Benefit-and-Cost Analysis of Strategic Acquisition of Limited Access Right-of-Way near Interchanges

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INTRODUCTION

Past research shows that access connections and signalized intersections within the functional area of an interchange can adversely impact safety and operations at the interchange and on the freeway. A variety of transportation problems occur when driveways and intersections are too close to interchange ramps. Signalized intersections too close to ramp termini can cause heavy volumes of weaving traffic, complex traffic signal operations, accidents, congestion, and traffic backing up the ramps on to the main line (*1*).

It follows, therefore, that avoiding access in the functional area of freeway interchanges through effective planning and access control will preserve traffic safety and operations and may eliminate or postpone the need for interchange improvements. Alternatively, access in the functional area of a freeway interchange may shorten the functional life of the interchange and lead to serious safety and operational problems on the mainline, as well.

Although the safety and operational benefits of managing interchange area access are clear, the cost-effectiveness of strategically acquiring additional limited access right of way has not been examined. For example, would acquiring more access control in the vicinity of interchanges preserve the safety and operations of an interchange and the freeway for a longer period, thereby reducing the need for interchange reconstruction? If so, will the up front cost of acquiring more access control, be outweighed by the benefits of improved driver safety and not having to reconstruct the interchange sooner than planned? And if inadequate access management contributes to early interchange failure, what about the potential costs of right-of-way acquisition for reconstructing the interchange after development has occurred?

The Center for Urban Transportation Research (CUTR), under a grant from the Florida Department of Transportation (FDOT), is examining these policy questions. The primary objective of the study is to determine if the potential benefits of acquiring additional limited access right of way at interchange areas outweigh the potential costs. The study is particularly important given the dramatic increases in right-of-way costs that have been observed in Florida over the past few decades.

BACKGROUND

The control of access around interchanges has been an issue in planning and engineering for decades. As early as the 1960's, Ross Netherton addressed this issue in the landmark work *Control of Highway Access*, and concluded that interchange areas present special challenges concerning access management and land use control, due to the discrepancy in traffic volumes and speeds where the interchange connects with surface road systems (*2*). Managing this interface is critical to preserving the capital investments made in interchange areas (*3*).

A 1968 study, which provided the basis for changes to Illinois access control policies at interchange areas, recommended expanding the acquisition of property access rights "in critical cross-route problem areas."(*4*) The study encouraged the development of a comprehensive plan for interchanges when the interchange is designed to discourage shallow frontages in the vicinity of interchanges and to redirect site frontage and access onto service drives or local streets.

Netherton noted that a properly planned and managed interchange area can become an economic asset for a community, while a poorly planned interchange can become a quagmire of reconstruction costs and property rights issues (*2*). He goes own to conclude, however, that efforts to restrict access through police power had not been particularly effective in areas with high value property, because political pressure to allow access can be overwhelming (*2*). For these reasons, he advocated the purchase of access rights for control of interchange area access.

The methods used to control access have historically fallen into two areas — police power and eminent domain. Governments may exercise police power for access control for the health, safety, and welfare of the traveling public. Examples of police power techniques for interchange access management include service road ordinances, policies and regulations for the permitting of access connections in interchange areas, and implementing ordinances for access management plans. Police power activities are generally not compensable to property owners, if the regulation addresses a legitimate public health, safety, or welfare issue and is applied within the limits of the U.S. Constitution.

Eminent domain is the right of government to take private property for a public use with compensation to the property owner, and is the process under which transportation right-of-way is acquired for interchanges and other transportation facilities. Compensation in Florida is determined based upon market value, as well as any business or severance damages that may have been incurred by the impacted site. The acquisition of limited access right-of-way not only involves the purchase of land for right-of-way, but acquiring a property's right to access, as well. A key issue in purchasing limited access right-of-way is whether reasonable access exists for the remainder of the site. Otherwise, state transportation agencies may be required to purchase the entire property.

Current Practice

Most state transportation agencies address limited access right-of-way in their roadway design manuals, which reflect policies of the American Association of State Highway and Transportation Officials (AASHTO). The AASHTO publication, *A Policy on Design Standards – Interstate System*, recommends that access control lines for interchanges "should extend beyond the ramp terminal at least 100 feet in urban areas and 300 feet in rural areas (*5*). However, in areas where the potential exists for traffic problems, it may be appropriate to consider longer lengths of access control." Therefore, state interchange access control policies are still primarily limited to the immediate area of the interchange.

