

WARRANT METHODOLOGY FOR EVALUATING AND RANKING TRANSIT “PASS-THROUGH” LANES AT FREEWAY INTERCHANGES

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ABSTRACT

The provision of transit vehicle priority is often motivated by opportunities to reduce person-delay within the transportation network, increase transit reliability and speed, reduce transit operating costs, and/or encourage transit use due to the environmental and social benefits often associated with transit. Within a freeway environment, one form of transit vehicle priority is the provision of transit “pass-through” lanes at interchanges. “Pass-through” lanes allow a transit vehicle to exit the freeway at an interchange, cross straight through the intersecting arterial road, and re-enter the freeway. This treatment allows transit vehicles to by-pass congestion on the mainline between the beginning of the off-ramp and the end of the on-ramp.

The objective of this paper is to outline a methodology that can be applied by practitioners to evaluate if transit “pass-through” lanes are economically warranted at a given interchange, and to provide a method for prioritizing candidate locations. The warrant provides an objective and consistent decision making method, reduces the effort required for practitioners to assess the need for “pass-through” treatment at a given interchange, and helps ensure that limited resources are directed towards interchanges which are expected to experience the greatest benefit per dollar spent.

The proposed methodology is based on an analytical approach that compares the value of travel time savings (for passengers and transit vehicles) with the construction and maintenance costs of the transit “pass-through” lane treatment.

The methodology is demonstrated through application at a candidate freeway interchange in southern Ontario.

Transit vehicle priority is the preferred treatment of one vehicle class (transit) over other vehicle classes at a road network element (1). The provision of transit vehicle priority is often motivated by opportunities to reduce person-delay within the transportation network, increase transit reliability and speed, reduce transit operating costs, and/or encourage transit use due to the environmental and social benefits often associated with transit. Within a freeway environment, a potential form of transit priority is what is referred to as a transit “pass-through” lane (or bus bypass). “Pass-through” lanes allow a transit vehicle to exit the freeway at an interchange, cross the intersecting arterial road, and re-enter the freeway (Figure 1). This treatment allows transit vehicles to bypass congestion on the mainline between the beginning of the off-ramp and the end of the on-ramp. Transit “pass-through” lanes may make use of dedicated lanes and Transit Signal Priority (TSP) at intersections in order to increase their effectiveness.

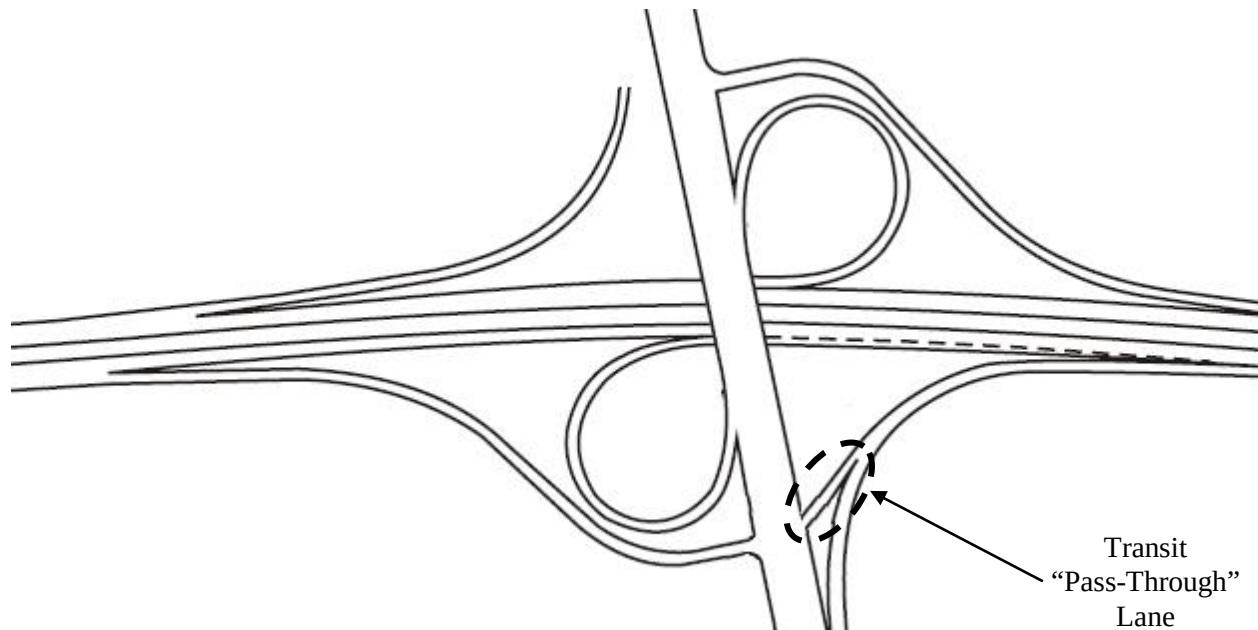


FIGURE 1 Transit “pass-through” lane.

In many situations, new transit “pass-through” lanes are implemented in conjunction with scheduled maintenance, rehabilitation, or construction of interchanges. However, there is a lack of a methodology, both in practice and in the literature, for evaluating whether a specific interchange is a worthwhile location for constructing a “pass-through” lane. Further, there is a benefit to being able to rank candidate interchanges such that locations with the greatest benefits are prioritized, allowing limited funds to be spent effectively.

