USING BENEFIT/COST ANALYSIS FOR AUXILIARY TURN LANES FOR NEW ACCESS CONNECTIONS

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ABSTRACT

The benefits to public safety and traffic operation compared to the costs of installing access connection improvements is a frequent topic of discussion and sometimes controversial. This paper discusses the difference between the applications of benefit-cost analysis (BCA) to access connections that are an element of a roadway reconstruction project compared to the BCA for a new access connection to an existing roadway. Use of a BCA for establishing access design warrants is discussed. The nature of the potential benefits and costs to road users (public) and to the private entity (developer/property owner) are identified and the allocation of and ability to establish a monetary value for each benefit and cost element evaluated.

Economic analysis is a useful method to identify situations in which turn lanes can be justified economically at an existing intersection taking into account construction and new right-of-way compared to operation and safety benefits. There have been several studies regarding the B/C of left-turn lane installations based on the underlying assumption that the analysis is for public intersections where costs will be paid by public funds and the benefits will accrue to the public in the form of safety and improved operations at an existing intersection; most recently, *NCHRP Report 745*, 2013.

However, when a new access connection will be to service a new development, the benefits and cost accrued are borne by different parties. There is always a negative benefit to the traveling public when comparing the before and after situation due to additional delay and increased crash risk. The primary benefit accrues to the development. In most jurisdictions, the cost of the new access is borne by the development.

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INTRODUCTION

Use of B/C analysis for establishing warrants for auxiliary turn lanes is discussed. The nature of the potential benefits and costs to the public (road users) and to the development entity are identified. The ability to establish a monetary value for each benefit and cost element is evaluated. An example is provided to illustrate the interpretation of the B/C ratio where reduced costs to the public are improperly used as a benefit.

The roadway design manual and access management regulations are separate but related criteria relating to roadway design and operation. The roadway design manual establishes standards for the design of new roadways and major reconstruction of existing roadways. Deviations typically require a design exception. Approval of an exception is commonly at a very high administrative level. Access management regulations govern the location and design of new access connections to an existing roadway. There regulations address the following three areas: 1) roadway classification for access management, 2) access management standards, and 3) permitting. Deviations from access management standards should be more flexible than design exceptions and approval levels should be relatively low administrative level.

This paper is concerned with: 1) access management standards – specifically left-turn lanes, right-turn lanes, shoulder bypass lanes, and median treatments to prohibit left-turns at an access connection; and 2) the difference between the roadway design manual and access management regulations in the permitting process.

Warrants for left-turn and right-turn lanes contained in the AASHTO Greenbook (Exhibit 9-75) and many state DOT design manuals are based on Harmelink [1]. (See van Schalkwyk and Stover [2], Kikuchi and Chakraborty [3], and Ivan, et al [4], for critiques of the Harmelink Methodology.) Warrants for left-turn lanes of unsignalized intersections based on a benefit-cost (B/C) analysis was recently developed by NCHRP Project 03-91, *NCHRP Report 745* [5]. A B/C analysis was also used to develop warrants for right-turn lanes on two-lane roadways [6].

BENEFIT AND COST ISSUES

A benefit/cost (B/C) analysis is applicable when both of the following conditions are satisfied:

1. All benefits and costs are measurable and can be qualified as a monetary value
2. All the benefits and all the costs accrue to the same identity

A benefit/cost (B/C) analysis is applicable on roadway design decisions to provide, or not provide, an auxiliary lane (left-turn, right-turn, or through lane) as an element in the retrofit of an existing roadway or new construction since both the benefits and costs accrue to the public. Hence, a B/C ratio of 1.0 or greater, indicates that the road users will “receive” at least one dollar of benefit of each dollar expended by the public agency to make the improvement.

RETROFIT AND NEW CONSTRUCTION

Public funds are frequently used in roadway reconstruction in the two following situations:

1. Retrofit of an auxiliary lane or median treatment to an existing access connection.
2. Retrofit of a segment on an existing roadway that will address changes in one or more access connections.

