the two-sided weaving operation. Based on these

[1]The term "unconstrained operations" is used by Fitzpatrick et al. to mean "free-flow to stable operations in which drivers can maneuver with relatively little impedance from other traffic and constrained operations represent stable operations in which drivers' ability to maneuver becomes more restricted due to other traffic" (1996, p. 8).

results, they recommended that a minimum of 492 feet (150 meters) of exit ramp-to-intersection spacing be provided.

Although simulation of operations is a very useful tool for analyzing road designs, Fitzpatrick et al. (1996) caution that engineering judgment and observation remain very important. This is because simulators are often limited in their behavioral assumptions. For example, NETSIM does not recognize use of turn bays, which can relieve congestion and improve levels of service; and NETSIM does not allow vehicles to begin merging until they reach the weaving link, when in fact many vehicles may commit earlier (see, e.g., Fitzpatrick, Nowlin, and Parham, 1996). Fitzpatrick et al.'s simulation models also assumed traffic at intersections to be relatively moderate and signal timing optimal, thereby minimizing delays, although this is not always the case in reality. Poor signalization can drastically impair the operational efficiency of roads (Fitzpatrick and Nowlin, 1996).

2.5.3 Ramp Metering

Ramp metering, as shown in Figure 2.3, is a form of entrance ramp control to enhance merging operations and freeway flows. Fitzpatrick et al. feel that its primary purpose is the maintenance of a "freeway's capacity to efficiently serve high priority urban traffic demands" (1996, p. 31). Ramp metering may be an effective strategy for eliminating short-trip traffic from close-to-congested mainlanes, particularly when access ramps are frequent, as in many Texas examples.

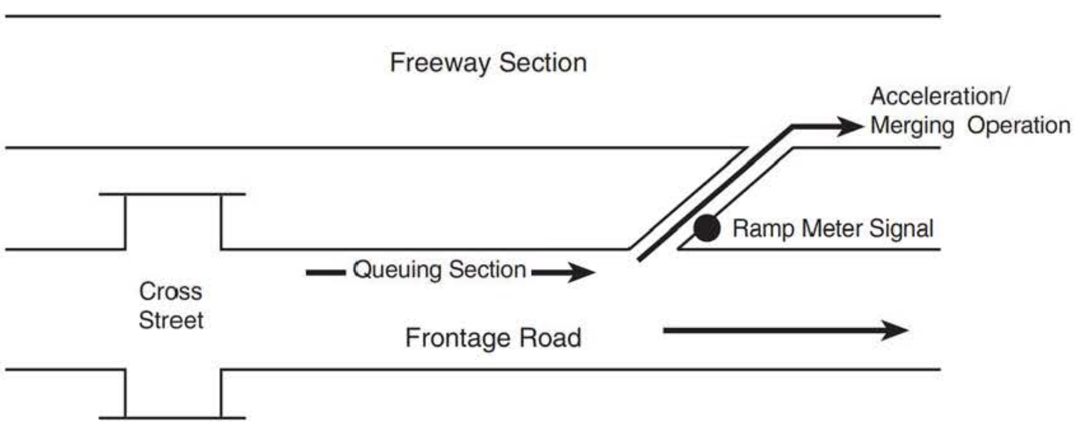

Figure 2.3 Example of ramp metering

If metering is used along frontage roads[2], proper spacing between freeway entrances and upstream intersections may become critical — in order to avoid congestion on frontage roads caused by inadequate storage for waiting vehicles. Insufficient spacing can inhibit both freeway and frontage road operations.

Assuming metering is in place, Sharma and Messer (1994) developed procedures to determine optimal spacing between intersections and entrance ramps. They studied

[2] Note that the ramp and the frontage road's meter signal should be located on the entrance ramp to avoid confusing frontage road drivers (Fitzpatrick, Nowlin, and Parham, 1996).

queue length as a function of entrance-ramp arrival rates, and distance requirements for freeway merging operations as functions of freeway speed. Defining the distance required to merge "as the distance from the ramp meter stop bar to the final merge point on the freeway," Fitzpatrick et al. (1996, p. 33) estimated both ramp distances available and attainable speeds for ramp signal offsets as functions of signal offsets. It was noted that, as ramp signal offsets increased, both the ramp distance available and the speed attainable increased.

2.5.4 Access Density

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 sixteen access points per mile (acc/mi) on one-way frontage roads or 20 acc/mi on two-way frontage roads.

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), much of which 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, 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 to the number allowed under the application of driveway restrictions to the original parcel rather than later subdivisions. The city facilitated this solution by allowing internal access only for several sites, and the limits were enforced 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 depend heavily 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. These options will be kept in mind through the remainder of this project.

2.6 SUMMARY

This review of literature related to frontage roads considers a variety of issues, including access-right valuation, access policies, and operations. Highlighted are reasonable access issues and their legal history, alternatives to frontage roads, corridor preservation, ramp location and spacing, merge lengths, and access-point densities. Overall, this review suggests that a wide variety of options are available to TxDOT for limiting access to and improving flows and safety along freeway corridors.

CHAPTER 3. DOT SURVEY SYNOPSIS

A survey of state DOTs was undertaken for this project. This survey was distributed on March 7 and 8, 2000, to contacts at thirty- two state departments of transportation nationwide.[3] The following states received a survey: Alaska, Alabama, Arkansas, California, Colorado, Florida, Georgia, Idaho, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, Virginia, Washington, West Virginia, and Wisconsin. To date, nineteen states have responded to the survey, giving a response rate of 59 percent.

3.1 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 1 (titled Responses to DOT Survey Questions). The respondents and their contact information can be found in Appendix 2 (DOT Survey Respondents by State). 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 3 (Frontage Road Policy by State). More of these documents will be added as they are received from the states.

3.2 SUMMARY OF RESPONSES

Responses to Question 1 fell into three categories: favorable, necessary, and negative. The responses from state DOT representatives of Massachusetts, Michigan, North Carolina, Pennsylvania, South Carolina, Virginia, and Vermont were considered to be favorable, because each of these representatives mentioned the benefits of frontage roads in their response. Their reasons included the ability of frontage roads to serve local traffic and keep it from congesting the freeway mainlanes, move traffic during accident 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.

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[3] 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.

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 like many cases in Texas, since many Montana freeways are built over right-of-ways that previously served local traffic, and so this state essentially was legally bound to continue serving such traffic via frontage roads.

State DOT 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 one another, or 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.

In response to Question 3, many states mentioned that they generally do not convert local roads or arterials into freeways. Because most of these states build all freeways on new locations, 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 I-69 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 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 that, 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.

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 the loss of access 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 arrangement 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 in several places that frontage road construction is sometimes paid for by entities other than CalTrans. 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 due to right-of-way or other constraints, Michigan'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. Also in Minnesota policy, X-configured interchanges are preferred to traditional, diamond interchanges, because they are believed to improve traffic flow on the mainlanes.

Official North Carolina policy mentions the cost analysis that to determines 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 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. 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 areas of the United States.

CHAPTER 4. CORRIDOR SIMULATION AND OBSERVATION

Simulation and observation of traffic flow in different networks is being pursued in order to compare a variety of corridor designs and development scenarios. The traffic-analysis software CORSIM (FHWA, 1999) is being used to analyze delay to different traveler types (e.g., local and through) using a frontage road with freeway network under different intensities of neighboring land uses; similar analyses will be conducted for a freeway-only scenario and for variations in interchange and ramp spacing and parcel-point (i.e., driveway) spacing.

4.1 DESIGN EXPERIMENT

4.1.1 Output or Dependent Variables

To understand when and why frontage roads made good sense, an evaluation of several output variables — including traffic delay, queue length, and speed — are crucial for the study. These factors reflect the performance level of both the local traffic (loading an arterial or collector network, both with and without frontage roads) and the freeway mainlanes. The use of CORSIM is particularly handy in determining these output factors (FHWA, 1999). Performance levels will be evaluated on a link-by-link basis, as well as on the network as a whole, both freeway and arterial networks. CORSIM also presents information on fuel consumption and emissions, such as CO, NO_x, and HC. The study is likely to address these environmental results in brief.

4.1.2 Input or Independent Variables

The input variables will be examined in several scenarios that differ by driveway spacings, interchange spacings, and traffic volume intensities for three specific cases: a freeway without frontage roads and with diamond interchanges, a freeway with frontage roads and X-type interchanges, and a freeway with frontage roads and diamond interchanges.

<u>Driveway and Interchange Spacings</u>

TxDOT 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 depend mainly on the sizes of connecting parcels. For this research, three specific driveway spacings are likely to be set at 50, 100, and 200 feet. Three major interchange spacings will be investigated; these are likely to be set at 0.5, 1.0, and 2.0 miles.

<u>Land Use Intensities</u>

Several scenarios of land use development, from strictly residential to highly commercial, will be investigated. The estimated input volume into CORSIM will be based on the ITE *Trip Generation Manual* (ITE, 1997). Each of the independent variables (i.e., driveway spacing, interchange spacing, and land use intensities) will be tested separately, keeping all other input variables fixed. Approximately sixty scenarios per network case will be displayed and tested.

Additional land use intensities and spacing scenarios will be built based on actual information from specific corridors (Austin's Loop 1 freeway, for example). These real-world corridor comparisons offer information on actual development patterns and corridor operations. Because they can be varied systematically, the hypothetical scenarios should prove very useful for proposing solutions to improve operations, on both frontage roads and the freeway mainlanes.

4.2 THE DESIGN NETWORKS

4.2.1 Description

Three network cases are to be evaluated in this research: 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 1 and 2 are extremely similar, except for interchange type. These two cases will use a six-lane freeway supplemented on both sides by a one-way, three-lane frontage road and six-lane secondary arterials located roughly 0.5 miles away. A six-lane underpass will connect the nonfreeway subnetwork on both sides. Each network will be subdivided into roughly eighteen different zones. CORSIM traffic volumes, including turn movements, will be 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, the traffic volumes across the total network will be the same for each of the three network cases. This is particularly important in the case of freeways without frontage roads, where driveways occur relatively far from freeway mainlanes, though trips may be generated by and attracted to the same areas of land.

4.2.2 Network Study Objectives

The study objectives are to assess the performance of each network case for several input variations, such as in driveway spacing, interchange spacing and land use intensities, and to appreciate the impact of each input variable on each network. A comparison among the three case studies will determine the conditions under which a case performs better than others, e.g., with lower average delays and queue lengths, and with higher speeds.

Based on several discussions and meetings with the different parties involved in the project, a series of focused approaches will be adopted. Each network will be built in a progressive manner: from a simple case such as a stretch of road (frontage road, ramps, secondary arterial or freeway, for example) in which the different input variables are closely evaluated, then, step-by-step, links are added to the main figure. This process continues until the general networks are built.

The simulation-based research will focus primarily on stopped and total/travel delay[4], queue length, and speed especially on the freeway mainlanes. These investigative efforts will produce 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 will permit assessment of network performance and design options.

Three illustrative network drawings are shown in the following figures (4.1-4.3).

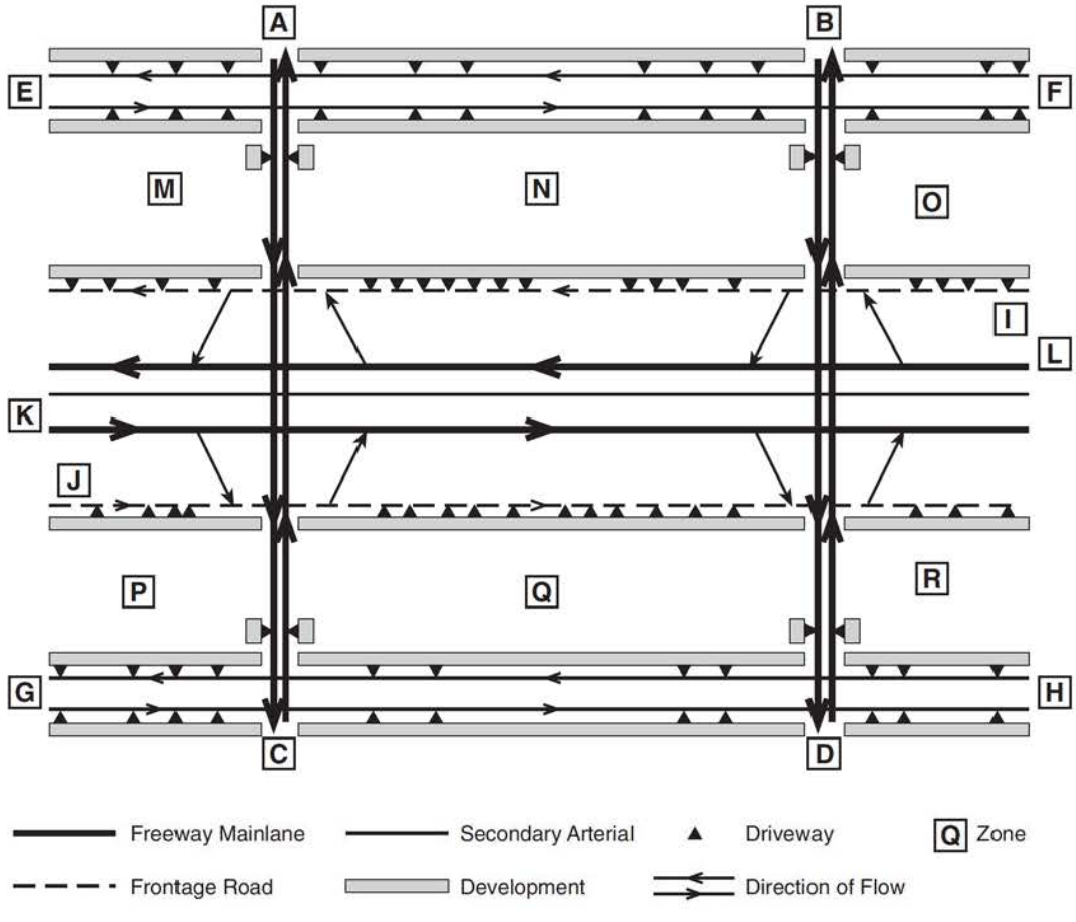

Figure 4.1 Freeway with frontage roads and diamond interchange

[4] Papacostas and Prevedouros define *travel delay* as "difference between the time a vehicle passes a point downstream of the intersection where it has regained normal speed and the time it would have passed that point had it been able to continue at its approach speed" while *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 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.