The evaluation and ranking of priority treatments can be done on the basis of relative benefits and costs associated with the treatments. In practice, detailed benefit/cost ranking tends to be cumbersome and time consuming to conduct; therefore, it can be beneficial to embed the benefit/cost analysis within a simplified warrant procedure.

This paper outlines a warrant methodology that can be used to aid in determining whether or not construction of a transit “pass-through” lane at a given interchange is justified, and provides a method for prioritizing candidate locations. The warrant methodology provides an objective and consistent decision making method, reduces the effort required for practitioners to assess the effectiveness of a “pass-through” treatment at a given interchange, and helps ensure that limited resources are directed towards interchanges which are expected to experience the greatest benefit per dollar spent.

The proposed methodology is based on an analytical approach to estimate expected daily travel time savings (for passengers and for transit vehicles) associated with providing transit “pass-through” lanes. The expected benefits of the treatment are derived by converting travel time savings into a dollar value. Costs of the treatment are estimated on the basis of annualized construction cost and estimated annual maintenance costs. The output of the methodology is a benefit/cost ratio (BCR).

METHODOLOGY

Transit priority treatments are often evaluated via analytical or microsimulation methods. In order to provide the repeatability and ease of use typically associated with a warrant methodology, the procedure outlined in this paper is based on analytical methods.

The ultimate output of the warrant methodology is a BCR. If the BCR exceeds a certain threshold (typically 1.0), the proposed transit “pass-through” is evaluated as economically warranted. The BCR is also useful to compare potential interchanges (2) and to prioritize those interchanges which will receive the greatest benefit per dollar spent.

The warrant methodology analyzes typical weekday conditions from 6:00 a.m. until 9:00 p.m., with this time interval broken up into 15-minute periods in order to capture temporal variations in traffic conditions and bus frequencies. Data requirements to complete the warrant methodology consist of:

- Freeway segment length (km),
- Bypass segment length (km),
- Freeway speed profile (km/hr, per 15-minute period),
- Off-ramp volume for lane group used for bypass (veh, per 15-minute period),
- Intersection configuration,
- Heavy vehicle percentage for lane group used for bypass (%),
- Traffic signal timing plan,
- Transit signal priority parameters, if applicable,
- Transit vehicle schedule,
- Transit vehicle loadings (passengers/vehicle),
- Capital (construction) cost of bypass infrastructure (\$),
- Service life of bypass infrastructure (years), and
- Annual maintenance cost of bypass infrastructure (\$).

Benefit Estimation

The benefit estimation portion of the warrant methodology involves estimating the travel time savings for transit vehicle passengers and the travel time savings for transit vehicles. These two values are used to quantify benefits such as reduced travel time for users, reduced vehicle requirements for transit agencies, reduced transit vehicle fuel consumption, and potential modal shifts from personal vehicles to transit among commuters.

The benefit estimation procedure is summarized in Figure 2 and consists of the following steps:

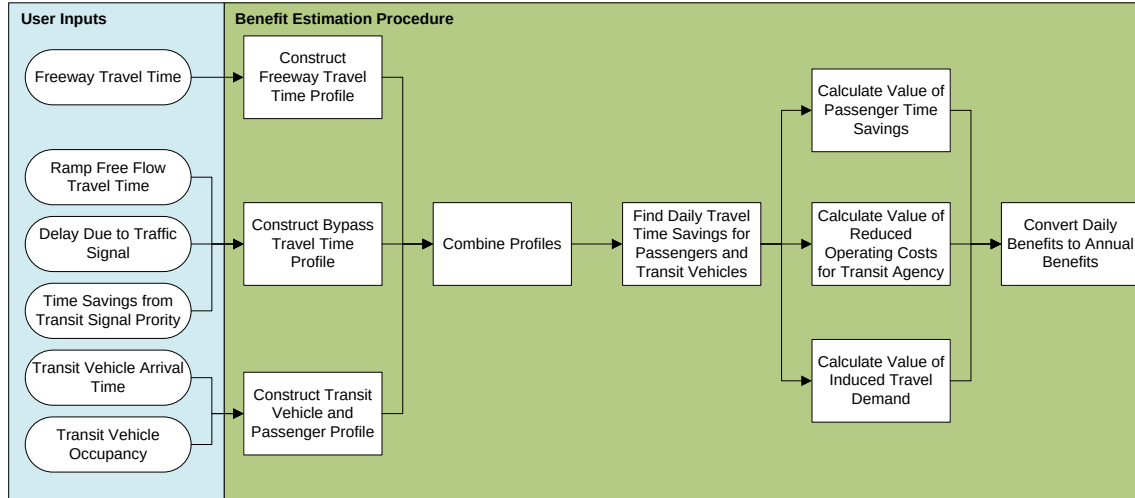


FIGURE 2 Benefit estimation procedure.

Benefit Calculation Step 1: Construct Freeway Travel Time Profile

Travel time for a bus along the mainline of the freeway (i.e. assuming the proposed transit “pass-through” lane is not used) is estimated for each 15-minute time period throughout the day. Travel time is calculated for each period based on freeway speeds (typically measured using loop detectors or other dedicated traffic sensors) in the vicinity of the interchange and the distance along the mainline which could be skipped by using the bypass (Equation 1).

$$TT_{Freeway,i} = \frac{3600 \cdot D_{Freeway}}{V_{Freeway,i}} \quad (1)$$

Where $TT_{Freeway,i}$ is the travel time on the freeway in period i , in seconds
 $D_{Freeway}$ is the distance along the freeway which could be skipped by the bypass, in km
 $V_{Freeway,i}$ is the speed on the mainline freeway in period i , in km/hr

The resulting output of this step is a freeway travel time profile over the course of a typical weekday. It is also possible to construct the freeway travel time profile directly using observed/archived travel time data for the freeway in the vicinity of the interchange.