In both cases the cost of the retrofit treatment(s) are borne by the public. The safety and operational benefits of the retrofit treatment(s) also accrue to the public. Therefore the economic criteria for a B/C analysis are satisfied.

A similar structure occurs with new construction. That is, both the cost of providing an auxiliary lane(s) or median treatment in the construction of a new roadway and the benefits of the auxiliary lane(s) or median treatment accrue to the public.

When the roadway volume is low and turns from the roadway are infrequent, the probability that a turning vehicle will interfere with a following through vehicle is extremely small. As the roadway volume and turn volume increase, the probability that a turning vehicle will interfere with a following through vehicle increases. As the roadway volume increases, the probability that a turning vehicle will impact following through vehicles approaches a value of 1.0. Under platoon flow, a turning vehicle will result all following vehicles to decelerate causing these vehicles to be "expelled" from the progression board width. A small number of turning vehicles will result in total distraction of traffic progression.

A NEW CONNECTION TO AN EXISTING ROADWAY

Certain roadway safety and operation conditions exist on a road segment prior to construction of a requested connection. Once a new access connection is constructed, there will be some negative effects on that roadway segment in the form of crashes, speed changes, delay, fuel consumption, vehicle emissions, etc. These are costs imposed on the public (road users) for the benefit of a private entity (applicant, developer, property owner). Thus, a new access connection involves a transfer of wealth from the public to a private entity. The private entity pays for the construction of required mitigation feature (left-turn lane, right-turn lane, bypass lane, or median/median barrier) while imposing a cost (increased crash and operating cost) on the public (road users). Consequently, benefits and cost as defined in an economic definition of benefit/cost analysis does not exist. Thus, as is discussed later in this paper, a B/C approach is not applicable to warrants for a new access connection to an existing roadway.

When permitting an access connection, some of the benefits and some of the costs associated with an auxiliary lane accrue to the public and some accrue to the developer/property owner as

indicated in Table 1. This results in serious issues in the application of the B/C analysis because it violates the fundamental principle that benefits and costs must accrue to the same entity.

Another critical issue is that adding an access connection where one does not exist at present results in safety and operational costs to the public (road users). Provision of an auxiliary turn lane will reduce these costs – but will not eliminate them. In most cases the benefit (increased in property value) to the applicant of an access treatment will be very small; if not zero. A right-turn lane improves safety and traffic operations on the roadway at and in close proximity of the access connection. In absence of documentation that clearly indicates that a right-turn, or left-turn lane, increases property value, the appraised value of a property will be the same with and without the turn lane. Where a median barrier is required to restrict movement to right-in/right-out only, the appraised value may to be less with the right-in/right-out restriction than without it – a disbenefit to the developer/property owner. Similarly, the effects on business activity (sales volume or rents) is so small as to be unmeasurable – resulting in no benefit to the applicant (developer/property owner.)

The value of a specific property with access, or without access to the public roadway system can be ascertained/estimated by a qualified real estate appraiser. However, in most if not all cases, it is not possible, at present, to establish benefits to the developer/property owner as a consequence of a turn lane. The cost component of the B/C ratio will be large and will consist of the two following components: 1) the cost of providing the auxiliary lane (borne by the applicant) and 2) the cost of degraded safety and operations (borne by the public). Therefore a B/C analysis is not rational.

Table 1: Benefit and Cost Components Involved In the Analysis of an Access Connection

Component	Cost or Benefit	Affected Party	Quantifiable
Crashes	Cost	Public	Yes (1)
Fuel Consumptions	Cost	Public	? (2)
Vehicle Emissions	Cost	Public	? (3)
Delay/Increased Travel Time	Cost	Public	? (4)
Right-of-Way	Cost	Developer	Yes
Construction	Cost	Developer	Yes
Maintenance	Cost	Public	Yes
Increased Property Value	Benefit	Developer	? (5)
Increased Property Tax	Benefit	Public	? (5)
Increased Rent/Sales	Benefit	Developer	? (6)
Increase Sales Tax	Benefit	Public	? (6)

(1) Yes indicates that the components can be quantified in a monetary (dollar) amount.

