The Bicycle Compatibility Index: A LEVEL OF Service Concept, Implementation Manual

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Implementation Manual

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Foreword

The vision of the 1998 Federal Highway Administration National Strategic Plan is to create the best transportation system in the world, a transportation system that is safe, efficient, and intermodal, allowing all Americans to have access within and beyond their communities. This transportation system will have significantly reduced crashes, delays, and congestion; roads that protect ecosystems and air quality; and will accommodate pedestrians and bicyclists.

One method of accommodating bicycle travel is to develop or improve roadways for shared use by both motor vehicles and bicycles. This document demonstrates the application of the Bicycle Compatibility Index (BCI) to evaluate the capability of urban and suburban roadway sections to accommodate both motorists and bicyclists. The BCI methodology will allow practitioners to evaluate existing facilities and determine and possible improvements and to determine operational and geometric requirements for new facilities.

This report should be of interest to State and local bicycle coordinators, transportation engineers, and planners involved in the design of bicycle facilities within highway system.

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Notice

Introduction

The goals of the United States Department of Transportation (USDOT) as stated in the *National Bicycling and Walking Study* are: 1) to double the number of trips made by bicycling and walking, and 2) to simultaneously reduce by 10 percent the number of pedestrians and bicyclists killed or injured in traffic crashes.[1] Meeting the first of these goals will require a substantial increase in the number of trips made by bicyclists using on-road or shared facilities. This increased exposure could, in turn, jeopardize the second goal of improved safety unless careful consideration is given to the needs of both bicyclists and motor vehicle operators in the enhancement of existing roadways or development of new roadways. To develop or improve roadways for shared use by these two modes of transportation, one must begin by evaluating existing roadways and determining what is considered user-friendly from the perspective of the bicyclist.

Currently, no methodology is widely accepted by engineers, planners, or bicycle coordinators that will allow them to determine how compatible a roadway is for allowing efficient operation of both bicycles and motor vehicles. Determining how existing traffic operations and geometric conditions impact a bicyclist's decision to use or not use a specific roadway is the first step in determining the bicycle compatibility of the roadway.

The primary objective of the current study was to develop a methodology for deriving a ***bicycle compatibility index (BCI)*** that could be used by bicycle coordinators, transportation planners, traffic engineers, and others to evaluate the capability of specific roadways to accommodate both motorists and bicyclists (see figure 1). This research effort expanded upon the stress level work of Sorton and Walsh[2] and the Geelong Bikeplan Team[3] to produce a practical instrument that can be used by practitioners to predict bicyclists' perceptions of a specific roadway environment and ultimately determine the level of bicycle compatibility that exists on roadways within their jurisdictions. *(For a more complete discussion of these and other efforts that have been undertaken in recent years to develop a systematic means of measuring the suitability of roadways for bicycling, refer to the final report for this study.[4])*

Streets with marked bicycle lanes

Streets with Standard or Wide-Curb Lanes

Streets with Parking

Figure 1. The bicycle compatibility index (BCI) allows practitioners to evaluate the capability of a variety of roadways to accommodate both motorists and bicyclists using geometric and operational characteristics such as lane widths, speed, and volume.

The BCI methodology was developed for urban and suburban roadway segments (i.e., midblock locations that are exclusive of major intersections) and incorporated those variables that bicyclists typically use to assess the "bicycle friendliness" of a roadway (e.g., curb lane width, traffic volume, and vehicle speeds). The BCI model developed and the subsequent level of service (LOS) designations provide practitioners the capability to assess their roadways with respect to compatibility for shared-use operations by motorists and bicyclists and to plan for and design roadways that are bicycle compatible. Specifically, the BCI model can be used for the following applications:

- Operational Evaluation - Existing roadways can be evaluated using the BCI model to determine the bicycle LOS present on all segments. This type of evaluation may be useful in several ways. First, a bicycle compatibility map can be produced for the bicycling public to indicate the LOS they can expect on each roadway segment. Second, roadway segments or "links" being considered for inclusion in the bicycle network system can be evaluated to determine which segments are the most compatible for bicyclists. In addition, "weak links" in the bicycle network system can be determined, and prioritization of sites needing improvements can be established on the basis of the index values. Finally, alternative treatments (e.g., addition of a bicycle lane vs. removal of parking) for improving the bicycle compatibility of a roadway can be evaluated using the BCI model.