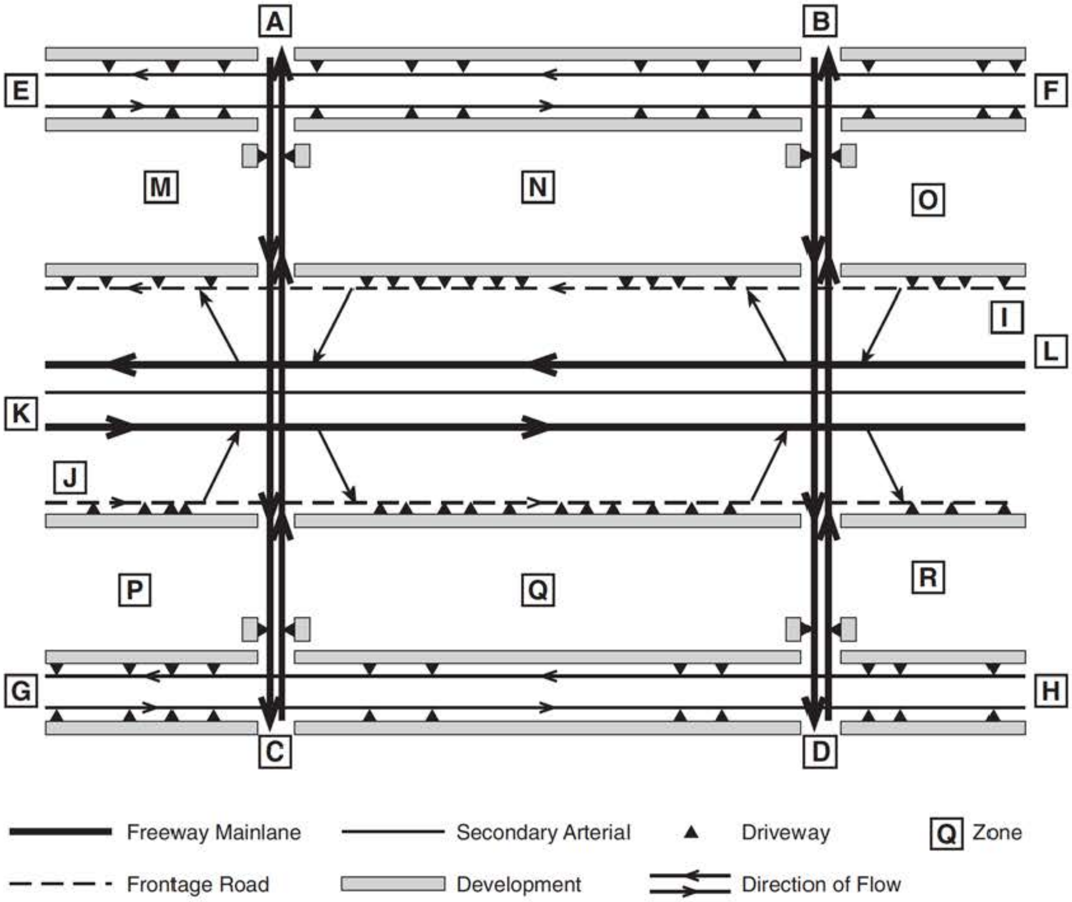

Figure 4.2 Freeway with frontage roads and X interchange

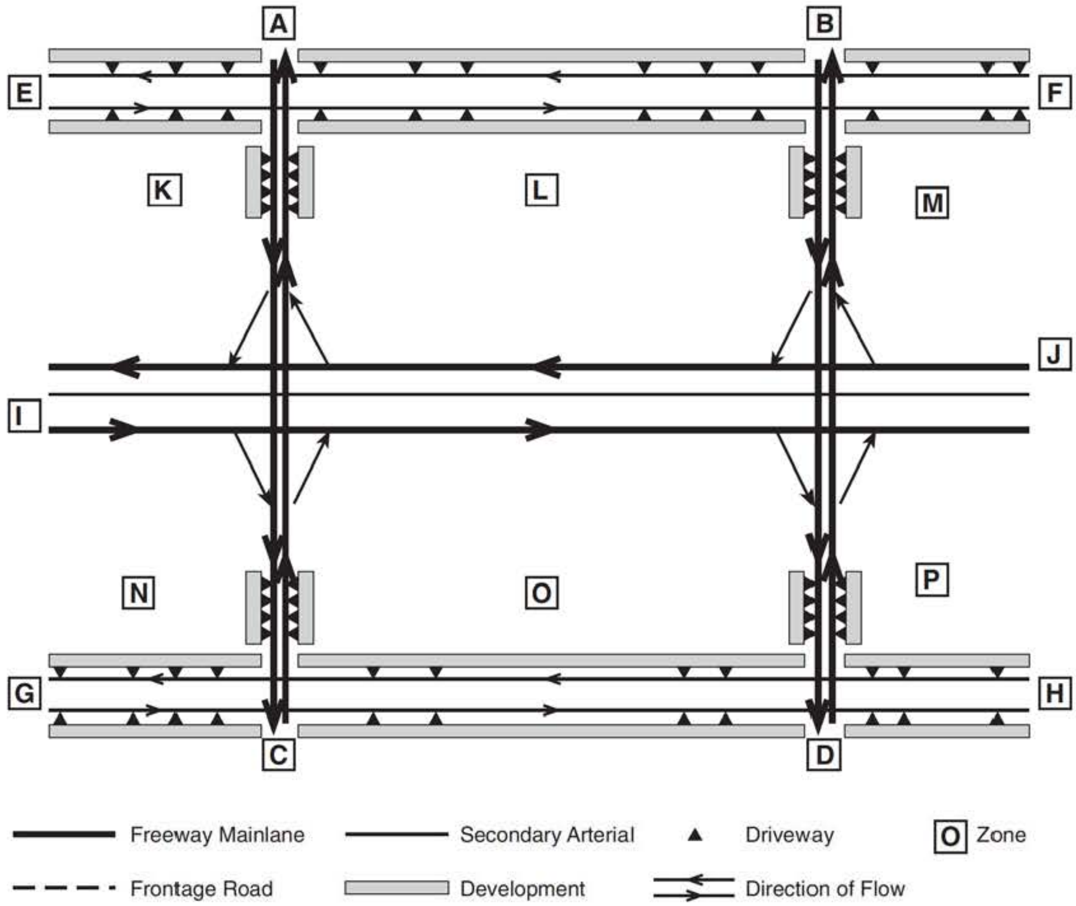

Figure 4.3 Freeway with diamond interchange and no frontage roads

4.3 AN ILLUSTRATION

A rather simple example of a freeway without frontage roads is used here to illustrate CORSIM outputs. These outputs are described in two sections of the CORSIM program manual (U.S. DOT, 1999).

- CORSIM outputs include a summary of inputs, to show how every entry was interpreted. This is particularly important for confirming that the program understood the models coded. These outputs also include speed, delay, and queue length results for every link in the model. The outputs are categorized in three separate sections:
    1. NETSIM outputs exhibit the delay, queue length, and speed results on the every link of the frontage road, if any, underpass, and secondary arterials.
    2. FRESIM outputs exhibit the delay, queue length, and speed results on every link of the freeway mainlanes and ramps.
    3. Network-wide average statistics evaluate the network as a whole combining NETSIM and FRESIM.
- TRAFVU (TRAF Visualization Utility) is a "graphics post-processor for the Federal Highway Administration's (FHWA's) CORSIM microscopic traffic simulation system" (U.S. DOT, 1999, TRAFVU Overview). TRAFVU displays traffic networks; animates simulated traffic, signals, and Measures of Effectiveness (MOEs); displays bus stations, bus routes, and parking zones; reports attributes for links, nodes, bus routes, bus stations, and parking zones; and displays a legend describing various elements depicted in the network display windows (U.S. DOT, 1999). TRAFVU results are attached to this document (see Appendix 4: Example CORSIM Output).

An example of such outputs is provided in Appendix 4. As can be seen, every link in NETSIM and FRESIM is interpreted in terms of stopped, moving and total delay, speed, and queue length. Moreover, the environmental impacts in terms of fuel emissions and consumption are also shown. Finally, the network is evaluated as a whole, with overall averages, at the end of the outputs.

CHAPTER 5. CORRIDOR PAIR ANALYSIS

One of the project objectives is 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. Thirteen corridor pairs, as listed in Table 5.1, were selected for 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.

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.

The census tracts along each corridor are from the 1990 U.S. Census Metropolitan Statistical Area (MSA) tract maps. Demographic information collected from each census tract included the following: median household income, per capita income, average household size, population density, percent who drive alone to work, percent who carpool to work, percent who take public transit to work, percent who bike to work, percent who walk to work, average travel time to work, average private vehicle occupancy to work, percent high school education or greater, percent college education or greater, unemployment rate, and percent below poverty level. For each corridor, a weighted average of every variable was then computed, where the more populous tracts were given more weight in computing the average as shown in Equation 5.1.

Equation 5.1 Weighted average of demographic by tract population

$$D_{C,avg} = \frac{\sum_j P_j D_j}{\sum_j P_j}$$

where $D_{C,avg}$ is the weighted demographic variable for corridor *C*,

P_j is the population in tract *j*, and

D_j is the demographic variable value for tract *j*.

Finally, differences of the weighted averages were taken (i.e., the average values for the frontage road corridors were subtracted from the averages for the corridors without frontage roads). If there are no significant demographic differences between the corridors, the overall, average of differences among all thirteen corridor pairs should be at or near zero for each demographic variable. In order to prove this, a statistical t-test was run on each demographic variable, with the null hypothesis being that the true, overall average is zero. Results of the tests for statistical significance are found in Table 5.2.

Table 5.2 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	Unemployment 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%
Average	-$3,851	-513.4	-0.38%	-0.08	2.30%
Variance	9.19E+07	2.83E+06	1.16E-04	7.07E-0:	2.83E-03
SE of Mean Difference	2.66E+03	4.66E+02	2.99E-03	7.37E-0:	1.47E-02
T statistic	-1.449**	-1.101*	-1.260*	-1.15(	1.562**
p-values	0.087	0.146	0.116	0.1	0.072

* significant at 80% confidence interval
** significant at 90% confidence interval

Among the differences that were found to be statistically significant at an 80 percent level of confidence or higher, census tracts near frontage roads appear to be 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 suggest somewhat lower per-capita incomes, larger household sizes, more single-occupancy vehicle commuting, lower educational levels, and more poverty (see Table 5.3). With a larger sample size of such paired corridors in the U.S., such results may become statistically significant. Overall, however, it is difficult to know what these demographic results suggest; information on variables such as employment density and land-use patterns would be helpful.