Benefit Calculation Step 2: Construct Bypass Travel Time Profile

Travel time for a bus using the transit “pass-through” lane is based on free-flow travel time along the bypass route, plus an additional delay due to the traffic signal at the arterial road crossing, minus some time savings from TSP if it is provided. Conceptually, the travel time for the bypass is calculated during each period as follows (Equation 2).

$$TT_{Bypass,i} = TT_{BypassFreeflow} + TT_{Signal,i} - TT_{TSP,i} \quad (2)$$

Where $TT_{Bypass,i}$ is the travel time on the bypass in period i , in seconds
 $TT_{BypassFreeflow}$ is the travel time on the bypass assuming free-flow conditions, in seconds
 $TT_{Signal,i}$ is the additional travel time added by the traffic signal at the crossing arterial road during period i , in seconds

$TT_{TSP,i}$ is the travel time savings attributable to transit signal priority at the traffic signal at the crossing arterial road during period i , in seconds

The travel time for the bypass under free-flow conditions is an idealized time that assumes that the route could be completed without the need to stop or slow due to the traffic signal or queues at the traffic signal. This free-flow travel time is therefore limited by the geometry and speed limit of the bypass route. Calculation of travel time for the bypass under free flow conditions is indicated in Equation 3. Since this value is independent of traffic volumes and signal operation, it is constant during all time periods.

$$TT_{BypassFreeflow} = \frac{3600 \cdot D_{Bypass}}{V_{BypassFreeflow}} \quad (3)$$

Where D_{Bypass} is the distance travelled on the bypass, in km
 $V_{BypassFreeflow}$ is the average free-flow speed on the bypass, in km/hr

Having to cross an arterial road at a traffic signal adds travel time to the bypass. The amount of additional travel time is a function of traffic volumes, signal timings, driver behavior, and intersection configuration, and will therefore vary throughout the day. The additional delay due to the traffic signal during each period is estimated by following the methodology outlined in Chapter 16 of the Highway Capacity Manual 2000 (3), as outlined in Equation 4.

$$TT_{Signal,i} = d_1 + d_2 + d_3 \quad (4)$$

Where d_1 is the uniform control delay based uniform arrivals, in seconds
 d_2 is the incremental delay due to random arrivals and oversaturation queues, in seconds
 d_3 is the initial queue delay, in seconds

The delay due to the traffic signal can be partially mitigated through the provision of transit signal priority. To quantify the expected delay reduction due to transit signal priority, a simplified analytical model has been used (4). The model presents expected delay reduction as a function of the “aggressiveness” of the transit signal priority parameters, i.e. the maximum green extension and red truncation permitted (Equation 5).

$$TT_{TSP,i} = \frac{\delta}{C} R + \frac{R^2 - R_{min}^2}{2C} \quad (5)$$

Where C is the cycle length, in seconds
 R is the length of red phase for the bus approach, in seconds
 R_{min} is the minimum permissible red phase for the bus approach, in seconds
 δ is the maximum permissible green extension for the bus approach, in seconds

Note that the total signal delay ($TT_{Signal,i}$) acts as an upper bound on the travel time savings due to TSP ($TT_{TSP,i}$).

The resulting output of this step is a bypass travel time profile over the course of a typical weekday.

Benefit Calculation Step 3: Construct Transit Vehicle and Passenger Profile

A daily profile of transit use (both in terms of number of passengers and number of vehicles) must be known in order to evaluate the effectiveness of a proposed bypass. The profile can be created based on a known or planned transit schedule, and based on a known or assumed bus occupancy level. The profile must identify the number of buses and passengers expected during each period

Benefit Calculation Step 4: Combine Profiles and Find Daily Travel Time Savings

The daily travel time savings, in terms of passenger hours and transit vehicle hours saved, can be found by combining the profiles created in steps 1 to 3.

The transit “pass-through” lane only provides a benefit during periods in which a transit vehicle’s travel time using the bypass is less than its travel time using the freeway. During periods when this is not the case, it is likely that the transit vehicle will simply stay on the freeway, and the bypass will not be used. As well, regardless of the difference in travel times between the freeway and the bypass, travel time savings can only be accrued during periods in which transit vehicles are scheduled to arrive. Therefore, travel time savings only exist during specific periods of the day. Travel time savings during each these periods can be calculated as the difference between travel time on the bypass and travel time on the freeway multiplied by either the number of passengers or the number of vehicles. Total daily travel time savings will be the sum of these values over the course of the day, as indicated in Equations 6 and 7.

$$\Delta TT_{Pass} = \frac{1}{3600} \sum_{i=1}^n \left(\begin{cases} TT_{Bypass,i} - TT_{Freeway,i} & ; TT_{Bypass,i} < TT_{Freeway,i} \\ 0 & ; TT_{Bypass,i} \geq TT_{Freeway,i} \end{cases} \right) \cdot N_{Passenger,i} \quad (6)$$