- Design - New roadways or roadways that are being re-designed or retrofitted can be assessed to determine if they are bicycle compatible. The planned geometric parameters and predicted or known operational parameters can be used as inputs to the model to produce the BCI value and determine the bicycle LOS and compatibility level that can be expected on the roadway. If the roadway does not meet the desired LOS, the model can be used to evaluate changes in the design necessary to improve the bicycle LOS.

- Planning - Data from long-range planning forecasts can be used to assess the bicycle compatibility of roadways in the future using projected volumes and planned roadway improvements. The model provides the user with a mechanism to quantitatively define and assess long-range bicycle transportation plans.

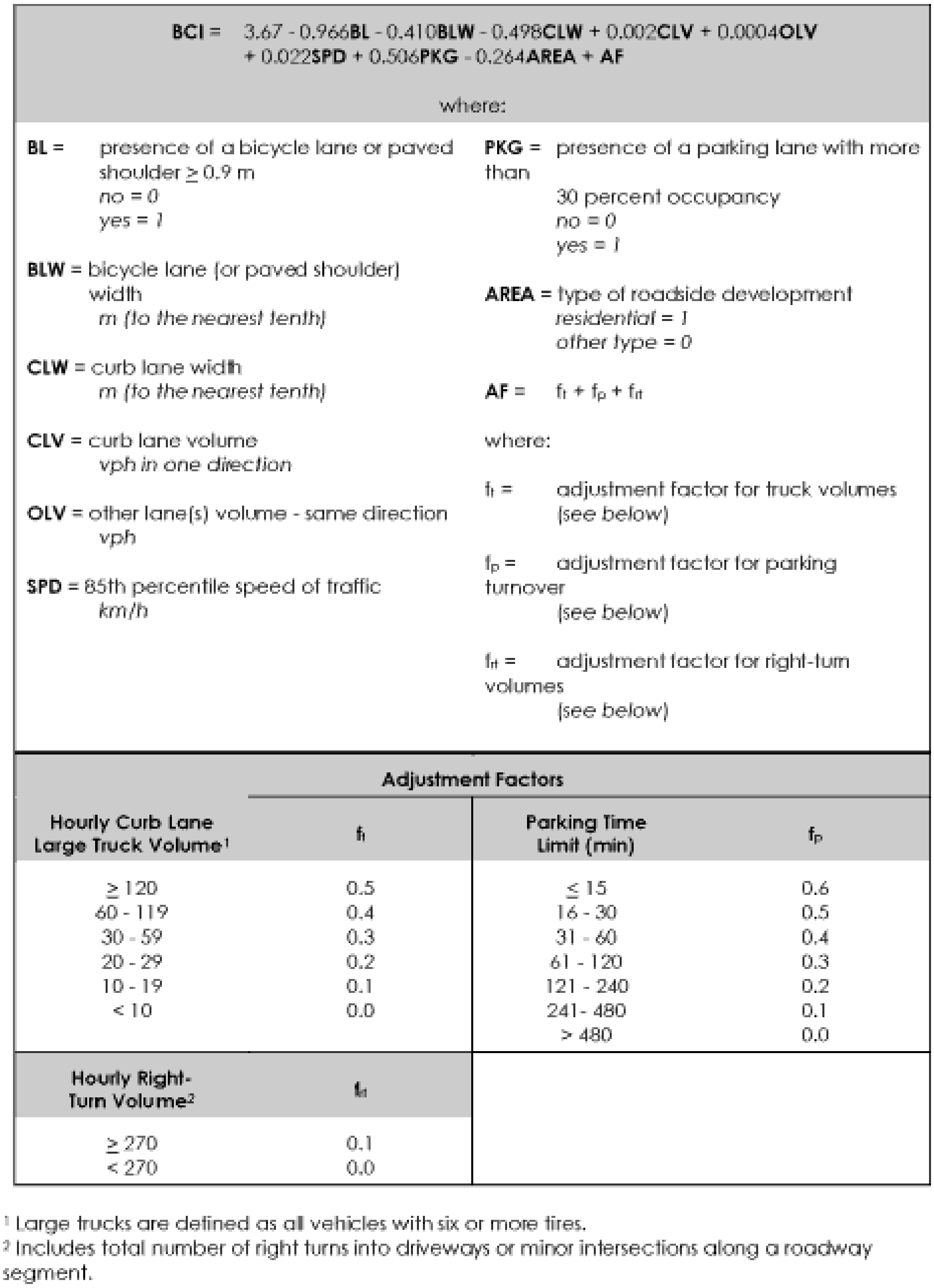
This report provides practical information on using the BCI model in real-world applications. Included in the report is a brief summary of the model development, data requirements for using the model, a description of the workbook or spreadsheet developed to facilitate its use, and practical examples illustrating a variety of applications. For more details regarding the research and development of the model, refer to the companion document *Development of the Bicycle Compatibility Index: A Level of Service Concept, Final Report.*[4]