Table 5.3 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
1	$1,393.99	0.512	4.62%	-2.40%	-0.35%	-1.38%	2.44	3.95%	3.98%	-8.07%
2	$1,321.00	-0.148	2.22%	-0.72%	-1.71%	-0.65%	1.82	1.11%	-0.41%	-2.00%
3	$10,033.68	-0.377	22.90%	-8.33%	-11.67%	-1.36%	-3.10	15.81%	17.90%	-14.86%
4	-$1,995.95	0.565	20.74%	-6.34%	8.92%	-22.77%	7.14	-14.77%	-3.14%	3.34%
5	-$2,375.77	0.823	-5.42%	5.07%	0.15%	0.21%	2.41	-18.63%	-3.31%	7.62%
6	$890.74	-0.836	-5.09%	3.32%	1.01%	0.85%	-4.96	-2.45%	-12.60%	4.70%
7	$495.87	-0.113	2.91%	-0.34%	-2.88%	-0.16%	-0.36	0.48%	-3.15%	0.42%
8	-$4,222.85	0.094	-0.13%	1.48%	-0.78%	0.34%	1.41	-1.05%	-6.38%	0.15%
9	-$591.29	0.151	2.19%	4.10%	-2.07%	1.01%	-1.09	-8.02%	-3.13%	5.39%
10	$970.89	-0.685	-1.82%	-5.22%	2.77%	3.02%	-2.16	7.60%	3.45%	4.22%
11	-$2,453.29	0.139	1.93%	0.14%	-0.71%	-0.22%	0.86	-5.59%	-6.93%	2.97%
12	$12,066.16	0.499	-7.88%	5.65%	0.41%	0.79%	0.51	-11.60%	-27.57%	13.58%
13	$2,544.19	-0.097	-3.59%	1.96%	0.34%	1.38%	1.62	0.21%	3.17%	4.84%
Average	-$466	0.041	2.58%	-0.13%	-0.51%	-1.46%	0.503	-2.53%	-2.93%	1.71%
Variance	2.41E+07	2.41E-01	8.71E-03	1.95E-03	1.99E-03	4.24E-03	9.04E+00	8.70E-03	1.08E-02	5.06E+01
SE of Mean Difference	1.36E+03	1.36E-01	2.59E-02	1.23E-02	1.24E-02	1.81E-02	8.34E-01	2.59E-02	2.88E-02	1.97E+00
T statistic	-0.342	0.299	0.998	-0.103	-0.410	-0.807	0.604	-0.979	-1.018	0.869
p-values	0.369	0.385	0.169	0.460	0.345	0.218	0.279	0.173	0.164	0.201

To this end, using a GIS database of the Dallas-Fort Worth metropolitan area, encompassing corridor pairs 1 and 2, data is being collected on average employment density, along with land-use proportions for several types of development such as commercial and industrial. Difficulties are present in this finer level of analysis, because there are so few corridors in the Dallas-Fort Worth region without frontage roads, and those that remain may not pair well with frontage road corridors elsewhere in the region. A better analysis may result from a census block-level analysis of the selected corridors; results from this effort are forthcoming but not yet available.

To summarize, some significant differences exist in a corridor pair analysis of frontage road corridors versus nonfrontage road corridors. These include lower household incomes, lower population densities, lower percentages of bike trips to work, lower vehicle occupancies for work trips, and higher unemployment rates. However, one must be careful in interpreting these differences, since no perfect pairings exist in the analysis and other, unexamined factors besides the presence or lack of frontage roads may in fact be responsible for the differences seen here.

CHAPTER 6. ADDITIONAL WORK TO BE UNDERTAKEN

In addition to the initial research results presented here, there are several areas of study that are in progress. These include simulation of several network configurations as previously discussed, estimation of construction cost distinctions, case studies of corridors, and further analysis of land-use data sets alongside paired corridors in the Dallas-Fort Worth area, as previously described.

The differences in construction costs including right of way when building freeways with frontage roads may prove interesting. It is possible that frontage road construction is more expensive than purchasing access rights or acquiring properties outright. Interviews of TxDOT personnel are being undertaken and frontage road justification memos are being studied, in order to collect construction cost data that will give a better sense of this issue.

The Austin Loop 1 or MoPac freeway provides an opportunity for a case-study comparison of freeway operations with and without frontage roads. This is a relatively rare example of a Texas facility having frontage roads in some places but not others. The analysis of such a real case study will provide an anecdotal test of the hypothesis that frontage roads tend to attract more short trips to freeway corridors, thereby increasing access-ramp volumes and reducing potential freeway capacity — when compared to nonfrontage road sections. In addition, the simulation results described earlier are likely to suggest mitigating actions, to improve freeway and frontage road performance.

Other case studies that are being investigated are the following:

Interstate Highway 35 at

- Onion Creek
- Hancock Center
- Parmer Lane
- Farm to Market Road 1325

and US Highway 183 at

- Tweed Court (Oak Knoll Exit Ramp)
- Loop 360: Gateway Shopping Center
- Balcones Woods
- Ohlen Road

In addition to traffic counts, average speeds, and accident rates of the past several years, information on driveway spacing, ramp-to-intersection distances, setbacks of structures from right-of-way, land use types, densities of development, sidewalk provision, bike lanes, shoulder design, mainlane design, merge-lane design, and other qualities of interest, e.g., bus stops, cross-walks, driveway design, will be assessed. This case-study effort will seek examples of corridors and locations that are well managed versus those that are not, and try to determine what makes some locations operate without incident while others are chronic trouble spots.

Work on the network simulation will continue, and after the networks are fully constructed, a detailed comparison of each case will result. Likewise, additional data will be collected and analyzed in the corridor pair analysis from Dallas-Fort Worth GIS data. This information will give land-use fractions and employment densities to suggest whether frontage road provision has any effect on these variables.

CHAPTER 7. CONCLUSION

The first year of work on this project has made inroads into a number of different areas of research, and work continues on virtually all of them in order to complete this comprehensive study of frontage roads. All together, these efforts aim to produce a comprehensive assessment of the benefits and costs entailed by frontage road provision — as well as suggest optimal design strategies.

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 DOTs 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.

For the simulation and observation of traffic operations, three network cases are being developed: 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. Study objectives for the CORSIM network simulations are an assessment of network performance — under several variations in input characteristics (i.e., driveway spacings, interchange spacings, and land use intensities) and appreciation of the impacts of each input variable. A comparison among the myriad simulations is expected to identify conditions under which certain network cases perform better than others, e.g., with lower average delays and queue lengths, and with higher speeds. These investigative efforts will produce 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 will permit assessment of network performance and design options. A much more detailed analysis of traffic operations is forthcoming, as the CORSIM networks are still being developed and refined.

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 is 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. Preliminary results were presented here, suggesting, for example, 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 SOV commuting, lower educational levels, and more poverty in corridors utilizing frontage roads. The census and geographic information systems data for the corridor pair analysis are currently being added to, which should result in a richer analysis and a better understanding of the effects of frontage roads on urban environments and human behavior.

Finally, a case-study analysis of sites in the Austin region and an investigation of construction-cost differences are still in the preliminary stages; results from these analyses will be forthcoming in the final research report. The project team is proud of its efforts to date, and expects the final results to be insightful and useful to TxDOT and the entire state of Texas.

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APPENDIX 1. 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 and conversion of remaining two-way frontage roads. The second type of frontage road facility is usually rather short and may be required of the developer or purchased as public right-of-way. It is becoming more common as Montana's one million 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, we and certain cities 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, P.O. 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 2. 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
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Access Program Administrator, Safety and Traffic Engineering Branch
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Phone: 303-757-9844, FAX 303 757 9219
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Colorado Access Mgmt Web page
http://www.dot.state.co.us/business/accessmgt/

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

Nebraska
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North Carolina
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NCDOT - Planning and Programming
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Dewayne Sykes, PE
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New Mexico
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Phone: 505-827-5473

Pennsylvania
Larry M. King
Deputy Secretary for Planning
Pennsylvania DOT, 555 Walnut St., 9th Floor, Forum Place, Harrisburg, PA 17101
Phone: 717-787-3154

South Carolina
E. Warren Davis, Jr.
Preliminary Design Manager
SCDOT, PO 191, Columbia, SC 29202
Phone: 803-737-1134
Email: DavisEW@dot.state.sc.us

South Dakota
Tim Bjorneberg
Chief Road Design Engineer, 700 E Broadway, Pierre, SD 57501
Phone: 605-773-3433
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Vermont
Robert F. Shattuck
Roadway & Traffic Design Engineer
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Virginia
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APPENDIX 3. 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."

"Existing Road as Frontage Road

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."

"Consider Future Land Use in Initial Design

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."

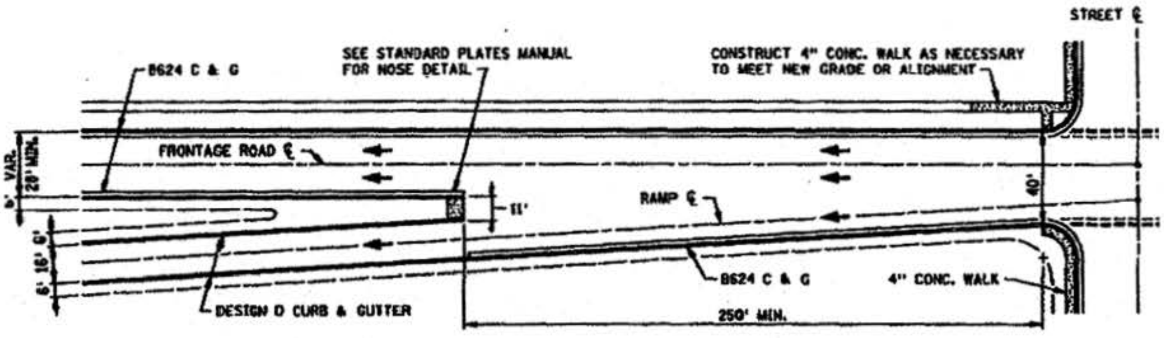
MINNESOTA

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

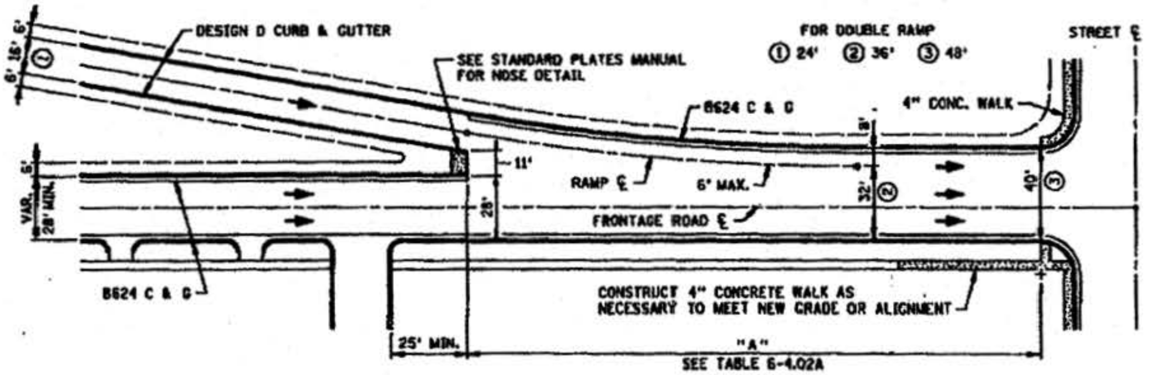
"Where frontage roads are present adjacent to freeways, the ramp/minor road intersection is greatly complicated. If possible, the frontage road should be curved away from the interchange and allowed to intersect the minor road a sufficient distance away from the ramp intersection. This treatment allows 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

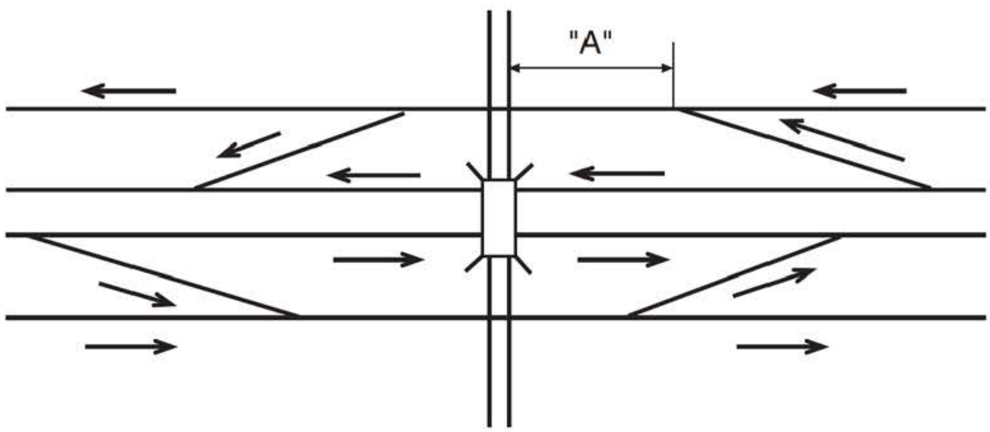


MERGING OF RAMP AND FRONTAGE ROAD

Figures 6-4.02A and 6-4.02B

Table 6-4.02A Distance "A" from ramp/frontage road to intersection with minor road

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



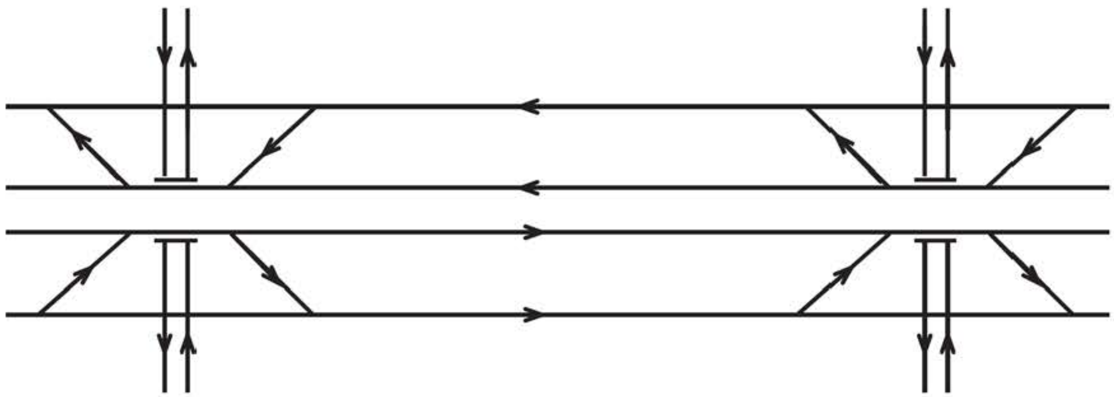
Distance "A" from ramp/frontage road to intersection with minor road