However, state practice is beginning to shift in response to contemporary guidance emerging from AASHTO and the Transportation Research Board. The 2001 edition of the AASHTO *Policy on Geometric Design of Highways and Streets* (“Greenbook”) provides more extensive treatment of the subject of interchange area access control than previous editions. It addresses the importance of access control on interchange crossroads and mentions techniques to control access (*6*). The TRB *Access Management Manual* includes guidelines for interchange area access spacing ranging from 750 feet to ½ mile, depending upon the geometric characteristics of the interchange and crossroads, and whether the access is signalized (*7*).

METHODOLOGY

This study seeks to determine whether acquiring additional limited access right-of-way at the time an interchange is built and before the surrounding area is subdivided and developed, is in fact cost effective in light of potential costs and benefits. The methodology included the following basic steps: 1) traffic operations analysis of the interchange with varying configurations of signalized access spacing, 2) safety analysis of interchanges with varied access spacing in Florida, and 3) a cost/benefit analysis of acquiring varying amounts of limited access right-of-way. Each component of the methodology and research findings is described below.

OPERATIONS ANALYSIS

Site Selection

With the assistance of FDOT, a list of potential sample interchanges was developed for possible use in this study. The criteria used to select the sample interchanges included:

- Availability of CORSIM research data;
- Availability of cost data on past improvements (ramp and/or access improvements);
- Scheduled future improvements; and
- Land development and access characteristics

An interchange at I-75 and Bruce B. Downs, in Tampa, Florida, was identified that met these criteria and was therefore selected for further analysis.

Computer Simulation

CORSIM files for the interchange at I-75 and Bruce B. Downs were obtained from FDOT. The original CORSIM models simulated the interchange I-75/Bruce B. Downs and its influence zone, which includes several signalized intersections along Bruce B. Downs and a nearby interchange at I-75 and Fletcher Avenue. These CORSIM simulation models were investigated further to evaluate the operational effects of limiting access near the freeway interchange ramp.

Although the initial analysis began with a case study evaluation of the actual interchange, it soon became clear that a case study approach would confound the analysis with too many variables and situational characteristics unique to the interchange. To better isolate the effects of acquiring varying amounts of limited access right-of way on the operational life of an interchange, the existing interchange characteristics were modified to reflect a standard diamond interchange area configuration.

The extraneous links of the CORSIM network were then removed, so the analysis could focus on the effects of varied signalized access spacing on traffic operations at the interchange. The final CORSIM network contained one direction of the freeway, a small segment of the arterial cross-street, the northbound off-ramp, the corresponding on-ramp, and the downstream traffic signal. The number of lanes on the freeway, off-ramp, arterial, and intersections were the same as those for the actual study interchange, except for the elimination of a free flow right-turn opportunity.

Variables other than signalized access spacing certainly would have an impact on interchange operations. However, to simplify and focus the analysis, the following variables were considered to be constants:

1. Distribution of traffic volumes on the freeway mainline and off ramp,
2. Percentage of turning movement counts at the intersections,
3. Proportion of weaving vehicles
4. Heavy vehicle percentage,
5. Signal progression effects.

In summary, the final methodology for the operational analysis included the following three steps:

1. Modify the existing interchange configuration to an average urban diamond design including the elimination of a free flow right-turn opportunity. Then increase the traffic flowing through the interchange area until the interchange fails operationally.

2. Model the modified interchange with 200 feet of access spacing between the freeway ramp intersection and the first signalized intersection on the arterial (permitting no additional access between the ramp terminus and the intersection) and increase traffic flow until the interchange fails operationally.

3. Continue to model the interchange with the varied access spacing between the freeway ramp intersection and the first signalized intersection on the arterial at 200-foot increments (continuing to permit no additional access between the ramp terminus and the intersection) until the intersection is approximately one-quarter mile downstream and increasing traffic flow at each increment until the interchange fails operationally.

For the purpose of the analysis, a three percent annual growth rate in all traffic was assumed. “Fails operationally” indicates that the off-ramp traffic queue from the interchange traffic signal was observed backing up onto the interstate mainline based on CORSIM simulation. To measure the effects the various limited access right-of-way lengths on interchange operations, two measures of effectiveness relating to the traffic characteristics of the interchange were used:

1. Queue Length on the interchange off-ramp
2. Vehicle Hours of Delay for the entire network

Based on initial simulation studies, a highly significant correlation was observed between the queue length on the interchange off ramp and access spacing. The relationship between these two variables reveals how insufficient access spacing causes off-ramp traffic to back into the freeway mainline and create major delays on the interstate. The delay of the entire network could be used to quantify the operational benefits from reduced delay for the varied access spacings.