Where ΔTT_{Pass} is the daily passenger travel time savings due to the bypass, in hours
 $TT_{Bypass,i}$ is the travel time on the bypass during period i , in seconds
 $TT_{Freeway,i}$ is the travel time on the freeway during period i , in seconds
 $N_{Passenger,i}$ is the number of passengers on the transit vehicles in period i
 n is the number of 15-minute periods from 6 a.m. to 9 p.m. ($n=60$)

$$\Delta TT_{Bus} = \frac{1}{3600} \sum_{i=1}^n \left(\begin{cases} TT_{Bypass,i} - TT_{Freeway,i} & ; TT_{Bypass,i} < TT_{Freeway,i} \\ 0 & ; TT_{Bypass,i} \geq TT_{Freeway,i} \end{cases} \right) \cdot N_{Bus,i} \quad (7)$$

Where ΔTT_{Bus} is the daily transit vehicle travel time savings due to the bypass, in hours
 $TT_{Bypass,i}$ is the travel time on the bypass during period i , in seconds
 $TT_{Freeway,i}$ is the travel time on the freeway during period i , in seconds
 $N_{Bus,i}$ is the number of transit vehicles in period i

Benefit Calculation Step 5: Convert Daily Travel Time Savings into Annual Dollar Value Benefits

The additional passenger travel time savings and transit vehicle travel time savings have several benefits that are considered in this warrant methodology.

There is the inherent value of passenger’s time that is saved due to the provision of the bus “pass-through” lane. The U.S. Department of Transportation recommends a value of time equal to average wage plus value of fringe benefits for business travel, and 50% of average wage for personal travel (5, 6). Based on this recommendation and input from the Ontario Ministry of Transportation (MTO), a value of

\$15/person-hour has been selected as a default. Practitioners can modify this value from the default based on their own experience of local conditions and values.

Travel time savings also benefit transit service agencies, since they can result in reduced bus operating times and a corresponding reduction in agency operating costs. To get a significant benefit, time savings should be high enough to reduce the number of transit vehicles the agency needs to operate a route. However, this can be difficult to quantify, since one individual transit “pass-through” lane at an interchange may not provide sufficient time savings on its own, but could be sufficient in combination with other improvements such as “pass-through” lanes at other interchanges, TSP, transit schedule changes, and more. By default, a value of \$90/bus-hour is used to represent the value of transit vehicle time savings to the transit agency. This value can be modified based on the experience of the affected transit agencies. The default value has been taken from the “cost efficiency” for overall Ontario transit operation, as given in the 2005 Ontario Urban Transit Fact Book (7). Cost efficiency is defined as the total operating hours divided by total vehicle hours, and provides an approximation of the cost to run transit services on a per-hour operated basis.

A third benefit is that by improving the performance of transit, transit becomes more attractive relative to auto use. This has the potential to induce transit demand. The shift of travelers from personal vehicles to transit has obvious benefits such as a decrease in the number of vehicles on the road (reduced congestion), reduced emissions, etc. It is difficult to quantify the level and value of induced transit demand attributable to the reduction in travel time on a transit route. By default, the warrant methodology uses a value of \$0/person-hour for this benefit, which means it is not accounted for in the warrant. However, an agency may wish to modify this value based on their experience or data they have in-house which supports a higher value.

Total daily benefits can be found by multiplying the daily travel time savings by the appropriate conversion factors (Equation 8)

$$B_{Daily} = \Delta TT_{Pass} \cdot \alpha_{Time} + \Delta TT_{Pass} \cdot \alpha_{OpCost} + \Delta TT_{Bus} \cdot \alpha_{InducedDemand} \quad (8)$$

Where B_{Daily} is the daily value of the benefits, in dollars
 α_{Time} is the passenger car value of time, in \$/passenger-hour
 α_{OpCost} is the value of reduced bus operating times, in \$/passenger-hour
 $\alpha_{InducedDemand}$ is the value of induced transit demand, in \$/bus-hour

As a final step, the daily benefits are converted into annual benefits by multiplying by the number of weekdays with transit service in a year (Equation 9).

$$B = B_{Daily} \cdot ServiceWeekdays \quad (9)$$

Where B is the annual value of the benefits, in dollars
 $ServiceWeekdays$ is the number of weekdays per year on which a transit service operates, in days

Cost Estimation

Costs of a transit “pass-through” lane treatment are estimated on the basis of construction and maintenance costs. The cost estimation procedure is summarized in Figure 3 and consists of the following steps:

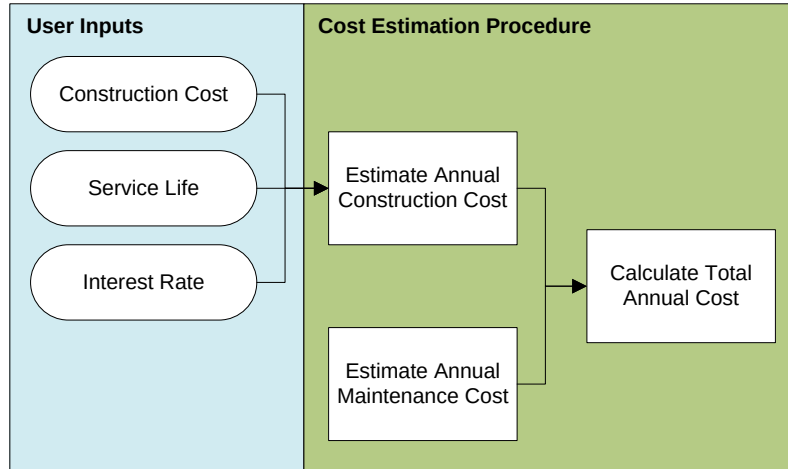


FIGURE 3 Cost estimation procedure.