[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 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 4. EXAMPLE CORSIM OUTPUT

1. CUMULATIVE NETSIM STATISTICS

LINK	VEHICLE MILES	VEHICLE TRIPS	VEHICLE MINUTES MOVE TIME	VEHICLE MINUTES DELAY TIME	VEHICLE MINUTES TOTAL TIME	RATIO MOVE/ TOTAL	MINUTES/MILE TOTAL TIME	MINUTES/MILE DELAY TIME	SECONDS / VEHICLE TOTAL TIME	SECONDS / VEHICLE DELAY TIME	SECONDS / VEHICLE QUEUE* TIME	SECONDS / VEHICLE STOP* TIME	AVERAGE VALUES STOPS (%)	AVERAGE VALUES VOLUME VPH	AVERAGE VALUES SPEED MPH
(8010, 1)		125												500	
(1, 15)	11.74	124	23.5	64.5	88.0	.27	7.50	5.50	42.6	31.2	24.8	24.0	83	496	8.0
(15, 60)	11.82	104	23.6	519.1	542.7	.04	45.92	43.92	313.1	299.5	209.5	204.6	100	416	1.3
(60, 4)	13.54	143	27.1	7.4	34.5	.79	2.55	.55	14.5	3.1	.2	.0	0	572	23.6
(8050, 4)		125												500	
(4, 60)	11.74	124	23.5	54.0	77.5	.30	6.60	4.60	37.5	26.1	20.9	20.3	74	496	9.1
(60, 15)	13.07	115	26.1	260.0	286.2	.09	21.90	19.90	149.3	135.7	109.6	108.5	100	460	2.7
(15, 1)	14.68	155	29.4	7.8	37.2	.79	2.53	.53	14.4	3.0	.2	.0	0	620	23.7
(8020, 2)		125												500	
(2, 30)	12.12	128	24.2	57.1	81.3	.30	6.71	4.71	38.1	26.8	21.1	20.4	77	512	8.9
(30, 45)	12.16	107	24.3	291.8	316.1	.08	26.00	24.00	177.3	163.6	134.6	132.6	100	428	2.3
(45, 3)	14.77	156	29.5	7.0	36.5	.81	2.47	.47	14.1	2.7	.1	.0	0	624	24.3
(8040, 3)		125												500	
(3, 45)	12.03	127	24.1	59.7	83.8	.29	6.97	4.97	39.6	28.2	22.2	21.4	77	508	8.6
(45, 30)	13.30	117	26.6	380.9	407.5	.07	30.65	28.65	209.0	195.3	157.9	155.5	100	468	2.0
(30, 2)	13.64	144	27.3	7.6	34.8	.78	2.55	.55	14.5	3.2	.1	.0	0	576	23.5
(15,7000)	4.64	98	9.3	2.1	11.4	.81	2.46	.46	7.0	1.3	.3	.0	0	392	24.4
(7070, 11)	2.53	107	5.1	.6	5.6	.90	2.22	.22	3.1	.3	1.4	1.2	8	428	27.1
(11, 60)	2.46	104	4.9	21.9	26.9	.18	10.91	8.91	15.5	12.7	9.6	8.7	38	416	5.5
(60,7060)	3.55	75	7.1	1.7	8.8	.81	2.48	.48	7.1	1.4	.2	.0	0	300	24.2
(7010, 12)	3.22	136	6.4	24.8	31.3	.21	9.71	7.71	13.8	11.0	11.7	11.3	18	544	6.2
(12, 15)	3.20	135	6.4	49.3	55.7	.11	17.43	15.43	24.8	21.9	19.1	18.6	29	540	3.4
(30,7020)	3.84	81	7.7	1.3	9.0	.85	2.35	.35	6.7	1.0	.2	.0	0	324	25.6
(7050, 13)	3.69	156	7.4	12.1	19.5	.38	5.28	3.28	7.5	4.7	5.0	4.6	23	624	11.4
(13, 45)	3.72	157	7.4	32.4	39.9	.19	10.73	8.73	15.2	12.4	9.1	8.6	22	628	5.6
(45,7040)	4.83	102	9.7	2.5	12.1	.80	2.51	.51	7.1	1.4	.2	.0	0	408	23.9
(7030, 14)	2.72	115	5.3	.0	5.3	1.00	1.95	.00	2.8	.0	1.1	1.0	6	460	30.0
(14, 30)	2.63	111	5.3	21.7	26.9	.20	10.24	8.24	14.5	11.7	9.4	9.1	34	444	5.9
0SUBNETWORK=	195.63	954	6.52	31.46	37.98	.17	11.65	9.65	2.39	1.98	1.62	1.58	111.7		5.2

NETSIM PERSON MEASURES OF EFFECTIVENESS

LINK	PERSON MILE	PERSON TRIPS	DELAY PERSON-MIN	TRAVEL TIME PERSON-MIN
(1, 15)	22.1	233.0	121.3	165.4
(15, 60)	19.4	171.1	854.0	892.9
(60, 4)	20.9	221.2	11.5	53.4
(4, 60)	21.9	230.9	100.6	144.3
(60, 15)	22.1	194.5	439.8	484.0
(15, 1)	23.5	248.4	12.5	59.6
(2, 30)	22.6	238.4	106.4	151.5
(30, 45)	21.2	186.4	508.3	550.7
(45, 3)	23.6	249.2	11.2	58.4
(3, 45)	21.8	230.5	108.4	152.1
(45, 30)	21.7	190.9	621.4	664.8
(30, 2)	21.4	225.6	11.8	54.6
(15,7000)	7.2	152.5	3.3	17.7
(7070, 11)	3.2	136.9	.7	7.2
(11, 60)	3.1	133.0	28.1	34.4
(60,7060)	5.5	116.2	2.7	13.7
(7010, 12)	4.4	185.4	33.8	42.6
(12, 15)	4.4	184.2	67.3	76.0
(30,7020)	6.3	133.4	2.2	14.8
(7050, 13)	4.8	204.0	15.8	25.5
(13, 45)	4.9	205.4	42.4	52.2
(45,7040)	7.5	157.7	3.8	18.7
(7030, 14)	3.5	147.8	.0	6.8
(14, 30)	3.4	142.6	27.8	34.6

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE I

0 LINK	VEHICLE-MILE			VEHICLE-TRIPS			SPEED (MPH)			STOPS (PCT)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8010, 1)				0	125	0						
(1, 15)	.00	8.14	3.60	0	86	38	.0	6.3	19.6	.0	77.9	94.7
(15, 60)	.00	11.82	.00	0	104	0	.0	1.3	.0	.0	100.0	.0
(60, 4)	.00	13.54	.00	0	143	0	.0	23.6	.0	.0	.0	.0
(8050, 4)				0	125	0						
(4, 60)	.00	8.43	3.31	0	89	35	.0	7.4	21.5	.0	75.3	71.4
(60, 15)	.00	13.07	.00	0	115	0	.0	2.7	.0	.0	100.0	.0
(15, 1)	.00	14.68	.00	0	155	0	.0	23.7	.0	.0	.0	.0
(8020, 2)				0	125	0						
(2, 30)	.00	8.43	3.69	0	89	39	.0	7.1	21.0	.0	76.4	79.5
(30, 45)	.00	12.16	.00	0	107	0	.0	2.3	.0	.0	100.0	.0
(45, 3)	.00	14.77	.00	0	156	0	.0	24.3	.0	.0	.0	.0
(8040, 3)				0	125	0						
(3, 45)	.00	8.43	3.60	0	89	38	.0	6.9	20.2	.0	77.5	76.3
(45, 30)	.00	13.30	.00	0	117	0	.0	2.0	.0	.0	100.0	.0
(30, 2)	.00	13.64	.00	0	144	0	.0	23.5	.0	.0	.0	.0
(15,7000)	.00	4.64	.00	0	98	0	.0	24.4	.0	.0	.0	.0
(7070, 11)	.00	2.53	.00	0	107	0	.0	27.1	.0	.0	8.4	.0
(11, 60)	.62	.97	.88	26	41	37	5.8	5.4	5.4	34.6	36.6	43.2
(60,7060)	.00	3.55	.00	0	75	0	.0	24.2	.0	.0	.0	.0
(7010, 12)	.00	3.22	.00	0	136	0	.0	6.2	.0	.0	18.4	.0
(12, 15)	.83	1.44	.92	35	61	39	3.1	3.1	5.0	28.6	34.4	23.1
(30,7020)	.00	3.84	.00	0	81	0	.0	25.6	.0	.0	.0	.0
(7050, 13)	.00	3.69	.00	0	156	0	.0	11.4	.0	.0	23.1	.0
(13, 45)	1.04	1.59	1.09	44	67	46	5.6	5.7	5.5	20.5	22.4	26.1
(45,7040)	.00	4.83	.00	0	102	0	.0	23.9	.0	.0	.0	.0
(7030, 14)	.00	2.72	.00	0	115	0	.0	30.8	.0	.0	6.1	.0
(14, 30)	.85	1.04	.73	36	44	31	5.9	7.3	4.6	33.3	27.3	45.2

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE II

LINK	MOVING TIME (VEH-MINS)			DELAY TIME (VEH-MINS)			TOTAL TIME (VEH-MINS)			RATIO MOVE/TOTAL (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8010, 1)												
(1, 15)	.00	16.29	7.20	.00	60.71	3.84	.00	77.00	11.03	.00	.21	.65
(15, 60)	.00	23.64	.00	.00	519.10	.00	.00	542.73	.00	.00	.04	.00
(60, 4)	.00	27.08	.00	.00	7.42	.00	.00	34.50	.00	.00	.79	.00
(8050, 4)												
(4, 60)	.00	16.86	6.63	.00	51.39	2.62	.00	68.25	9.25	.00	.25	.72
(60, 15)	.00	26.14	.00	.00	260.03	.00	.00	286.17	.00	.00	.09	.00
(15, 1)	.00	29.36	.00	.00	7.81	.00	.00	37.17	.00	.00	.79	.00
(8020, 2)												
(2, 30)	.00	16.86	7.39	.00	53.94	3.16	.00	70.80	10.55	.00	.24	.70
(30, 45)	.00	24.32	.00	.00	291.80	.00	.00	316.12	.00	.00	.08	.00
(45, 3)	.00	29.55	.00	.00	7.00	.00	.00	36.55	.00	.00	.81	.00
(8040, 3)												
(3, 45)	.00	16.86	7.20	.00	56.23	3.50	.00	73.08	10.70	.00	.23	.67
(45, 30)	.00	26.59	.00	.00	380.88	.00	.00	407.47	.00	.00	.07	.00
(30, 2)	.00	27.27	.00	.00	7.56	.00	.00	34.83	.00	.00	.78	.00
(15,7000)	.00	9.28	.00	.00	2.12	.00	.00	11.40	.00	.00	.81	.00
(7070, 11)	.00	5.07	.00	.00	.55	.00	.00	5.62	.00	.00	.90	.00
(11, 60)	1.23	1.94	1.75	5.14	8.79	8.01	6.37	10.73	9.77	.19	.18	.18
(60,7060)	.00	7.10	.00	.00	1.71	.00	.00	8.82	.00	.00	.81	.00
(7010, 12)	.00	6.44	.00	.00	24.83	.00	.00	31.27	.00	.00	.21	.00
(12, 15)	1.66	2.89	1.85	14.64	25.35	9.34	16.30	28.23	11.18	.10	.10	.17
(30,7020)	.00	7.67	.00	.00	1.33	.00	.00	9.00	.00	.00	.85	.00
(7050, 13)	.00	7.39	.00	.00	12.10	.00	.00	19.48	.00	.00	.38	.00
(13, 45)	2.08	3.17	2.18	9.10	13.59	9.74	11.18	16.77	11.92	.19	.19	.18
(45,7040)	.00	9.66	.00	.00	2.46	.00	.00	12.12	.00	.00	.80	.00
(7030, 14)	.00	5.45	.00	.00	.00	.00	.00	5.45	.00	.00	1.00	.00
(14, 30)	1.70	2.08	1.47	7.03	6.52	8.12	8.73	8.60	9.58	.20	.24	.15