(2) Fuel consumption will occur in a very small increment per vehicle; quantification may be difficult.

(3) Vehicle emissions may be measurable; however, assigning a monetary (dollar) value is questionable.

(4) Delay/increased travel time may be determined but the delay/increased travel time per vehicle is (will be) small. However, the total time saved is (will be) substantial due to the large number of vehicles involved. Economic theory discounts the value of total time that occurs as a very small quantity for each of each event (e.g. the delay as travel time experienced by the occupants of each individual vehicle). For example, consider the "apparent" savings for 1.2 persons per vehicle (average) experiencing a 2.0 second per vehicle increase in travel time, and 20,000 vehicles per day impacted:
(1.2 persons/vehicle)(2.0 seconds/vehicle)(20,000 vehicles per day)(365 days/year) = 17,520,000 seconds => 4,867 hours per year
At $17.00 per hour, the "apparent" value of the increased travel time is (4.867 hours/year) ($17/hr.) = $82,739 per year. This appears to be a substantial cost. However, a 2.0 second interval has no practical values. Therefore the "apparent" value of $82,739 has no value to the economy. Note, the same rationale applies to the evaluation of time saving resulting from the addition of the auxiliary lane to an existing roadway, reconstruction of an existing roadway, or new construction.

(4) The increase in property value attributable to a turn lane is not measurable at present. Consequently, property tax revenue is also unmeasurable. Moreover, restriction of movement's right-in/right-out can be expected to result in a lower appraised value with the access treatment than without it. A disbenefit to the property owner while it would result in improved safety and roadway operations.

(5) At present, there is no research to show that an access treatment (such as turn lanes) will increase sales or rentals. It may be argued that restricting movements to right-in/right-out will decrease sales and, in turn, sales tax receipts.

Reduced Cost to the Public as a "Benefit"

Some agencies/individuals treat a reduction in cost as a "benefit". This may appear to be logical in access connection permitting when a connection must be permitted. However, such an approach may result in the B/C ratio "justifying" a transfer of cost from the applicant to road users. Consider the following example:

Circumstances

- Cost of public (present worth of expected crashes) without a turn lane = $280,000
- Cost to public (present worth of expected crashes) with turn lane = $170,000
- △ Cost = "Benefit" = $280,000 - $150,000 = $130,000
- Present worth of expected maintenance cost = $13,000
- Present worth of expected increase in tax revenue = nil
- Cost to applicant (construction of turn lane) = $160,000
- Benefit to applicant (increased property value with turn lane considered to without turn lane) = nil

B/C Ratio

- B/C ratio = ($130,000 + $0)/($13,000 + $160,000) = 0.75

Since the B/C ratio is less than 1.0, a turn lane would not be required. Not requiring a turn lane would result in a $280,000 cost (present worth of expected crashes) to the public. A $257,000 cost if the "avoidance" of maintenance cost of a turn lane is not required ($280,000 minus $23,000 present worth of maintenance). Consequently, not requiring a turn lane results in a transfer in wealth form the public section (road users) to the applicant. In this example, the applicants wealth is increased by $160,000 (cost avoided by not having to construct a turn lane) in exchange for $280,000 cost ($257,000 if "avoidance" of maintenance cost is considered) imposed upon the public (road users). The result is irrational in that the B/C analysis "justifies" a transfer of cost from the applicant to the road user, rather than an economic warrant for requiring, or not requiring an access connection treatment as a condition of the connection permit.

A benefit/cost ratio greater than 1.0 also presents a dilemma because the cost to the public and the cost to the applicant are co-mingled. When the public costs are high and the applicant costs are very low (such as when a right turn can be provided by striping an existing paved shoulder) a B/C ratio greater than 1.0 indicates that the public benefits exceed the public cost – this is not a rationale for requiring, or not requiring an access connection treatment as a condition of the permit.