Model development

The approach used in developing the BCI was to obtain the perspectives of bicyclists by having them view numerous roadway segments captured on videotape and rate these segments with respect to how comfortable they would be riding there under the geometric and operational conditions shown. The reliability of the results obtained using this video technique of data collection with respect to reflecting on-street comfort levels was validated in a pilot study. The procedure offered several advantages over other forms of data collection, including minimizing the risk to bicyclists, maximizing the range of roadway conditions to which the bicyclists could be exposed, and controlling the variables evaluated by the bicyclists.

It is important to note again that the BCI model developed is for midblock street segments only and is primarily intended for use on "through" streets. In other words, the ratings do not account for major intersections along the route where the bicyclist may encounter a stop sign or traffic signal. Within the research study, the video technique described above was piloted for a limited number of intersection sites. The results proved that this technique can be used in developing an intersection BCI, but further research is needed to fully develop such an index and incorporate that index with the segment BCI discussed in this manual. *(See the Final Report for a more complete discussion of the intersection index results.*[4]*)*

Table 1. Bicycle Compatibility Index (BCI) model, variable definitions, and adjustent factors



$$\mathbf{BCI} = 3.67 - 0.966\mathbf{BL} - 0.410\mathbf{BLW} - 0.498\mathbf{CLW} + 0.002\mathbf{CLV} + 0.0004\mathbf{OLV} + 0.022\mathbf{SPD} + 0.506\mathbf{PKG} - 0.264\mathbf{AREA} + \mathbf{AF}$$

where:

BL = presence of a bicycle lane or paved shoulder ≥ 0.9 m
no = 0
yes = 1

BLW = bicycle lane (or paved shoulder) width
m (to the nearest tenth)

CLW = curb lane width
m (to the nearest tenth)

CLV = curb lane volume
vph in one direction

OLV = other lane(s) volume - same direction
vph

SPD = 85th percentile speed of traffic
km/h

PKG = presence of a parking lane with more than 30 percent occupancy
no = 0
yes = 1

AREA = type of roadside development
residential = 1
other type = 0

AF = $f_t + f_p + f_{rt}$

where:

f_t = adjustment factor for truck volumes
(see below)

f_p = adjustment factor for parking turnover
(see below)

f_{rt} = adjustment factor for right-turn volumes
(see below)

Adjustment Factors

Hourly Curb Lane Large Truck Volume[1]	f_t	Parking Time Limit (min)	f_p
≥ 120	0.5	≤ 15	0.6
60 - 119	0.4	16 - 30	0.5
30 - 59	0.3	31 - 60	0.4
20 - 29	0.2	61 - 120	0.3
10 - 19	0.1	121 - 240	0.2
< 10	0.0	241- 480	0.1
		> 480	0.0

Hourly Right-Turn Volume[2]	f_{rt}
≥ 270	0.1
< 270	0.0

[1] Large trucks are defined as all vehicles with six or more tires.
[2] Includes total number of right turns into driveways or minor intersections along a roadway segment.