NETSIM MOVEMENT SPECIFIC STATISTICS - TABLE III

LINK	TOTAL TIME (SECS/VEH)			DELAY TIME (SECS/VEH)			QUEUE TIME** (VEH-MINS)			STOP TIME** (VEH-MINS)		
	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT	LEFT	THRU	RIGHT
(8010, 1)												
(1, 15)	.0	53.7	17.4	.0	42.4	6.1	.0	52.3	2.0	.0	50.5	1.9
(15, 60)	.0	313.1	.0	.0	299.5	.0	.0	551.8	.0	.0	538.7	.0
(60, 4)	.0	14.5	.0	.0	3.1	.0	.0	.4	.0	.0	.0	.0
(8050, 4)												
(4, 60)	.0	46.0	15.9	.0	34.6	4.5	.0	43.8	1.3	.0	42.5	1.1
(60, 15)	.0	149.3	.0	.0	135.7	.0	.0	237.6	.0	.0	235.0	.0
(15, 1)	.0	14.4	.0	.0	3.0	.0	.0	.5	.0	.0	.0	.0
(8020, 2)												
(2, 30)	.0	47.7	16.2	.0	36.4	4.9	.0	44.6	1.5	.0	43.2	1.4
(30, 45)	.0	177.3	.0	.0	163.6	.0	.0	311.8	.0	.0	307.2	.0
(45, 3)	.0	14.1	.0	.0	2.7	.0	.0	.1	.0	.0	.0	.0
(8040, 3)												
(3, 45)	.0	49.3	16.9	.0	37.9	5.5	.0	46.4	2.0	.0	44.8	1.9
(45, 30)	.0	209.0	.0	.0	195.3	.0	.0	413.1	.0	.0	406.8	.0
(30, 2)	.0	14.5	.0	.0	3.2	.0	.0	.3	.0	.0	.0	.0
(15,7000)	.0	7.0	.0	.0	1.3	.0	.0	.4	.0	.0	.0	.0
(7070, 11)	.0	3.1	.0	.0	.3	.0	.0	2.5	.0	.0	2.2	.0
(11, 60)	14.7	15.7	15.8	11.9	12.9	13.0	4.1	7.1	5.8	3.8	6.7	5.0
(60,7060)	.0	7.1	.0	.0	1.4	.0	.0	.3	.0	.0	.0	.0
(7010, 12)	.0	13.8	.0	.0	11.0	.0	.0	26.8	.0	.0	26.1	.0
(12, 15)	27.9	27.8	17.2	25.1	24.9	14.4	13.8	22.5	7.3	13.5	22.0	7.1
(30,7020)	.0	6.7	.0	.0	1.0	.0	.0	.3	.0	.0	.0	.0
(7050, 13)	.0	7.5	.0	.0	4.7	.0	.0	13.1	.0	.0	12.1	.0
(13, 45)	15.3	15.0	15.5	12.4	12.2	12.7	6.8	10.6	6.8	6.3	10.1	6.3
(45,7040)	.0	7.1	.0	.0	1.4	.0	.0	.3	.0	.0	.0	.0
(7030, 14)	.0	2.8	.0	.0	.0	.0	.0	2.0	.0	.0	1.9	.0
(14, 30)	14.6	11.7	18.5	11.7	8.9	15.7	6.2	5.2	6.7	6.0	5.0	6.6

** TIME FOR VEHICLES CURRENTLY ON THE LINK ARE INCLUDED IN THESE VALUES.

NETSIM CUMULATIVE VALUES OF FUEL CONSUMPTION AND OF EMISSIONS

	LINK	FUEL CONSUMPTION GALLONS			M.P.G.			VEHICLE EMISSION RATES (KG/MILE.HOUR)		
0		AUTO	TRUCK	BUS	AUTO	TRUCK	BUS	HC	CO	NO X
	(8010, 1)									
	(1, 15)	1.5	.2	.0	7.4	3.4	.0	.213	10.024	.594
	(15, 60)	5.2	1.4	.0	2.0	1.2	.0	.446	7.399	.889
	(60, 4)	1.3	.5	.0	8.4	3.5	.0	.188	9.418	.745
	(8050, 4)									
	(4, 60)	1.4	.2	.0	7.9	4.2	.0	.208	10.615	.562
	(60, 15)	3.2	.6	.0	3.7	2.0	.0	.318	9.974	.813
	(15, 1)	1.6	.4	.0	8.2	3.0	.0	.228	12.085	.898
	(8020, 2)									
	(2, 30)	1.4	.2	.0	7.8	3.5	.0	.219	11.189	.600
	(30, 45)	3.7	.7	.0	3.2	2.0	.0	.358	9.896	.848
	(45, 3)	1.4	.5	.0	8.9	3.7	.0	.203	10.940	.766
	(8040, 3)									
	(3, 45)	1.5	.1	.0	7.5	4.8	.0	.224	11.276	.608
	(45, 30)	4.6	.8	.0	2.8	1.5	.0	.422	9.579	.966
	(30, 2)	1.4	.3	.0	8.9	3.4	.0	.196	10.013	.766
	(15,7000)	.7	.1	.0	5.5	4.2	.0	.227	13.964	.843
	(7070, 11)	.1	.0	.0	11.4	4.1	.0	.051	1.752	.147
	(11, 60)	.3	.1	.0	6.0	4.2	.0	.149	3.762	.446
	(60,7060)	.5	.1	.0	5.6	3.6	.0	.162	9.868	.588
	(7010, 12)	.3	.1	.0	4.5	1.9	.0	.147	3.340	.382
	(12, 15)	.6	.2	.0	4.7	2.6	.0	.252	5.514	.671
	(30,7020)	.6	.1	.0	5.8	4.5	.0	.197	12.188	.705
	(7050, 13)	.3	.1	.0	6.2	2.8	.0	.124	3.078	.402
	(13, 45)	.5	.2	.0	5.9	3.0	.0	.229	6.845	.761
	(45,7040)	.6	.2	.0	6.4	3.7	.0	.202	12.281	.718
	(7030, 14)	.1	.0	.0	14.2	3.1	.0	.046	1.729	.121
	(14, 30)	.4	.1	.0	6.5	5.2	.0	.164	4.560	.476
0	SUBNETWORK-	32.9	7.4	.0	5.1	2.6	.0	.251	9.617	.717

0 EMISSION STATISTICS FOR TRUCKS AND BUSES ARE NOT AVAILABLE

THE HIGHEST NUMBER OF VEHICLES ON THE NETWORK WAS 228 VEHICLES (MAXIMUM ALLOWED IS 10000).
THIS MAXIMUM OCCURED AT 853 SECONDS.

2.CUMULATIVE FRESIM STATISTICS

LINK STATISTICS

LINK	VEHICLES IN	VEHICLES OUT	LANE CHNG	CURR CONT	AVG CONT	VEH-MILES	VEH-MIN	SECONDS/VEHICLE TOTAL TIME	MOVE TIME	DELAY TIME	M/T	VEH-MIN/VEH-MILE TOTAL	DELAY	VOLUME VEH/LN/HR	DENSITY VEH/LN-MILE	SPEED MILE/HR	LINK TYPE
(95, 90)	750	753	365	46	46.9	711.2	702.5	56.1	52.9	3.2	.94	.99	.06	1003.	16.5	60.75	FRWY
(90, 85)	644	642	59	5	7.1	97.4	106.1	9.9	8.4	1.5	.85	1.09	.16	858.	15.6	55.09	FRWY
(85, 80)	717	710	441	30	20.2	272.5	305.9	25.5	21.5	4.0	.84	1.12	.18	714.	13.4	53.46	FRWY
(80, 75)	548	546	48	6	5.9	82.9	88.9	9.8	8.4	1.4	.86	1.07	.15	730.	13.1	55.93	FRWY
(75, 700)	649	657	275	37	42.2	617.0	633.2	58.3	52.7	5.6	.90	1.03	.10	869.	14.9	58.47	FRWY
(701, 76)	750	745	339	49	46.6	711.3	698.6	55.8	52.9	2.9	.95	.98	.05	1003.	16.4	61.09	FRWY
(76, 82)	630	633	57	5	6.8	95.7	101.3	9.6	8.4	1.2	.87	1.06	.13	843.	14.9	56.71	FRWY
(82, 86)	714	710	404	30	26.4	271.1	429.2	36.0	24.4	11.6	.68	1.58	.51	659.	17.4	37.90	FRWY
(86, 91)	568	568	43	4	6.7	85.8	100.2	10.6	8.4	2.2	.79	1.17	.24	756.	14.7	51.37	FRWY
(91, 96)	665	646	257	62	43.6	627.4	652.9	59.1	52.9	6.3	.89	1.04	.11	884.	15.3	57.66	FRWY
(7000, 89)	98	97	0	1	.4	2.6	5.9	3.3	2.8	.4	.87	2.30	.31	432.	16.6	26.05	RAMP
(89, 91)	97	97	0	0	.3	2.3	4.7	2.9	2.7	.3	.91	2.05	.18	387.	13.2	29.32	RAMP
(90,7070)	109	108	0	2	.6	5.3	9.6	5.1	4.2	.9	.83	1.80	.31	436.	13.1	33.32	RAMP
(7060, 84)	75	74	0	2	.3	2.0	4.4	3.2	2.8	.4	.88	2.24	.26	334.	12.5	26.81	RAMP
(84, 85)	74	75	0	0	.2	1.7	3.6	2.9	2.7	.3	.91	2.05	.18	295.	10.1	29.24	RAMP
(86,7010)	142	138	0	5	3.8	6.7	81.0	34.3	14.8	19.6	.43	12.09	6.90	402.	81.1	4.96	RAMP
(7020, 81)	81	81	0	0	.3	2.1	4.5	3.1	2.8	.3	.91	2.18	.20	351.	12.7	27.57	RAMP
(81, 82)	81	81	0	0	.3	1.9	3.9	2.9	2.6	.2	.91	2.01	.17	324.	10.9	29.78	RAMP
(80,7050)	162	159	0	7	1.6	7.7	31.3	11.5	7.0	4.5	.61	4.04	1.58	513.	34.5	14.85	RAMP
(7040, 74)	102	102	0	0	.4	2.7	6.3	3.3	2.8	.5	.86	2.31	.33	460.	17.7	25.94	RAMP
(74, 75)	102	103	0	0	.3	2.4	5.1	3.0	2.7	.3	.90	2.10	.21	408.	14.2	28.62	RAMP
(76,7030)	115	115	0	0	.6	5.6	8.9	4.5	3.9	.6	.87	1.58	.20	470.	12.4	37.90	RAMP

NETWORK STATISTICS

VEHICLE-MILES = 3615.4, VEHICLE-MINUTES = 3987.6, MOVING/TOTAL TRIP TIME = .869,

AVERAGE CONTENT = 261.6, CURRENT CONTENT = 291.0, SPEED(MPH) = 54.40,

TOTAL DELAY (VEH-MIN) = 520.75, TRAVEL TIME (MIN)/VEH-MILE = 1.10, DELAY TIME (MIN)/ VEH-MILE = .14

FRESIM CUMULATIVE VALUES OF FUEL CONSUMPTION

LINK	LINK TYPE	FUEL CONSUMPTION GALLONS 1	2	3	4	5	6	7	M.P.G. 1	2	3	4	5	6	7
VEHICLE TYPE-															
(95, 90)	FRWY	8.07	16.62	12.67	8.81	7.91	3.37	.00	17.94	25.45	3.21	5.80	4.70	4.42	.00
(90, 85)	FRWY	1.78	3.19	2.31	1.31	1.53	.76	.00	11.48	18.07	2.45	4.60	3.86	2.77	.00
(85, 80)	FRWY	4.02	7.60	5.91	3.61	3.98	1.15	.00	13.82	21.47	2.72	4.53	4.06	4.63	.00
(80, 75)	FRWY	1.46	2.80	2.18	1.14	1.41	.40	.00	11.53	17.78	2.26	4.05	3.64	4.22	.00
(75, 700)	FRWY	7.05	16.40	10.93	6.52	8.31	2.39	.00	17.06	23.53	2.92	4.78	4.44	4.76	.00
(701, 76)	FRWY	7.92	16.18	12.76	10.67	8.20	2.39	.00	18.29	25.41	3.25	6.10	4.75	4.29	.00
(76, 82)	FRWY	1.45	2.75	2.60	2.01	1.39	.41	.00	13.13	19.78	2.22	4.66	4.02	3.74	.00
(82, 86)	FRWY	3.98	7.87	5.69	5.16	3.43	.77	.00	13.81	20.13	2.71	4.65	4.16	4.85	.00
(86, 91)	FRWY	1.56	3.13	2.09	1.74	1.33	.51	.00	10.80	16.26	2.26	4.29	3.54	2.50	.00
(91, 96)	FRWY	7.84	16.29	11.61	10.07	7.35	2.04	.00	16.01	23.17	2.97	5.04	4.29	4.24	.00
(7000, 89)	RAMP	.06	.11	.07	.05	.02	.02	.00	10.47	15.34	1.92	3.08	4.25	1.90	.00
(89, 91)	RAMP	.04	.05	.03	.01	.01	.01	.00	15.38	30.61	4.54	10.74	3.85	1.85	.00
(90, 7070)	RAMP	.06	.12	.08	.15	.02	.03	.00	18.33	24.78	3.53	4.60	2.44	1.71	.00
(7060, 84)	RAMP	.03	.08	.07	.03	.02	.02	.00	11.32	17.37	2.37	4.11	2.43	1.90	.00
(84, 85)	RAMP	.02	.04	.03	.02	.01	.01	.00	19.78	29.05	3.92	6.36	2.37	1.85	.00
(86, 7010)	RAMP	.26	.40	.26	.08	.08	.00	.00	6.23	9.52	1.84	4.95	3.82	61.72	.00
(7020, 81)	RAMP	.04	.08	.03	.01	.00	.00	.00	11.78	19.75	3.55	7.57	.00	.00	.00
(81, 82)	RAMP	.02	.04	.01	.00	.00	.00	.00	22.14	34.59	5.23	10.82	.00	.00	.00
(80, 7050)	RAMP	.11	.22	.12	.08	.11	.04	.00	12.80	20.50	4.23	6.55	3.97	2.36	.00
(7040, 74)	RAMP	.03	.13	.03	.06	.04	.02	.00	8.73	16.23	1.68	3.96	3.69	1.89	.00
(74, 75)	RAMP	.02	.08	.02	.02	.02	.01	.00	13.87	25.16	2.15	5.48	4.88	1.86	.00
(76, 7030)	RAMP	.06	.13	.05	.06	.04	.00	.00	17.50	26.55	6.73	7.03	3.59	.00	.00
SUBNETWORK-		45.87	94.31	69.54	51.61	45.19	14.37	.00	15.86	22.90	2.93	5.21	4.37	4.26	.00