When the cost to the applicant is very high compared to the cost to the public, a B/C ratio greater than 1.0 indicates that the investment by the applicant compensates the public for the negative

effects of the connection. However, if the present worth of increased tax receipts (with the access treatment compared to without the treatment) is very large compared to the benefits to road users, a B/C ratio greater than 1.0 indicates that those taxing jurisdiction(s) will receive more than one dollar in revenue for each dollar invested in the access treatment.

APPLICATION OF BENEFIT/COST ANALYSIS

As previously indicated, a benefit/cost (B/C) analysis is appropriate when both the benefits and costs are quantifiable and accrue to the same entity – such is the case when a state or local agency retrofits a specific access connection, or roadway segment, so as to improve safety and/or increase capacity and/or improve traffic questions. *NCHRP Report 745* [5] and the web only companion *Report 193* [6] document exceptionally well executed research. As indicated in Table 2, a left-turn treatment as justified at low left-turn and roadway volumes. For example, at 5 left-turns per hour, a left-turn lane is justified at a 3-leg access connection when the roadway volume exceeds 200 vehicles per hour per lane (vph/ln) and 150 vph/ln at a 4-leg intersection. On a rural 4-lane roadway a left-turn lane is warranted when the roadway volume exceeds 75 vph/ln (approach volume of 150 vph) and 50 vph/ln at a 4-leg intersection. Any successful business located on a rural highway will exceed these volume warrants, and therefore justify a left-turn lane. The volume warrants for a by-pass lane support the Becker County Minnesota practice of using by-pass lanes.

Table 2: Warrants for Left-Turn Treatments at Unsignalized Access Connection Rural 2-Lane Roadway

Left-Turn Volume (vph)(1)	3-Leg Intersection		4-Leg Intersection	
	By-Pass Volume (vph/ln)[2]	Roadway Volume (vph/ln)[2]	By-Pass Volume (vph/ln)[2]	Roadway Volume (vph/ln)[2]
5	50	200	50	150
10	50	100	50	50
15	<50	50	<50	50
Rural 4-Lane Roadway				
Left-Turn Volume (vph)[1]	3-Leg Intersection (vph/ln)[2]		4-Leg Intersection (vph/ln)[2]	
5	75		50	
10	75		25	
15	50		25	
Urban/Suburban Arterial				
Left-Turn Volume (vph)[1]	3-Leg Intersection (vph/ln)[2]		4-Leg Intersection (vph/ln)[2]	
5	450		50	
10	300		50	
15	250		50	
20	200		50	

Source: adopted for NCHRP Report 745 [5] Tables 1, 2 and 3

(1) Vehicles per hour
(2) Vehicles per hour per lane

The volume warrants presented in Table 3, page 9 of *NCHRP Report 745* [5] are less than the roadway and left-turn volumes that occur in urban/suburban arterials and many major collectors. This supports a policy that requires left-lanes at all median openings on divided roadways and at access connections on undivided roadways. The TRB Access Management Manual, 2nd edition, Section 17.41— specifically the examples shown in Exhibit 17-34, page 422, provides guidance as to when an unsignalized midblock median opening can be provided. The warrants also support a policy that all access connections that do not confirm to the adapted traffic signal interval be limited to right-in/right-out only by the presence of a nontraversal median or median barrier.

Note: The reader is referred to the web only *Report 193* [6] for an explanation of the large difference in roadway volume for a 3-leg access connection as opposed to a 4-leg intersection.

A "possible rationale" for using a B/C criteria as warrants for auxiliary lanes as a condition of the permit for an access connection to an existing roadway may cause safety and/or traffic

operational problems that will require the public agency to make appropriate improvements to the access connection at a later date.