Using the perspectives of more than 200 study participants in three locations (Olympia, WA; Austin, TX; and Chapel Hill, NC), the BCI model was developed for all bicyclists as shown in table 1 (see appendix A for the English units version). The participants rated each of 67 sites included on a videotape with respect to how comfortable they would be riding there under the conditions shown. The ratings were made using a six-point scale where a ***one*** indicated that the individual would be "extremely comfortable" riding there while a ***six*** indicated that the individual would be "extremely uncomfortable" riding in those conditions. This model predicts the overall comfort level rating of a bicyclist using the eight significant (at p £ 0.01) variables shown and an adjustment factor (AF) to account for three additional operational characteristics. The basic model (excluding the adjustment factor) has an R^2-value of 0.89, indicating that 89 percent of the variance in the index or comfort level of the bicyclist is explained by the eight variables included in the model. In other words, the model is a reliable predictor of the expected comfort level of bicyclists on the basis of these eight variables describing the geometric and operational conditions of the roadway. The variable with the largest effect on the index is the presence or absence of a bicycle lane or paved shoulder (**BL**); the presence of a bicycle lane (paved shoulder) that is at least 0.9 m wide reduces the index by almost a full point, indicating an increased level of comfort for the bicyclist. Increasing the width of the bicycle lane or paved shoulder (**BLW**) or the curb lane (**CLW**) also reduces the index as does the presence of residential development along the roadside (**AREA**). On the other hand, an increase in traffic volume (**CLV** and **OLV**) or motor vehicle speeds (**SPD**) increases the index, indicating a lower level of comfort for the bicyclist. The presence of on-street parking (**PKG**) also increases the index.

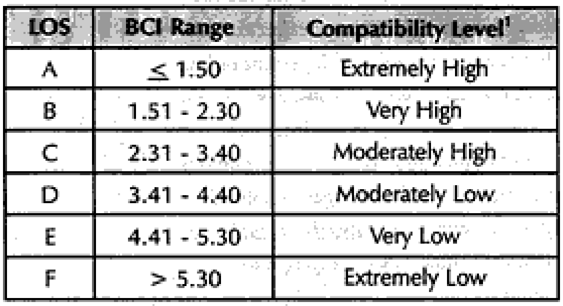
In addition to the primary variables included in the BCI model, three additional variables defining specific operating conditions were also examined. These supplemental variables were identified during the pilot phase of the study as having a potential impact on the comfort level of bicyclists and included the presence of: 1) large trucks or buses, 2) vehicles turning right into driveways, and 3) vehicles pulling into or out of on-street parking spaces. An analysis of the overall comfort level ratings made when viewing video clips illustrating these conditions showed all three of these variables to significantly increase the index, thus indicating a lower level of comfort when these conditions were present. For all bicyclists, the overall mean rating increased by 0.50 when large trucks or buses were present. When there were vehicles pulling into or out of parking spaces, the average rating increased by 0.60. And finally, the presence of right-turning vehicles resulted in an increase in the mean rating of 0.10.

While the presence of these three specific operating conditions was not evaluated across all possible combinations of geometrics and operations, the results of the limited sample do indicate a need for adjustment to the BCI model when large trucks or buses are present, when there is a high number of vehicles pulling into or out of on-street parking spaces, or when there is a high volume of right-turning vehicles. Thus, a series of adjustment factors that can be added to the model have been developed for each of these scenarios (*see table 1*). These factors were developed based on the theory that the conditions shown to the survey participants represented worst-case scenarios and, subsequently, the increase in the overall mean comfort level rating represented the maximum adjustment that would be required.