VEHICLE TYPES 1, 2 = AUTO, VEHICLE TYPES 3, 4, 5, 6 = TRUCK, VEHICLE TYPE 7 = TRANSIT BUS

FRESIM CUMULATIVE VALUES OF EMISSION

1. HC Emissions

LINK	LINK TYPE	VEHICLE EMISSIONS (GRAMS/ MILE) HC						
VEHICLE TYPE-		1	2	3	4	5	6	7
(95, 90)	FRWY	.13	.13	11.16	9.24	9.01	8.16	.00
(90, 85)	FRWY	.30	.34	15.19	10.10	8.77	7.68	.00
(85, 80)	FRWY	.22	.23	13.63	10.39	8.50	5.87	.00
(80, 75)	FRWY	.29	.34	16.57	11.17	9.14	6.22	.00
(75, 700)	FRWY	.14	.16	12.44	10.26	8.43	6.57	.00
(701, 76)	FRWY	.12	.13	11.02	8.69	8.94	8.59	.00
(76, 82)	FRWY	.24	.27	16.99	10.02	8.96	7.71	.00
(82, 86)	FRWY	.21	.24	13.65	9.78	8.42	6.73	.00
(86, 91)	FRWY	.32	.40	16.96	10.32	8.49	8.55	.00
(91, 96)	FRWY	.16	.17	12.10	9.80	8.32	7.08	.00
(7000, 89)	RAMP	.20	.29	17.79	10.61	6.15	11.91	.00
(89, 91)	RAMP	.10	.07	6.58	5.20	6.76	9.91	.00
(90, 7070)	RAMP	.20	.23	10.25	7.59	8.83	8.77	.00
(7060, 84)	RAMP	.20	.23	14.15	8.76	8.80	11.83	.00
(84, 85)	RAMP	.05	.07	7.84	6.71	8.76	9.91	.00
(86, 7010)	RAMP	.24	.23	16.45	7.09	6.41	.67	.00
(7020, 81)	RAMP	.17	.22	8.66	6.05	.00	.00	.00
(81, 82)	RAMP	.02	.02	5.20	5.16	.00	.00	.00
(80, 7050)	RAMP	.18	.18	7.79	6.14	6.22	7.59	.00
(7040, 74)	RAMP	.23	.28	20.48	8.89	7.04	12.76	.00
(74, 75)	RAMP	.09	.10	15.88	7.35	6.27	10.99	.00
(76, 7030)	RAMP	.21	.24	5.08	5.28	6.77	.00	.00
SUBNETWORK-		.16	.18	12.42	9.53	8.66	7.43	.00

VEHICLE TYPES 1, 2 = AUTO, VEHICLE TYPES 3, 4, 5, 6 = TRUCK, VEHICLE TYPE 7 = TRANSIT BUS

2. CO Emissions

LINK	LINK TYPE	VEHICLE EMISSIONS (GRAMS/ MILE) CO						
VEHICLE TYPE-		1	2	3	4	5	6	7
(95, 90)	FRWY	7.48	7.55	205.96	161.24	155.92	138.17	.00
(90, 85)	FRWY	22.60	26.76	288.14	172.95	147.05	119.91	.00
(85, 80)	FRWY	15.99	16.99	258.21	182.89	142.71	89.02	.00
(80, 75)	FRWY	22.34	26.98	315.86	194.51	152.94	93.80	.00
(75, 700)	FRWY	8.33	10.65	232.53	179.19	140.79	102.38	.00
(701, 76)	FRWY	6.87	7.76	203.49	149.09	154.40	146.02	.00
(76, 82)	FRWY	17.03	20.38	325.69	172.19	151.15	125.83	.00
(82, 86)	FRWY	14.13	17.11	258.33	167.99	139.47	107.39	.00
(86, 91)	FRWY	24.60	31.83	329.42	175.87	137.27	135.62	.00
(91, 96)	FRWY	10.45	11.49	224.17	170.02	138.00	112.70	.00
(7000, 89)	RAMP	10.42	20.11	315.02	167.61	88.47	171.35	.00
(89, 91)	RAMP	7.70	4.38	101.41	71.27	98.61	144.31	.00
(90, 7070)	RAMP	12.79	15.81	190.08	118.90	129.91	130.48	.00
(7060, 84)	RAMP	11.86	13.82	246.38	136.30	130.14	170.49	.00
(84, 85)	RAMP	3.80	6.24	124.85	98.12	131.77	144.31	.00
(86, 7010)	RAMP	15.83	15.88	256.46	112.53	93.73	7.72	.00
(7020, 81)	RAMP	9.08	15.09	138.02	85.48	.00	.00	.00
(81, 82)	RAMP	1.07	1.76	71.49	70.44	.00	.00	.00
(80, 7050)	RAMP	11.57	11.70	132.76	95.04	93.96	109.99	.00
(7040, 74)	RAMP	13.65	18.80	363.94	135.29	101.85	183.26	.00
(74, 75)	RAMP	4.97	8.14	281.76	109.76	89.23	161.15	.00
(76, 7030)	RAMP	12.94	15.65	89.76	84.07	100.02	.00	.00
SUBNETWORK-		10.62	12.18	231.74	165.00	146.35	120.80	.00

VEHICLE TYPES 1, 2 = AUTO, VEHICLE TYPES 3, 4, 5, 6 = TRUCK, VEHICLE TYPE 7 = TRANSIT BUS

3. NO Emissions

LINK	LINK TYPE	VEHICLE EMISSIONS (GRAMS/ MILE) NO						
VEHICLE TYPE-		1	2	3	4	5	6	7
(95, 90)	FRWY	.82	.79	27.90	24.69	24.27	22.45	.00
(90, 85)	FRWY	1.27	1.21	36.61	27.52	24.27	21.60	.00
(85, 80)	FRWY	1.01	.97	32.58	27.25	23.45	15.38	.00
(80, 75)	FRWY	1.27	1.24	39.65	30.00	25.49	16.81	.00
(75, 700)	FRWY	.85	.87	30.60	27.37	23.59	18.72	.00
(701, 76)	FRWY	.80	.80	27.55	23.61	24.22	23.54	.00
(76, 82)	FRWY	1.11	1.08	40.45	27.29	24.79	21.42	.00
(82, 86)	FRWY	.97	.95	32.44	25.72	22.85	18.00	.00
(86, 91)	FRWY	1.34	1.35	39.52	28.43	24.04	24.05	.00
(91, 96)	FRWY	.89	.88	29.98	26.26	23.43	19.51	.00
(7000, 89)	RAMP	1.10	1.18	44.90	27.70	13.84	26.80	.00
(89, 91)	RAMP	.39	.24	13.01	9.44	15.94	23.48	.00
(90, 7070)	RAMP	.63	.63	23.63	19.98	22.01	22.78	.00
(7060, 84)	RAMP	.91	1.00	35.65	21.62	22.34	26.93	.00
(84, 85)	RAMP	.20	.25	17.03	16.00	23.73	23.48	.00
(86, 7010)	RAMP	1.02	.90	31.35	18.69	13.58	.38	.00
(7020, 81)	RAMP	.93	.80	20.35	12.85	.00	.00	.00
(81, 82)	RAMP	.10	.12	9.43	9.48	.00	.00	.00
(80, 7050)	RAMP	.62	.52	16.10	14.88	17.21	17.72	.00
(7040, 74)	RAMP	1.51	1.11	52.98	23.06	16.35	28.48	.00
(74, 75)	RAMP	.58	.43	38.22	15.31	14.52	26.87	.00
(76, 7030)	RAMP	.64	.61	11.92	14.01	15.36	.00	.00
SUBNETWORK-		.90	.89	30.42	25.56	23.81	20.45	.00

VEHICLE TYPES 1, 2 = AUTO, VEHICLE TYPES 3, 4, 5, 6 = TRUCK, VEHICLE TYPE 7 = TRANSIT BUS

3.NETWORK-WIDE AVERAGE STATISTICS

TOTAL VEHICLE- MILE = 3811.01 VEHICLE-HOURS OF: MOVE TIME = 64.30 , DELAY TIME = 40.14 , TOTAL TIME = 104.44

AVERAGE SPEED (MPH)= 36.49 MOVE/TOTAL = .62 MINUTES/MILE OF: DELAY TIME = .63 , TOTAL TIME = 1.64
TOTAL CPU TIME FOR SIMULATION = 58.60 SECONDS
TOTAL CPU TIME FOR THIS RUN = 58.60 SECONDS
0LAST CASE PROCESSED