SUGGESTIONS RELATIVE TO DEVELOPING CRITERIA FOR A NEW ACCESS CONNECTION TO AN EXISTING ROADWAY

A new access connection to an existing roadway will impose some costs (increased crash potential, increased vehicle operating and maintenance, increased emissions, and inconvenience) to roadway users. An objective of access management is to hold these additional costs to an acceptable level which is, or at least should be related to the functional importance of the roadway to which the access will be provided (Colorado DOT, City of Lewisville, TX) or to the operational characteristics (Georgia DOT; New Mexico DOT; Gwinell County, GA; Irvine, CA).

Selecting warrants for auxiliary lanes based on roadway function is especially appropriate for local governments. The existing and proposed major streets are identified in the through lane plan element of the thoroughfare. The city of Lewisville, TX, General Development Distance, effective June 4, 2003, requires a deceleration lane at all driveways classified in the city through lane plan as a major traffic carrier (pg 53). The ordinance provides for an exception for existing lots with limited frontage (225 feet or less).

Where the state highway system consists of a wide range of roadway operational conditions, adopting warrants based on operational parameters include the following: 1) posted speed, 2) number of lanes (2-lane, multilane undivided/divided), 3) roadway volume, 4) turn volume, 5) the probability that a turning vehicle will interfere with a following through vehicle, 6) the amount of acceleration noise (deceleration followed by acceleration) in the traffic stream, and 7) the excess vehicle emissions due to deceleration and acceleration.

Since major roadways tend to have higher volumes and higher speeds than roadways of lower classification [and the likelihood of a serious incident increases as speed and volume increases] the warrants for an auxiliary lane should logically be lower for higher speed and higher volume roadways than for roadways with lower volume and speed.

It is suggested that research to develop operational warrants for turn lanes incorporate the following steps:

1. Summarize the best practices of state (Georgia, New Mexico, and Colorado) and local agencies (Lewisville, TX).

2. Review and evaluate models that might be used to develop the warrants. This should include Harmelink's model with corrections identified by Kikuchi and Chakraborty [3] and the data representing current driver parameters (see van Schalkwyk and Stover [2]).

3. Collect data to reflect current driver characteristics. Considerable data is available but some field data collection will likely be necessary. Data and modeling should represent average (50^{th} percentile) and most (85^{th} percentile) drivers.

4. Use selected model, with field observations to verify model results, to develop criteria including speed, number of lanes (2-lane, multilane undivided, multilane divided), roadway values, and flow characteristics (random arrivals-vs-platoon flow), and access connection volume (left-turns and right-turns). Also for a by-pass lane on a 2-lane roadway where a left-turn lane may not be warranted.

5. Provide guidance for state and local agencies to interpret/use the information to select and adopt warrants for left-turn lanes, by-pass lane where a left-turn lane is not warranted, and right-turn lanes.

6. Provide guidance as to warrants for dual and triple left-turn lanes and dual right-turn lanes.

CONCLUSION

A B/C ratio methodology is applicable to the following:

(1) Retrofit of an existing access connection by the public agency
(2) Retrofit of a segment of an existing roadway by the public agency
(3) Construction of a new roadway

A B/C methodology is not applicable to access connection permitting since a B/C ratio less than 1.0 will "justify" the imposition of the cost of degraded safety and traffic operations on the public with a "saving" to the applicant.

Safety and operational criteria (speed, through volume, turn volume, functional classification of the roadway segment) should be developed/used as warrants for permitting a new access connection to an existing roadway.

A procedure that considers traffic operations (speed, turn volume, through value), safety, and functional class of the roadway needs to be developed as a basis for warrants for right-turn lanes in the access connection permitting process.

Permitting a new access connection with a mitigating treatment(s) (right-turn lane, left-turn lane, bypass lane, or median treatment) will impose some costs on the public (road users). Therefore, it is logical that the volume warrants for an auxiliary lane and/or median treatment as a condition of new access connection should be less than for a retrofit application or for new construction.

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