It should be noted that one variable not included in the development of the BCI model was the grade of the roadway. Results from a preliminary effort showed that changes in grade of 2 percent or less were not distinguishable on the video. The advantages of using video, including not exposing bicyclists to high-risk conditions, incorporating a much larger sample of sites, and controlling specific variables to ensure all subjects were exposed to identical conditions, were believed to outweigh the absence of this one variable. It is also believed that the variables having the most significant effect on the bicycle compatibility of a roadway have been included in the BCI model. Specifically, the variables of width, speed, volume, and on-street parking were shown to have the greatest impact on the index. At this time, the impact of grade relative to these and the other significant variables included in the model is unknown but may be determined in future research efforts.

Once the BCI model was developed, bicycle level of service (LOS) criteria were established based on the results of applying the model to the sites included in this study. Currently, there are no bicycle LOS criteria provided in the *Highway Capacity Manual*.[5] However, the definition of LOS according to the manual is founded on the concept of users' perceptions of qualitative measures that characterize the operational conditions of the roadway. Two of the terms used in the manual to describe LOS are comfort/convenience and freedom to maneuver. Both of these terms are applicable to bicyclists and are directly reflected in the BCI since the rating scale used by the study participants was an indication of comfort level.

Table 2. Bicycle Compatibility Index (BCI) ranges associated with level of service (LOS) designations and compatibility level qualifiers.



LOS	BCI Range	Compatibility Level[1]
A	≤ 1.50	Extremely High
B	1.51 - 2.30	Very High
C	2.31 - 3.40	Moderately High
D	3.41 - 4.40	Moderately Low
E	4.41 - 5.30	Very Low
F	> 5.30	Extremely Low

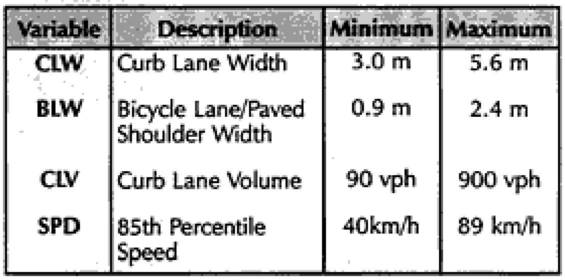
[1] Qualifiers for compatibility level pertain to the average adult bicyclist.

Thus, using the distribution of BCI values produced from the representative set of locations included in this study, LOS designations were established for LOS A through LOS F as shown in table 2. LOS A (represented by an index £ 1.50) indicates that a roadway is extremely compatible (or comfortable) for the average adult bicyclist while LOS F (represented by an index > 5.30) is an indicator that the roadway is extremely incompatible (or uncomfortable) for the average adult bicyclist.

In developing the BCI model, several other issues were addressed, including the effect of bicycling experience level on perceived comfort levels. Using the results from a questionnaire completed by the participants, the bicyclists were stratified into three groups based on their riding habits, such as number of bicycle trips per week and types of facilities used (e.g., major roadways vs. bicycle paths). A comparison of the comfort level ratings of these three groups showed that **casual recreational** bicyclists were generally less comfortable across all sites than **experienced recreational** or **experienced commuter** bicyclists. As a result of these differences, separate BCI models were produced for each of the three groups in addition to the model for **all** bicyclists. However, in real-world applications, it is most likely that bicyclists of all experience levels will have the opportunity to ride on any given segment of roadway. Thus, it is recommended that the BCI model developed for all bicyclists and shown in table 1 be used without modification for most applications**. It is important to note that the LOS designations shown in table 2 were developed on the basis of this model, and thus are only applicable to results produced with the "all bicyclists" model.**