Findings

The operational analysis included two parts: 1) effects of the length of access controlled frontage on the traffic back ups on the interstate; 2) estimated delay savings between varied lengths of access controlled frontage.

To test the effect of varied length of access controlled frontage on traffic back ups on the interstate, the length was set from 200 feet to 1320 feet at 200-foot increments. For each signalized access spacing, traffic volumes were gradually increased until the traffic on the off-ramp was observed to back into the freeway mainline. Figure 1 illustrates traffic volumes on the off-ramp and arterial that make the interchange fail operationally.

To reduce the number of combinations of traffic volumes on the off-ramp and arterial, the volume on the off-ramp was set same as the directional volume on the arterial. Figure 1 illustrates the impact of increasing signalized access spacing on traffic volumes that the off-ramp can accommodate before interchange failure. For example, when the signalized access spacing was equal to 200 feet, the interchange failed operationally when the off-ramp volume or directional arterial volume reached 1,500 vph.

As seen in the figure, increasing access spacing from 200 feet to 600 feet resulted in the most significant capacity gains, and these capacity gains began to level off between 600 feet to 1320 feet. Volume of the off-ramp and arterial was increased by approximately 400 vph when the access spacing was increased from 200 feet to 600 feet. Between 600 feet to 1320 feet, volume of the off-ramp increased by about 100 vph.

Given the study assumptions, including a 3% growth rate in traffic volume, the increase of access spacing from 200 feet to 600 feet would postpone interchange failure for approximately 8 years. Acquiring one-quarter mile of limited access right-of-way could potentially extend the operational life of the interchange for approximately 10 years.

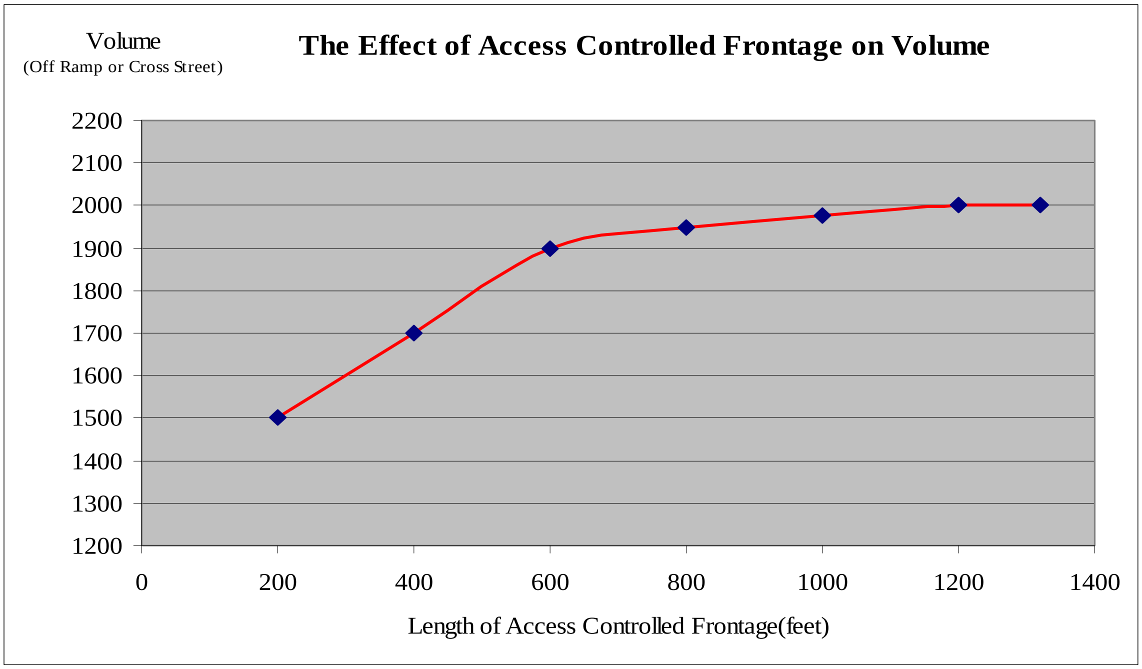

Figure 1 the Effect of Access Controlled Frontage on Volume

Based on the above analysis, three alternatives for signalized access spacing—200 feet, 600 feet, and 1320 feet—were recommended for evaluation in the cost benefit analysis. The difference of total network delay was used to quantify operational benefits of one alternative over the other. In this study, the traffic volume was assumed to increase at a 3% growth rate. Usually, a new interchange was designed for a normal 20 year life. The geometry of the simulation network was assumed to keep same over the interchange lifetime. A total of 20 CORSIM simulation runs were conducted for each alternative.