Cost Calculation Step 1: Estimate Annual Construction Cost and Annual Maintenance Cost

Once the construction cost is estimated, it can be converted in to an annual value over the service life of the infrastructure using Equation 10.

$$A|C_{Construction} = C_{Construction} \cdot \frac{i(1+i)^n}{(1+i)^n - 1} \quad (10)$$

Where $A|C_{Construction}$ is the annual value of the construction cost, in dollars
 $C_{Construction}$ is the construction cost, in dollars
 i is the annual interest rate used by the agency to represent the time-value of money
 n is the service life of the infrastructure, in years

The maintenance cost should be expressed as an annual cost over the service life of the infrastructure.

Cost Calculation Step 2: Calculate Total Annual Cost

The total cost of a proposed transit “pass-through” lane is the sum of the annualized construction cost and the maintenance costs (Equation 11).

$$C = A|C_{Construction} + A|C_{Maintenance} \quad (11)$$

Where C is the annual value of the costs, in dollars
 $A|C_{Maintenance}$ is the annual maintenance costs, in dollars

The full warrant methodology has been implemented in an automated spreadsheet format in order to ease its application.

Assumptions and Limitations

When developing a warrant methodology, there is a need to find an appropriate balance between complexity and accuracy. The time and data requirements to complete the warrant methodology should not act as a serious impediment to its use, while still ensuring that the output of the warrant is of sufficient accuracy to allow the warrant be used as the decision making tool it is intended to be.

In order to achieve this balance, the proposed warrant methodology relies on several assumptions to simplify application and minimize excessive data requirements. The following key assumptions are made in this warrant methodology:

- Travel time and transit profiles stay constant over the service life of the transit pass-through lane. This will typically result in a conservative bias in the warrant methodology since, in most cases, congestion is increasing and correspondingly traffic speeds on the highway are being reduced as time goes on. Therefore, if a “pass-through” is warranted using the current methodology, it would likely also be warranted had speed profile changes over time been taken into account.
- HCM 2000 signalized delay calculations are applicable. Since this warrant methodology uses the HCM 2000 signalized delay equations to estimate the delay experienced by the transit vehicle when passing through the signalized intersections, the assumptions included in the HCM 2000 method are inherently part of this warrant methodology.
- Simplified TSP delay reduction equation is applicable. This methodology uses a simplified analytical equation to estimate expected delay reductions from transit signal priority. This equation makes several simplifying assumptions, including that the bus is detected and reacted to instantly by the TSP system, and that buses have sufficient headways such that TSP system recovery time is not a factor (4).

In addition to the assumptions discussed above, there are also several factors which are not considered in the warrant in order to maintain simplicity. The main limitations of this warrant methodology include the following:

- Disbenefit to cross street traffic is not accounted for. If transit signal priority is provided at the signalized intersection to help the bus cross the arterial road, this will provide a benefit to the transit vehicles while having some negative effects on through traffic on the arterial road (such as loss of green time and disruption to coordination along the arterial road). Quantifying this disbenefit would significantly increase data requirements. Therefore, this disbenefit is not accounted for in the warrant methodology. In most cases, the disbenefit is unlikely to have a significant effect on the results of the warrant, since freeway transit routes generally do not have high frequencies.
- Benefit of service reliability has not been accounted for. In addition to reducing travel time for transit vehicles, a transit “pass-through” lane should have the benefit of increasing the reliability of the transit service. This is not accounted for in the warrant methodology.
- Transit stops at interchanges are not accounted for. The warrant methodology assumes that a stop is not going to be added at the interchange. However, a potential benefit of a transit “pass-through” lane is that a transit stop can be added at an interchange with a smaller impact on travel time than would be experienced if a stop was added without a “pass-through” lane. The benefit of the ability to add a stop with less impact is not accounted for in this warrant methodology.

Interpretation

The ultimate output of the warrant is a BCR. The transit “pass-through” lane meets the minimum requirements of the warrant when the BCR exceeds a certain threshold. Typically this threshold will be 1.0 (benefits exceed costs), however individual agencies should have some flexibility in the threshold for meeting the warrant. This flexibility recognizes that the warrant represents a simplified BCR and that its results are subject to the assumptions and limitations as outlined previously.

In addition to evaluating whether a transit “pass-through” lane is warranted at a given location, a greater value is that the warrant methodology can be used to easily compare multiple potential locations. Locations that meet the minimum requirements of the warrant can be ranked from highest BCR to lowest BCR, which allows those locations which are expected to experience the greatest benefit per dollar spent to be prioritized over locations which also meet the minimum warrant requirements, but provide relatively lower benefits for the investment.

APPLICATION

To test the warrant methodology, it has been applied at the Highway 401 Eastbound/Avenue Road freeway interchange in southern Ontario. This interchange had a transit “pass-through” lane constructed in 2007, however the “pass-through” lane is not yet in use.