APPENDIX 5. CENSUS DATA FOR CORRIDOR PAIR ANALYSIS

Corridor ID	Census tracts	Persons	Persons (for density calculation)	Land area (sq. mi.)	House holds	Median household income, 1989	Per capita income, 1989	Average House hold Size	Population density (pers./sq. mi.)	Percent SOV to work	Percent carpool to work	Percent public transit to work	Percent bike to work	Percent walk to work	Average travel time to work (min)
1a	1114.03	7860	7848	10.18	3310	26016	14321	2.41	770.9	85.69%	12.56%	0.00%	0.00%	1.74%	22.7
	1115.13	2087	2077	1.86	713	51517	17734	3.00	1116.7	85.93%	11.75%	0.60%	0.00%	0.51%	27.8
	1115.14	4851	4861	1.37	1539	44473	14422	3.21	3548.2	88.35%	10.84%	0.47%	0.00%	0.34%	27.8
	1115.15	6812	6812	3.94	2308	46645	16029	2.93	1728.9	88.81%	10.75%	0.00%	0.00%	0.23%	26.7
	1115.16	3655	3655	1.71	1445	40103	16247	2.54	2137.4	89.74%	9.92%	0.00%	0.00%	0.00%	26.3
	1115.23	4693	4693	1.86	1655	35325	13547	3.00	2523.1	87.35%	12.27%	0.00%	0.00%	0.38%	25.6
	1115.25	5495	5495	2.01	1800	36463	12550	3.06	2733.8	87.17%	10.89%	0.00%	0.00%	1.66%	24.0
	1115.27	6733	6733	1.87	2488	39819	16986	2.70	3600.5	86.44%	12.63%	0.00%	0.00%	0.36%	22.7
	1115.28	6993	7004	3.91	2332	54325	21302	3.02	1791.3	88.84%	9.79%	0.00%	0.00%	0.57%	24.0
	1115.30	5782	5782	2.02	1935	62788	24527	2.98	2862.4	90.96%	7.72%	0.00%	0.00%	0.22%	24.0
	1115.31	4636	4636	1.36	1528	49141	17563	3.01	3408.8	88.80%	9.29%	0.00%	0.41%	0.41%	24.4
	1115.32	3408	3408	0.73	1171	50731	18071	2.88	4668.5	88.37%	10.62%	0.37%	0.00%	0.63%	25.6
	1115.35	506	478	1.14	161	54723	18330	3.12	419.3	77.74%	22.26%	0.00%	0.00%	0.00%	32.5
	1216.09	5369	5369	1.53	1572	73317	27513	3.32	3509.2	90.85%	8.01%	0.00%	0.00%	0.19%	24.1
	1216.11	3785	3785	1.14	1253	47466	15648	3.13	3320.2	90.13%	7.86%	0.00%	0.35%	0.91%	26.6
1b	1065.03	4901	4901	1.07	1955	34834	15121	2.56	4580.4	79.84%	15.64%	2.60%	0.00%	1.92%	22.5
	1065.09	2443	2258	6.48	1287	27526	18392	1.90	348.5	81.84%	15.63%	0.00%	0.00%	1.42%	23.5
	1065.11	3588	3588	3.40	1568	31757	14858	2.30	1055.3	86.82%	12.35%	0.00%	0.00%	0.60%	22.9
	1065.12	3126	3126	0.90	1453	28459	17933	2.18	3473.3	87.60%	9.82%	0.88%	0.00%	1.71%	21.9
	1065.14	3077	3020	1.66	1773	26731	18228	1.71	1819.3	88.42%	9.04%	0.00%	0.00%	1.54%	21.8
	1131.06	8176	8176	1.16	3792	22441	15599	2.19	7048.3	79.32%	16.19%	0.00%	0.22%	3.17%	21.4
	1131.07	2685	2685	0.90	933	65678	23459	2.94	2983.3	91.75%	6.79%	0.40%	0.00%	0.13%	23.2
	1131.08	4308	4308	2.11	1443	66858	25922	2.97	2041.7	90.43%	7.66%	0.00%	0.26%	0.38%	21.8
	1216.04	5803	5803	1.17	2318	28568	13689	2.42	4959.8	84.07%	12.36%	0.65%	0.00%	1.40%	24.9
	1216.05	2981	2981	1.05	1172	37768	18064	2.41	2839.0	89.94%	9.59%	0.00%	0.00%	0.47%	20.8
	1217.01	7717	7717	1.54	2847	22369	9727	2.64	5011.0	76.85%	16.72%	0.00%	0.44%	4.58%	22.4
2a	170.01	6138	6066	32.31	1913	26288	10937	2.79	187.7	72.93%	23.01%	0.00%	0.00%	1.78%	27.9
	170.02	10198	10260	12.80	3302	26060	10515	2.95	801.6	76.82%	21.15%	0.15%	0.09%	0.15%	28.9
2b	117	8609	8640	3.92	2636	26402	8659	3.22	2204.1	70.01%	24.04%	3.60%	0.00%	1.13%	27.9
	171	6080	6266	16.15	2032	26963	9896	2.90	388.0	76.91%	20.85%	0.31%	0.00%	1.00%	26.6
	172.01	4789	4789	2.30	1645	25141	9296	2.92	2082.2	71.58%	23.72%	1.72%	0.00%	2.69%	26.9
	172.02	5466	5489	2.32	1781	29521	9890	3.01	2365.9	75.23%	21.17%	0.71%	0.00%	1.20%	25.0
3a	405.01	3031	3040	0.56	1932	33980	34550	1.56	5428.6	79.51%	9.33%	5.31%	0.54%	4.40%	16.4
	407.01	4888	4929	1.33	3011	34201	32074	1.60	3706.0	77.39%	10.60%	4.34%	0.00%	6.32%	16.8
	407.02	3540	3499	0.79	2216	26629	25224	1.60	4429.1	80.73%	8.99%	5.10%	0.43%	4.33%	18.2
	419.02	2051	2090	0.51	971	48854	37934	2.05	4098.0	96.57%	0.83%	1.48%	0.00%	0.56%	15.4
	419.03	836	829	0.46	589	29926	25657	1.49	1802.2	87.76%	7.43%	1.17%	1.17%	1.17%	17.2
3b	306	3507	3577	0.65	1437	14605	10396	2.34	5503.1	42.15%	22.08%	29.38%	1.74%	4.65%	22.5
	316.01	2375	2434	0.40	845	13690	8639	2.26	6085.0	42.46%	20.98%	24.44%	0.92%	9.98%	24.6
	404.01	2708	2643	0.32	1601	24179	20969	1.72	8259.4	66.71%	14.82%	8.16%	4.17%	6.14%	17.5
	404.02	3543	3608	0.69	1969	44036	40960	1.80	5229.0	81.22%	9.88%	2.45%	1.42%	3.38%	16.3
4a	205.01	2614	2661	0.69	906	8674	5167	2.90	3856.5	49.22%	17.91%	28.77%	0.00%	3.24%	28.4

Corridor ID	Census tracts	Persons	Persons (for density calculation)	Land area (sq. mi.)	House holds	Median household income, 1989	Per capita income, 1989	Average House hold Size	Population density (pers./sq. mi.)	Percent SOV to work	Percent carpool to work	Percent public transit to work	Percent bike to work	Percent walk to work	Average travel time to work (min)
	205.98	3934	3934	0.49	1313	10123	4783	2.93	8028.6	58.25%	13.85%	17.58%	0.00%	8.55%	29.1
	206.01	2254	2395	0.44	888	12023	9325	2.57	5443.2	39.44%	17.30%	32.32%	0.00%	6.62%	30.7
	207.03	2111	2063	0.49	749	11758	5845	2.67	4210.2	64.29%	9.69%	21.43%	0.00%	3.57%	24.5
	207.04	613	615	0.75	173	14777	4721	3.53	820.0	77.09%	7.26%	3.35%	0.00%	7.82%	20.8
4b	121	7005	7005	1.53	366	30833	9935	1.46	4578.4	25.50%	21.00%	8.33%	0.00%	42.67%	17.8
	300.22	2603	2600	0.68	725	10505	4298	3.67	3823.5	37.88%	27.00%	27.13%	0.75%	6.25%	24.7
	300.23	1443	1409	0.64	334	20465	4867	3.66	2201.6	67.46%	7.69%	18.05%	0.00%	2.07%	28.4
5a	1503	4690	4690	0.99	1419	15351	5674	3.36	4737.4	60.34%	22.94%	12.93%	0.00%	3.25%	21.7
	1504	4502	4502	0.58	1376	15495	6397	3.29	7762.1	63.97%	24.06%	7.89%	1.19%	2.88%	23.4
	1505	8814	8814	1.03	2471	13630	4559	3.70	8557.3	59.71%	22.33%	12.25%	0.00%	2.79%	24.3
	1506	4607	4607	0.73	1349	18925	6252	3.52	6311.0	69.72%	18.14%	8.09%	0.38%	3.29%	22.5
	1511	7605	7605	1.35	2012	18372	5857	3.70	5633.3	70.75%	17.28%	4.13%	0.00%	5.89%	20.8
	1512	8641	8641	2.79	2189	22012	6455	3.77	3097.1	69.20%	22.42%	3.75%	0.00%	3.13%	23.7
	1513	8544	8544	2.64	2273	21470	6342	3.74	3236.4	67.76%	25.38%	3.71%	0.30%	1.77%	23.8
	1610.85	2698	2670	2.91	793	14441	5361	3.48	917.5	65.86%	27.76%	5.52%	0.00%	0.85%	25.9
	1611	7892	7846	4.03	1870	21383	5572	4.25	1946.9	67.34%	25.90%	4.58%	0.00%	1.29%	25.3
5b	1402	3248	3205	0.75	1085	16236	7253	2.95	4273.3	57.25%	25.00%	10.75%	0.00%	6.37%	21.3
	1403	3590	3590	0.61	1080	17557	6015	3.27	5885.2	59.39%	26.05%	11.17%	1.32%	0.83%	20.8
	1408	5158	5158	0.83	1734	17473	6893	3.07	6214.5	76.47%	12.64%	7.94%	0.00%	1.56%	20.3
	1410	3022	2996	0.71	1050	17346	7409	2.76	4219.7	69.99%	15.68%	13.06%	0.00%	0.00%	25.1
	1411	7360	7360	1.91	2548	17908	7347	2.55	3853.4	69.57%	20.52%	5.21%	0.23%	3.00%	21.4
	1414	8590	8590	3.97	3029	27551	10977	2.82	2163.7	80.95%	15.32%	2.01%	0.00%	0.81%	20.9
	1415	775	830	2.13	169	30703	9928	3.47	389.7	57.40%	3.60%	0.00%	1.20%	34.80%	12.7
	1416	1000	987	1.31	314	30208	9097	3.29	753.4	90.19%	5.37%	3.27%	0.00%	0.00%	18.8
6a	1211.06	6208	6208	3.18	2512	41750	19584	2.48	1952.2	87.88%	11.23%	0.00%	0.00%	0.73%	22.9
	1211.07	9185	9185	2.11	3785	43710	22268	2.43	4353.1	89.27%	8.30%	0.87%	0.00%	1.02%	22.9
	1211.08	5393	5393	1.67	2425	38265	19915	2.25	3229.3	87.10%	11.71%	0.63%	0.00%	0.00%	20.9
	1912	8289	8289	1.80	3541	34561	18204	2.37	4605.0	84.45%	9.95%	1.82%	0.42%	2.48%	18.7
	1913	5805	5805	6.82	2630	20566	14789	2.27	851.2	77.06%	14.42%	2.56%	0.00%	4.83%	19.0
	1914.02	2200	2243	1.22	802	85099	40936	2.72	1838.5	88.07%	10.73%	0.00%	0.00%	0.65%	16.3
	1914.03	6013	6013	1.43	3363	26818	18773	1.80	4204.9	84.66%	9.95%	1.45%	0.61%	2.67%	21.2
	1917	6567	6553	5.49	2257	61669	28120	2.87	1193.6	92.07%	6.56%	0.03%	0.41%	0.07%	23.1
6b	1219.02	3598	3613	5.86	1082	62935	19864	3.23	616.6	92.64%	5.78%	0.00%	0.18%	0.91%	25.8
	1918.02	685	677	5.93	219	59928	23286	3.16	114.2	85.35%	12.09%	0.00%	0.00%	0.00%	27.1
7a	239.03	3352	3319	1.48	1393	72526	43110	2.37	2242.6	90.07%	5.67%	1.93%	0.26%	0.71%	19.3
	240.02	7100	7110	1.53	4148	31291	25439	1.74	4647.1	83.78%	3.98%	6.43%	0.36%	4.94%	19.3
	243	4252	4252	0.74	2178	27221	16211	1.95	5745.9	76.38%	15.34%	6.68%	0.29%	1.30%	16.1
	246	3775	3775	0.73	1673	32910	15512	2.27	5171.2	77.89%	8.15%	8.76%	1.69%	2.86%	18.6
	254.01	3827	3827	1.08	1500	35641	16013	2.46	3543.5	84.53%	10.22%	2.65%	0.32%	1.96%	17.3
	255.01	3528	3528	1.56	1398	32208	15018	2.49	2261.5	84.68%	9.30%	2.09%	0.80%	2.29%	16.3
	256.01	2545	2477	0.95	1066	34268	15768	2.35	2607.4	84.75%	9.73%	2.76%	0.61%	1.38%	16.4
	256.03	3997	4065	1.40	1540	44722	19416	2.57	2903.6	85.40%	9.59%	2.62%	0.00%	2.40%	17.5
	256.05	3757	3757	1.45	1667	40047	19529	2.29	2591.0	87.09%	7.44%	2.31%	0.00%	2.35%	17.3
	259.03	6704	6704	3.25	2567	55860	26156	2.60	2062.8	87.40%	7.47%	2.57%	0.00%	1.38%	21.0