SAFETY ANALYSIS

The safety analysis examined crash rates in the vicinity of exit ramps at several interchanges. The study sites, selected in coordination with FDOT, were interchanges characterized by traffic back-ups onto the freeway mainline due to insufficient separation of signalized access on the crossroad. The objective of the safety analysis was to relate crash frequency to the length of access controlled frontage, and provide an approximate measure of potential crash reduction for the benefit and cost analysis.

Crash data for the study sites were obtained from FDOT for a five year period from 1999 to 2003. For each site, crash data were obtained for a one mile freeway section before the off ramp. This freeway segment was believed to most likely have safety problems due to insufficient access controlled right-of-way. The study sites are listed as follows:

- I-295 N/Blanding Boulevard(Duval County)
- I-295 S/Blanding Boulevard(Duval County)
- I-95 S/J. Turner Butler Boulevard(Duval County)
- I-75 N/SR 54 (Pasco County)
- I-4 N/Lee Road (Orange County)

- I-95 N/Commercial Boulevard (Broward County)
- I-95 S/Commercial Boulevard (Broward County)
- I-275 N/Fowler Avenue (Hillsborough County)
- I-275 S/Fowler Avenue (Hillsborough County)
- I-275 N/Hillsborough Avenue (Hillsborough County)
- I-275 S/Hillsborough Avenue (Hillsborough County)

The crash data on the one mile of freeway section at above study sites were collected for a five year period. Figure 2 illustrates the relationship between actual number of crashes in five years and varying signalized access spacing. It indicates that the potential number of crashes could be reduced when signalized access spacing is increased.

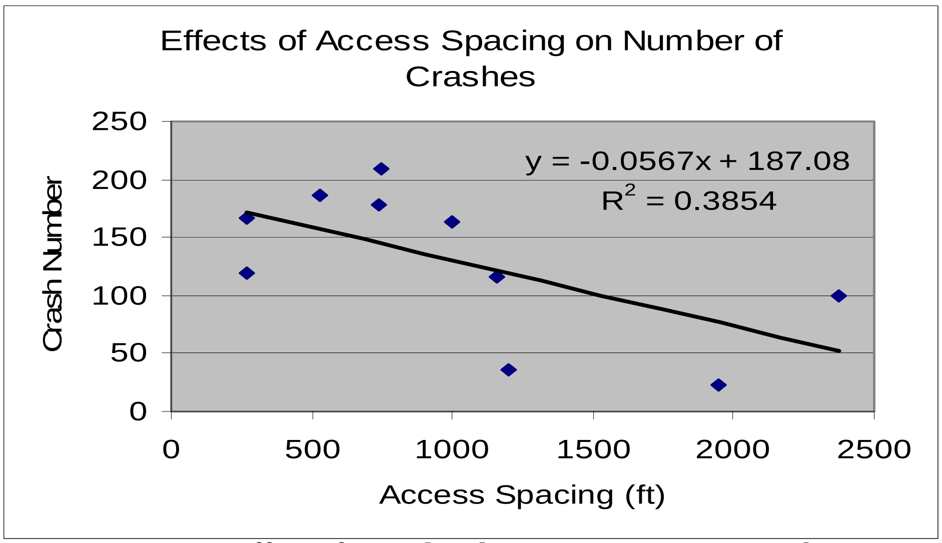

Figure 2: Effect of Signalized Access Spacing on Crashes

Cost/Benefit Analysis

The final step was to conduct a cost/benefit analysis to compare the relative costs and benefits associated with purchasing different lengths of right of way. The benefit-and-cost ratio was calculated for two comparisons: Alternative A (200') vs. Alternative B (600') and Alternative A (200') vs. Alternative C (1320') using the following equation: B/C = (B1+B2+B3)/C1. The future benefits in each area were converted into present values using the federally recommended discount factor of 7% (*8*). Below is a detailed overview of the calculations.

Benefits:

1. \$ savings for not purchasing LA ROW on developed land (B1)
   $B1 = \text{Average Cost of ROW Per Front Foot} * 400/(1+\text{DiscountFactor})^{20}$

Where,

B1 = present value of ROW for 400 feet of developed land. 400 feet was believed to be the minimum length that needs to be purchased in order to reconstruct the freeway off ramp area.