Highway 401 is a major freeway within the City of Toronto. The eastbound direction of Highway 401 operates with an express-collector configuration at Avenue Road, with the Avenue Road exit only available from the collector lanes. A full day freeway speed profile was not available at this location, therefore the freeway speed profile was estimated based on data collected in a 2006 travel time study for the MTO. The travel time study used probe vehicles and focused on peak a.m., midday, and afternoon periods. Since there was a limited sampling frequency, travel times were interpolated during peak periods and the freeway was assumed to be free flowing at all other times. The data sources used are summarized in Table 1.

TABLE 1 Highway 401 EB/Avenue Road Warrant – Data Sources

Data	Source
Freeway segment length	Measured from aerial photo
Bypass segment length	Measured from aerial photo
Freeway speed profile	2006 Travel Time Study ^a
Off-ramp lane group volume	MTO turning movement count
Intersection configuration	MTO sketches
Heavy vehicle percentage	MTO turning movement count
Traffic signal timing plan	City of Toronto
TSP parameters	N/A
Transit vehicle schedule	Existing transit schedules
Transit vehicle loadings	Full buses assumed (52 passengers)
Construction Cost	Discussions with MTO (\$500,000)
Service Life	Discussions with MTO (30 years)
Maintenance Cost	Discussions with MTO (\$10,000)

a. data only available for a portion of the study period, travel speeds were interpolated during peak periods and assumed to be free flowing at other times

The travel time and transit profiles found by applying the warrant methodology are illustrated in Figure 4. Based on the profiles, the transit “pass-through” lane would provide a significant time savings during the afternoon peak period, and a moderate time savings during small portions of the morning and midday peak period. During the rest of the day, no benefits are expected to be accrued from the transit “pass-through” lane because freeway speeds are fast enough that transit vehicles would not be using the “pass-through” lane.

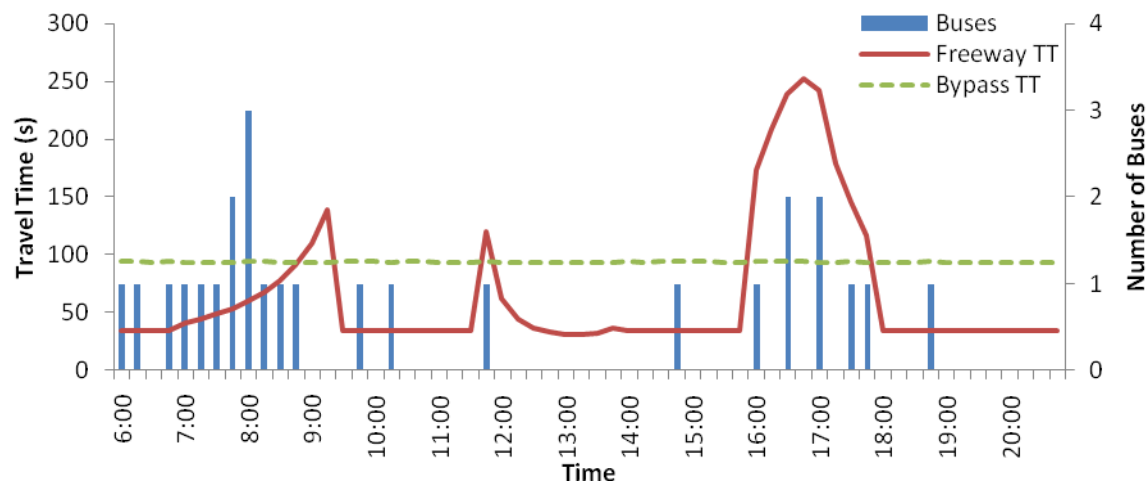


FIGURE 4 Highway 401 EB/Avenue Road travel time and transit profile.

Based on the profiles constructed using the warrant methodology, the final warrant calculations are summarized in Table 2. Default values to convert travel time savings to dollar benefits (as discussed previously) were used in the final calculations.

TABLE 2 Highway 401 EB/Avenue Road Warrant – Results

Item	Value
Daily Passenger Travel Time Savings (person-hours)	11.1
Daily Bus Travel Time Savings (bus-hours)	0.21
Daily Benefits (\$)	185.99
Annual Benefits (\$)	46,498.51
Construction Cost (\$)	500,000.00
Annualized Construction Cost (\$)	32,525.72
Annualized Maintenance Cost (\$)	10,000.00
Total Cost (\$)	42,525.72
BCR	1.093

The results of the warrant analysis indicate that benefits are expected to exceed costs for a transit “pass-through” lane at this interchange. Ultimately, the final BCR can be compared with warrant results at other locations in order to prioritize candidate locations.

CHANGING TRAVEL TIME AND TRANSIT PROFILES

The warrant methodology assumes that travel time and transit profiles remain constant over the service life of the transit “pass-through” lane. As discussed, this assumption usually results in an underestimation of benefits because congestion tends to be increasing at many locations. However, in situations where the user is not comfortable with this assumption, the warrant methodology can be modified to account for changing travel time and transit profiles over the service life of the transit “pass-through” lane. This can be done by conducting the warrant analysis at the present year and at several horizon years. Future benefits can be brought back to a present value which can then be converted into an annuity. The benefit annuity can then be compared with the annual costs.

This allows future changes in travel time and transit profiles to be accounted for; however the disadvantage is a significant increase in data requirements to complete the warrant analysis.

DISCUSSION

Development and testing of the warrant methodology has led to several findings with regard to the importance and sensitivity of the input parameters. The sensitivity of the input parameters was further investigated through sensitivity testing on the results of the Highway 401/Avenue Road warrant application.