7b	117.02	3547	3547	0.74	1452	43281	19827	2.48	4793.2	81.40%	8.62%	8.29%	0.27%	0.98%	18.6
	120.01	5969	5969	1.00	2544	38301	19946	2.34	5969.0	80.15%	9.40%	8.60%	0.00%	1.60%	19.4
	120.02	5031	5031	0.90	2110	31703	15904	2.33	5590.0	72.58%	8.45%	14.42%	0.25%	3.64%	19.0
	237	4774	4774	1.81	1727	60186	25954	2.77	2637.6	84.17%	10.86%	2.76%	0.34%	1.57%	19.1
	238.01	4886	4886	1.25	1946	52499	27101	2.53	3908.8	84.60%	8.78%	5.00%	0.00%	1.27%	19.7
	238.02	2654	2654	0.55	1111	45452	21344	2.37	4825.5	79.65%	9.49%	8.88%	0.38%	1.61%	18.0
	239.01	3706	3706	1.34	1287	65229	29115	2.80	2765.7	87.80%	8.72%	2.41%	0.32%	0.75%	17.7
	240.01	3468	3468	1.17	1701	39097	27219	1.88	2964.1	82.59%	6.97%	5.97%	0.00%	3.91%	18.9
	241	3624	3614	0.70	1624	34866	17746	2.23	5162.9	80.93%	8.86%	4.48%	0.26%	5.47%	16.1
	244	3076	3181	0.63	1653	24403	15917	1.85	5049.2	78.03%	6.41%	9.08%	0.77%	5.70%	20.6
	247	3237	3237	0.75	1338	37615	16241	2.43	4316.0	85.29%	6.03%	5.31%	0.00%	2.66%	16.7
	249.01	2269	2322	0.44	913	36541	15012	2.53	5277.3	79.43%	10.44%	7.14%	0.00%	1.92%	18.0
8a	303.02	4431	4431	0.90	1505	31232	11641	2.92	4923.3	76.65%	16.99%	2.04%	0.00%	2.38%	23.7
	303.18	2786	2786	0.81	942	35405	13347	2.84	3439.5	83.21%	11.01%	1.38%	0.83%	2.68%	22.2
	303.21	6170	6170	9.01	2493	30294	13533	2.46	684.8	75.44%	15.47%	1.06%	1.15%	4.73%	24.5
	1036.08	1758	1834	0.95	636	37429	16273	2.81	1930.5	82.69%	10.83%	2.73%	1.52%	0.81%	22.2
	1036.09	4813	4737	0.95	2247	29864	17199	2.19	4986.3	78.06%	17.18%	1.17%	0.52%	0.00%	23.5
	1039	5612	5612	0.96	2124	32403	13919	2.74	5845.8	83.12%	11.40%	1.35%	0.85%	1.93%	24.0
	1044	4996	4996	1.99	2484	23068	13131	2.04	2510.6	78.44%	13.02%	3.59%	0.76%	3.42%	21.9
	1055	5481	5481	1.00	3082	22944	14325	1.80	5481.0	68.75%	15.22%	3.61%	0.96%	8.96%	20.4
	1060	5917	5917	0.99	2546	25103	12546	2.32	5976.8	82.04%	12.02%	2.52%	0.00%	1.50%	21.9
	1068	6938	6938	1.01	3105	21768	11429	2.21	6869.3	65.96%	22.77%	5.86%	1.39%	3.67%	24.3
	1073	4908	4908	1.00	2054	21989	11390	2.36	4908.0	65.64%	22.18%	4.97%	2.15%	4.08%	26.1
	1090	9821	9821	0.99	4129	19922	9760	2.32	9920.2	65.47%	18.61%	6.95%	1.42%	5.28%	19.1
	1103	6130	6130	0.97	2643	22767	12016	2.31	6319.6	69.43%	15.37%	9.15%	1.11%	3.22%	20.3
	1120	1865	1818	1.01	757	27539	14502	2.48	1800.0	80.14%	10.39%	2.31%	4.27%	1.96%	19.1
	1128	735	711	1.01	239	9370	10856	3.02	704.0	50.47%	32.24%	9.35%	0.00%	3.27%	21.7
	1144	3845	3845	1.01	1191	14396	5290	3.35	3806.9	58.30%	22.16%	8.91%	2.04%	6.54%	22.9
	1148	2467	2490	2.13	792	11296	5377	3.09	1169.0	52.01%	28.83%	17.88%	0.00%	1.28%	23.3
	1149	2983	3049	1.11	992	7343	5327	2.88	2746.8	41.21%	38.06%	7.35%	0.92%	12.47%	24.2
	1150	3511	3422	1.16	870	16467	4807	3.98	2950.0	49.43%	37.75%	3.95%	0.79%	6.41%	21.8
8b	1048.01	3851	3851	2.20	1450	47500	21136	2.66	1750.5	85.64%	9.49%	1.52%	1.12%	0.91%	23.6
	1051.02	3581	3580	7.44	1662	55556	36643	2.16	481.2	88.22%	8.18%	0.46%	0.00%	1.54%	20.0
	1052	5640	5640	1.58	2453	28419	15286	2.33	3569.6	77.83%	10.34%	2.13%	1.20%	6.11%	21.1
	1064	3052	3052	0.99	1439	36458	26401	2.12	3082.8	81.56%	8.91%	4.89%	0.00%	2.78%	19.4
	1077	3565	3539	1.02	1746	33508	22920	2.07	3469.6	88.26%	8.05%	1.82%	0.34%	1.02%	19.2
	1085	4423	4423	0.99	2218	24637	15119	1.93	4467.7	78.00%	13.18%	3.34%	2.57%	2.10%	17.5
	1107	4974	4974	1.02	2220	25901	13199	2.11	4876.5	68.71%	20.03%	4.44%	0.90%	4.75%	17.6
	1116	7087	7087	1.00	2745	18301	8804	2.52	7087.0	57.82%	22.59%	10.58%	1.13%	5.41%	23.1
	1133	5273	5249	1.01	1702	8540	4363	3.10	5197.0	44.96%	28.42%	13.28%	6.67%	3.27%	24.8
	1139	1754	1622	1.03	498	8441	3499	3.54	1574.8	28.39%	52.01%	8.29%	4.52%	6.78%	22.8
	1151	226	238	1.34	58	13462	4763	3.71	177.6	62.50%	0.00%	13.89%	0.00%	23.61%	19.3
9a	1148	2467	2490	2.13	792	11296	5377	3.09	1169.0	52.01%	28.83%	17.88%	0.00%	1.28%	23.3
	1149	2983	3049	1.11	992	7343	5327	2.88	2746.8	41.21%	38.06%	7.35%	0.92%	12.47%	24.2
	1150	3511	3422	1.16	870	16467	4807	3.98	2950.0	49.43%	37.75%	3.95%	0.79%	6.41%	21.8
9b	1129	5269	5293	1.00	1689	16684	7391	2.95	5293.0	51.17%	26.78%	8.08%	4.19%	7.88%	23.6
	1130	1476	1623	0.51	725	16166	10924	1.95	3182.4	54.59%	8.55%	18.11%	4.59%	10.33%	22.9
	1132	8847	8661	1.01	2384	15130	4685	3.66	8575.2	40.25%	39.50%	10.18%	1.35%	5.80%	24.2
	1133	5273	5249	1.01	1702	8540	4363	3.10	5197.0	44.96%	28.42%	13.28%	6.67%	3.27%	24.8

10a	2	4534	4565	0.74	1967	17703	9657	2.29	6168.9	67.93%	13.34%	8.91%	2.38%	5.83%	16.7
	3	1628	1655	0.52	687	10528	6247	2.20	3182.7	54.47%	16.10%	3.90%	4.07%	19.02%	17.0
	10	1238	1267	0.46	380	6995	5049	3.22	2754.3	61.17%	8.42%	16.12%	6.59%	7.69%	24.4
	11	3045	3016	0.47	911	17356	6727	3.56	6417.0	54.33%	32.78%	7.64%	0.92%	2.21%	19.7
	23	5093	5090	1.01	1682	9869	5071	3.07	5039.6	47.12%	27.80%	16.82%	2.12%	5.53%	24.2
	25.01	5398	5401	2.58	1263	18665	5497	3.43	2093.4	66.83%	24.32%	3.88%	0.00%	3.34%	20.4
	45.04	5122	5122	3.43	2554	15560	9710	1.98	1493.3	72.89%	13.37%	2.76%	1.35%	4.92%	21.0
10b	24	6129	6129	1.25	1817	13606	5065	3.37	4903.2	55.25%	28.75%	8.36%	0.00%	4.33%	23.8
	25.01	5398	5401	2.58	1263	18665	5497	3.43	2093.4	66.83%	24.32%	3.88%	0.00%	3.34%	20.4
	37.03	8884	8982	1.57	2528	21218	6578	3.47	5721.0	65.58%	25.36%	5.05%	0.51%	2.49%	21.9
	38	8709	8709	1.56	2451	16220	5523	3.49	5582.7	62.88%	25.62%	5.01%	0.55%	2.75%	22.4
	39	8290	8294	2.54	2312	24972	7641	3.64	3265.4	66.64%	25.59%	4.62%	0.00%	0.56%	24.3
11a	29	3654	3654	1.55	1349	17255	8501	2.65	2357.4	74.51%	16.62%	4.34%	0.59%	2.63%	18.3
	34	3966	3947	3.10	1810	15412	9407	2.14	1273.2	76.47%	13.27%	2.86%	0.42%	6.19%	17.5
	37.03	7085	7006	3.65	2804	27079	11977	2.55	1919.5	85.34%	12.06%	0.80%	0.31%	0.89%	19.4
	37.05	8750	8750	1.53	3525	38411	16834	2.48	5719.0	85.49%	10.27%	1.32%	0.63%	1.67%	19.1
	37.97	3683	3661	0.90	1396	18607	7805	2.71	4067.8	76.86%	14.29%	2.53%	0.32%	3.86%	16.3
	37.98	3638	3630	8.81	1374	26026	10900	2.61	412.0	86.15%	11.26%	0.00%	0.37%	2.23%	18.5
11b	1.23	5409	5409	0.96	2017	31612	15718	2.65	5634.4	82.78%	13.29%	0.42%	0.69%	0.92%	17.2
	1.24	3486	3486	0.66	1935	17161	13134	1.75	5281.8	78.99%	9.82%	5.34%	0.80%	3.46%	16.4
	2.07	3669	3669	0.97	1499	30422	13624	2.49	3782.5	84.59%	5.41%	3.81%	1.49%	2.68%	14.5
	2.08	3031	3031	0.80	1284	24134	11029	2.41	3788.8	83.31%	9.13%	1.77%	1.50%	2.86%	14.8
	3	6446	6446	1.45	3096	29894	19531	2.05	4445.5	76.98%	9.88%	1.95%	3.05%	7.34%	15.0
	4	7826	7826	1.69	3541	29541	19287	2.26	4630.8	86.14%	8.64%	1.82%	1.77%	1.05%	17.2
	6.01	3908	3908	0.93	1743	31063	16318	2.22	4202.2	88.00%	5.54%	2.80%	1.40%	1.46%	15.8
	7.03	9496	9496	2.51	3396	34234	14500	2.71	3783.3	81.56%	13.37%	1.93%	0.40%	1.41%	20.3
	7.04	3834	3834	1.01	1432	30062	12521	2.68	3796.0	83.60%	10.22%	1.04%	2.02%	1.86%	19.3
	7.07	5620	5621	1.31	2308	21037	9903	2.41	4290.8	66.11%	23.54%	5.19%	1.15%	2.77%	19.9
	7.08	4033	4072	1.16	1598	22099	10764	2.48	3510.3	72.86%	21.73%	1.98%	0.00%	2.14%	19.7
	34	3966	3947	3.10	1810	15412	9407	2.14	1273.2	76.47%	13.27%	2.86%	0.42%	6.19%	17.5
12a	1062	1764	1774	2.71	669	29744	12657	2.63	654.6	88.21%	10.36%	0.00%	0.00%	0.78%	17.9
	1063.01	3606	3606	0.99	1170	22416	8309	3.08	3642.4	83.99%	12.88%	0.82%	0.74%	0.00%	17.8
	1063.02	3647	3647	2.00	1358	21023	9459	2.63	1823.5	78.82%	15.43%	1.37%	0.00%	2.05%	20.7
	1083.01	1563	1441	5.96	471	30759	11888	3.12	241.8	77.75%	17.61%	0.00%	0.00%	3.10%	20.0
	1083.02	2282	2473	5.55	904	35643	22180	2.47	445.6	91.27%	6.78%	0.53%	0.00%	0.38%	21.1
12b	1066.08	3334	3341	1.04	1425	40016	21018	2.12	3212.5	93.54%	5.05%	0.00%	0.55%	0.00%	17.4
	1084.02	1490	1490	0.45	628	39286	17742	2.43	3311.1	91.90%	8.10%	0.00%	0.00%	0.00%	19.0
	1085.06	3254	3263	1.15	1378	50430	30924	2.38	2837.4	92.59%	5.36%	1.02%	0.00%	0.60%	19.0
	1085.07	1062	1153	0.33	639	41645	28301	1.68	3493.9	92.41%	7.59%	0.00%	0.00%	0.00%	20.1
	1085.08	1910	1819	2.40	710	47130	21019	2.65	757.9	85.36%	12.56%	0.00%	0.00%	0.93%	21.0
13a	50.01	2227	2224	0.53	1039	20036	11569	2.10	4196.2	87.20%	7.76%	1.61%	0.00%	2.72%	16.1
	50.02	4198	4150	0.98	1985	22699	20728	2.09	4234.7	81.83%	11.70%	2.87%	0.00%	3.03%	16.2
	51	1894	1942	0.95	832	50295	30336	2.39	2044.2	90.96%	7.09%	0.69%	0.00%	1.26%	14.3
	52	3323	3323	1.00	1609	34179	20403	2.10	3323.0	88.20%	6.87%	0.94%	0.75%	3.25%	16.2
	68.01	3205	3205	0.53	1479	19817	12237	2.15	6047.2	83.65%	13.42%	1.26%	0.47%	0.00%	19.7
	68.02	5888	5888	1.02	3057	24272	16091	1.96	5772.5	83.09%	12.41%	1.28%	0.28%	2.72%	15.8
	69.01	4473	4431	0.99	2222	36078	21776	1.97	4475.8	87.80%	10.34%	0.63%	0.00%	0.86%	15.7
	86	4436	4436	1.00	2151	21650	14868	1.96	4436.0	76.73%	11.64%	2.52%	0.00%	7.28%	16.8
	87	3532	3532	1.01	1790	31467	23976	1.99	3497.0	83.94%	12.43%	0.80%	0.43%	1.49%	17.4
13b	36	2277	2294	0.50	1136	33138	20503	2.00	4588.0	84.38%	9.54%	1.52%	1.44%	1.60%	15.7

39	4279	4279	0.97	2125	25223	13796	1.97	4411.3	90.60%	7.66%	0.00%	0.53%	0.87%	14.4
40	4727	4727	0.98	2151	27666	15578	2.11	4823.5	84.93%	11.06%	1.63%	0.00%	1.77%	14.7
42	1903	1928	0.47	905	39877	22000	2.09	4102.1	95.01%	3.83%	0.00%	0.00%	0.70%	14.2
53	5034	5034	0.99	2116	33156	15172	2.42	5084.8	93.66%	4.82%	0.87%	0.00%	0.35%	14.8
70	3176	3176	0.99	1450	25121	15065	2.14	3208.1	76.37%	16.49%	2.65%	0.51%	2.91%	15.7