2. decreased delay and travel time (B2)
   $B2= \sum[(\Delta\ Delay_i*1.25*2*250*\text{ average cost of time})/(1+DiscountFactor)^i]$

Where,

$\Delta\ Delay_i$=the difference of delay between two alternatives in i years
i=the number of years from the base year up to twenty
Working Days: 250 days per year
Average Cost of Time ($2002) $13.25 per person hour
2 refers to 2 PM peak hours per day,
Vehicle Occupancy: 1.25 persons per vehicle
(Source: TTI Urban Mobility Report)

3. fewer accidents (B3)
   $B3=\sum[(\Delta\ Fatality_i * \text{average cost per death} + \Delta\ Injury_i * \text{average cost per injury} + \Delta\ PDO_i * \text{average cost per PDO})/(1+DiscountFactor)^i]$

Where,

Δ Fatality=the difference of number of fatalities between two alternatives in i years
Δ Injury=the difference of number of injuries between two alternatives in i years
Δ PDO=the difference of number of Property Damage Only crashes between two alternatives in i years
i=the number of years from the base year up to twenty
Average cost for each type of crash:
Death: $1,120,000
Nonfatal Disability Injury: $45,500
PDO: $8,200
(Source: National Safety Council 2003)

Costs:

1. Initial cost for purchasing additional LA Right of Way of undeveloped land (C1)

The average costs of ROW per front foot were obtained from the Florida Department of Transportation (FDOT) as follows:

- Average Rural Unimproved: $500 per front foot
- Average Rural improved: $1,000 per front foot
- Average Urban unimproved: $1,625 per front foot
- Average Urban improved: $15,000 per front foot

B/C Ratio

The results of benefit-and-cost analysis for the two alternatives are provided in Tables 1-2. It is apparent from these findings that the combined benefits of acquiring additional limited access right-of-way near an interchange in advance of development far exceed the costs of cure after the fact

Table 1 Benefit-and-Cost Ratio of Alternative A (200') vs. Alternative B (600')

	Urban		Rural	
	Benefit	Cost	Benefit	Cost
ROW (B1)	$1,550,514	$650,000	$103,368	$200,000
Delay (B2)	$28,280,906	\	$28,280,906	\
Crashes (B3)	$1,809,178	\	$1,809,178	\
Total	$31,640,598	$650,000	$30,193,452	$200,000
B/C Ratio	49		151	

Table 2 Benefit-and-Cost Ratio of Alternative A (200') vs. Alternative C (1320')

	Urban		Rural	
	Benefit	Cost	Benefit	Cost
ROW (B1)	$3,085,196	$1,820,000	$205,680	$560,000
Delay (B2)	$31,256,063	\	$31,256,063	\
Crashes (B3)	$5,065,698	\	$5,065,698	\
Total	$39,406,957	$1,820,000	$36,527,441	$560,000
B/C Ratio	22		65	

CONCLUSIONS AND RECOMMENDATIONS

Rapid population growth and escalating right-of-way costs in Florida have potentially dire implications for the ability of the Florida Department of Transportation to keep pace with transportation improvement needs. For interchange areas the problem is particularly acute, given the rapid development that occurs when an interchange is built. If this development is not carefully planned, the resulting access problems can lead to premature interchange failure and safety hazards on the freeway. At that point, reconstructing the interchange may prove cost prohibitive, given the cost of acquiring limited access right-of-way on commercial property.

Although the Florida Department of Transportation regulates access spacing in interchange areas, managing interchange area access through police power alone has certain limitations. Political pressures tend to be high for interchange area access, development is rapid but incremental making coordinated planning difficult, and land ownership patterns and subdivision practices can limit the effectiveness of state policies. Access permits cannot be denied to individual properties when the result would be to deny all access, unless the property is acquired by the government agency or alternative access is provided.

Given these limitations, it is advisable for state transportation agencies to acquire additional limited access right-of-way (beyond the standard 100 or 300 feet) when the interchange is being planned and before the adjacent land is subdivided and developed. This would help redirect access to more appropriate locations for safety and traffic operations. It would also help promote adequate internal street and circulation networks for interchange area development. Those who own businesses or have homes in the interchange area would benefit from improved access design and the lower likelihood that their land would be damaged or needed for interchange expansion. Policy measures would help accomplish the desired outcomes.

These findings indicate that the long term safety, operational, and fiscal benefits of purchasing additional limited access ROW at interchange areas, greatly exceed the initial up front costs of acquiring additional limited access right-of-way. Clearly, the findings are preliminary, given the limited data set, the generalized nature of the study interchange, and the limitations of CORSIM. Additional research is suggested to further refine and expand upon these results. Nonetheless, the results suggest that state transportation agencies and the traveling public may benefit greatly by an increase in the amount of limited access right-of-way at interchange areas to a minimum 600’ and a desirable ¼ mile.

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