Sensitivity to Input Parameters

Freeway travel time is a significant factor influencing the outcome of the warrant analysis. Freeway travel time is directly related to freeway congestion, which has a major impact on the travel time difference between the mainline freeway and the bypass. If the freeway does not experience significant congestion during periods when transit vehicles use the freeway, the warrant is unlikely to be met. Conversely, high levels of freeway congestion significantly increase the benefits of a transit “pass-through” lane. The impact of changes to freeway speeds on the BCR at Highway 401 EB/Avenue Road is illustrated in Figure 5.

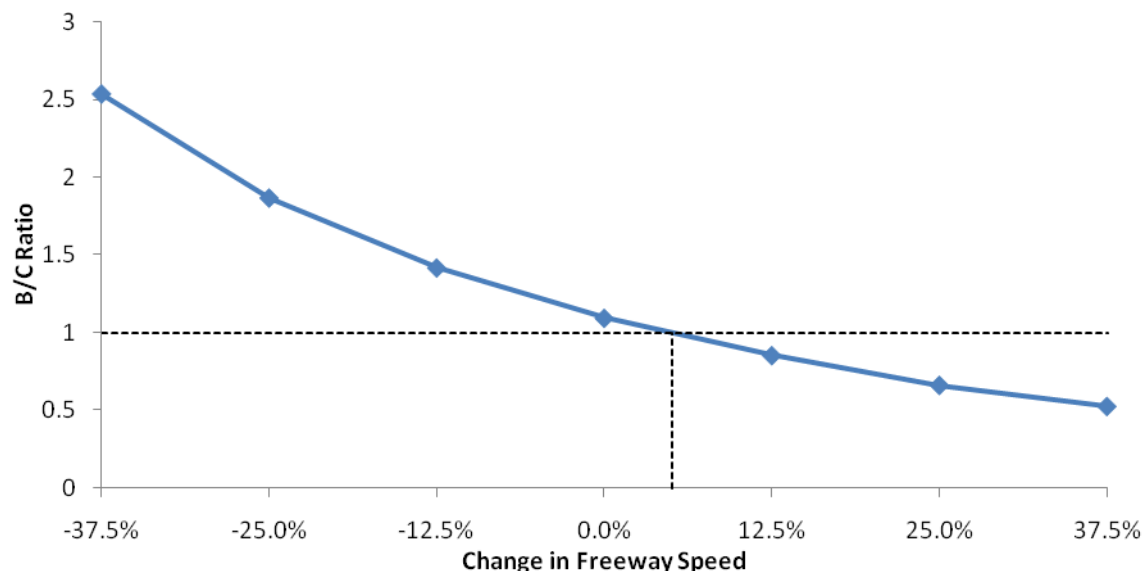


FIGURE 5 Sensitivity of BCR to freeway speed.

The results indicate that the relationship between freeway speed and the BCR is non-linear, such that benefits increase at higher rates as overall freeway speed decreases.

The effect of ramp volume on the warrant results is minimal at low ramp volumes. When ramp volumes approach or exceed capacity, intersection delay increases dramatically and the ramp volumes can have a significant impact on the outcome of the warrant. The impact of changes to ramp volumes on the BCR at Highway 401 EB/Avenue Road is indicated in Figure 6. Existing lane group volumes at this interchange are very small (generally in the range of 15 to 20 vehicles during each 15-minute period), therefore changes to the lane group volume for the purpose of sensitivity analysis were done as absolute values rather than as a percentage.

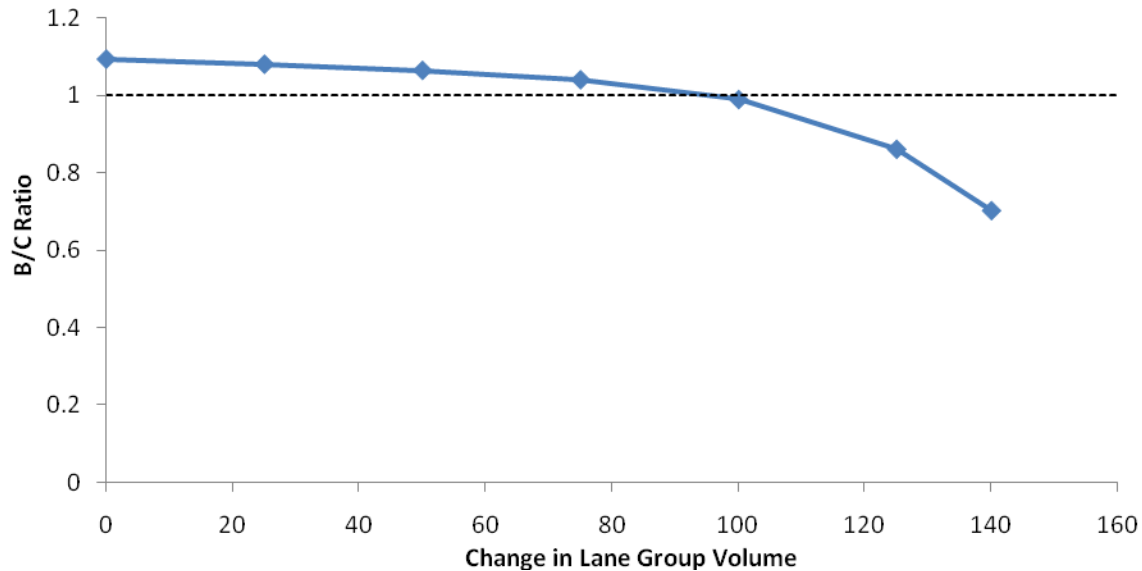


FIGURE 6 Sensitivity of BCR to ramp volume.

The transit schedule is also an important factor in the outcome of the warrant, since travel time savings can only be accrued during periods when a transit vehicle actually travels through the segment. Considering this, it is important that transit schedule and occupancy represent a realistic estimate of future conditions in order for the results of the warrant to be valid.

The choice of multiplication factors (to convert time savings to benefits) will affect the BCR in a linear manner. The rate of change will be proportional to the amount of time savings expected. The impact of changing the multiplication factors on the BCR at Highway 401 EB/Avenue Road is presented in Figure 7. Note that changes in the passenger value of time have a much larger impact on the BCR than changes in the value of bus operating costs. This is because for every second of travel time that a bus saves, that second is saved by many passengers.

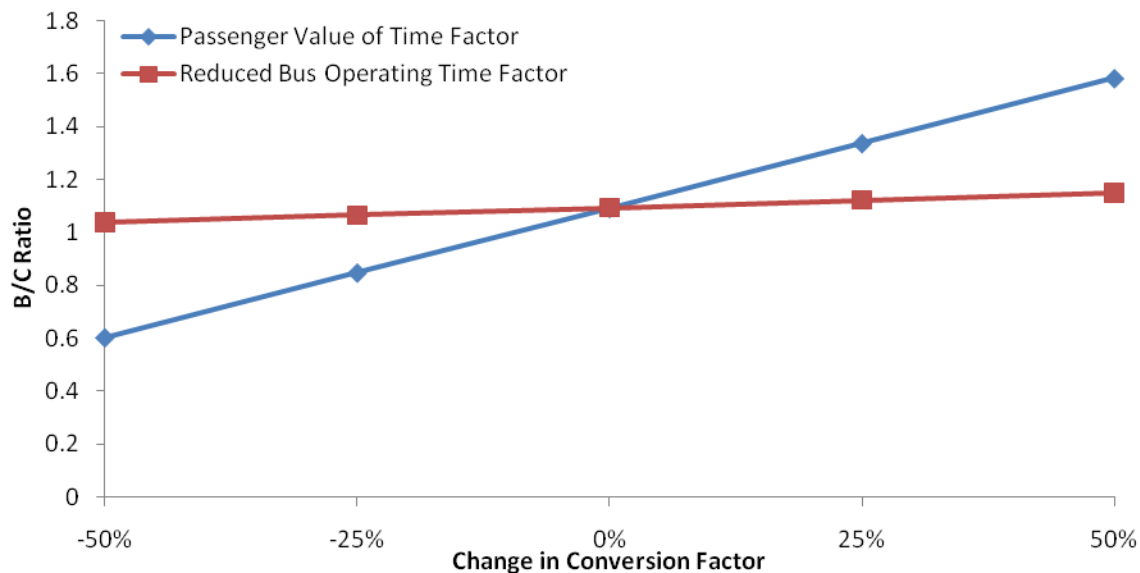


FIGURE 7 Sensitivity of BCR to multiplication factors.

Data Collection Requirements

In consideration of the above findings, full data collection is unlikely to be needed for the entire 6 a.m. to 9 p.m. period. Instead, with minimal impact on the output of the warrant methodology, data collection can be limited to periods containing any one of:

- Notable freeway congestion,
- High ramp volumes, and
- Notable transit volumes.

Under most circumstances, the time periods of the above three cases can be expected to roughly coincide.

CONCLUSIONS

One form of providing transit vehicle priority within a freeway environment is to create transit “pass-through” lanes at interchanges. “Pass-through” lanes allow a vehicle to exit the mainline of the freeway at an off-ramp, cross straight across the intersecting arterial road, and re-enter the freeway via the on-ramp. When the mainline of the freeway is heavily congested, this allows the transit vehicle to bypass a significant portion of the freeway.

These treatments are frequently implemented on an ad-hoc basis and there is a lack of a consistent methodology to determine if the benefits of implementing a transit “pass-through” lane treatment at a given location justify the associated costs. The paper outlines a warrant methodology that can be used to test individual candidate interchanges and to rank the locations such that interchanges with the greatest relative benefits are prioritized over interchanges with lower relative benefits. The output of the warrant methodology is a benefit/cost ratio.

It was found that freeway speeds have a significant influence on the results of the warrant analysis. If freeway speeds are generally high throughout the day, the warrant is unlikely to be met. Lane group volumes at the signalized intersection of the off-ramp have a smaller effect on the outcome of the warrant, unless volumes approach or exceed capacity. The transit schedule is also important, as travel time benefits are only accrued during periods in which transit vehicles pass through the interchange. Therefore, the key periods for the warrant to analyze should include times when (a) there is significant freeway congestion, (b) there are high-volumes on the transit “pass-through” lane group, or (c) there are notable transit volumes.

This methodology forms a good basis for analyzing potential interchanges for transit “pass-through” lanes in the future. The methodology is beneficial as it provides an objective and consistent decision making method, reduces the effort required to assess the need for “pass-through” treatment at a given interchange, and ensures that limited resources are directed towards interchanges which are expected to experience the greatest benefit per dollar spent.

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