Notwithstanding, when the practitioner knows that the large majority of riders are indeed casual bicyclists, the approach that should be used to ensure that facilities meet the desired comfort levels of this group is to simply design for a higher level of service. The results of the research showed that the model developed for the **casual** bicyclist, on average, produced BCI values that were 0.14 to 0.38 greater than those produced by **all** bicyclists. The differences in BCI values between LOS designations are, on average, 1.0 (*see table 2*). By designing for a higher LOS (e.g., LOS B rather than LOS C) on a facility known to attract a high number of casual bicyclists, the necessary comfort level for this group of bicyclists can be achieved with the BCI model as it is currently developed. **Note that where casual bicyclists are expected, the facility should always be designed at LOS C or better.**

Table 3. Ranges of variables included in the regression model.



Variable	Description	Minimum	Maximum
CLW	Curb Lane Width	3.0 m	5.6 m
BLW	Bicycle Lane/Paved Shoulder Width	0.9 m	2.4 m
CLV	Curb Lane Volume	90 vph	900 vph
SPD	85th Percentile Speed	40km/h	89 km/h

Another issue addressed was that of possible regional differences in the perceptions of bicyclists. If bicyclists in different geographic regions of the country perceive comfort levels differently, then separate models would need to be developed to reflect these differences. An analysis of the comfort level ratings across subjects in the three survey cities showed no differences in the mean overall comfort levels for the four variables rated (speed, volume, width, and overall). This lack of differences indicates that the perceptions of individuals with respect to bicycle compatibility are the same in the three regions where the survey was conducted, and that the BCI model should be applicable across all regions of the country.

The range of conditions included in the development of the model should be representative of most urban and suburban roadway conditions. However, since the sites included in the development contained a limited range of widths, volumes, and speeds, the model should not be extrapolated beyond the values shown in table 3. For example, the model may only be appropriate for bicycle lane or paved shoulder widths between 0.9 and 2.4 m and curb lane widths between 3.0 and 5.6 m.

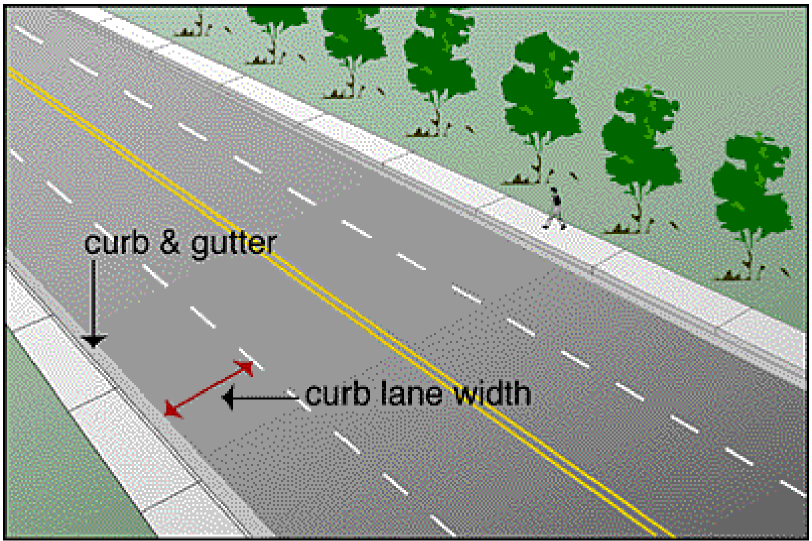
Data Requirements & Assumptions

The data needs for the BCI model are limited and, for the most part, include data that are traditionally collected by states and municipalities for other purposes. However, there will always be locations for which some of the data will not be available. In these cases, the practitioner must make judgments about appropriate values to use within the BCI model. It will also be the case that the available data are not in a form that can be directly input into the model. In that case, specific computations must be made to convert the data into the appropriate format. Described below are the variables required for the model and, where appropriate, computations and assumptions that can be used should the data be either not available or in the incorrect format. It should also be noted that the Microsoft Excel workbook on the enclosed diskette and described in the next section makes many of these computations for the user and incorporates some of the assumptions as default values.

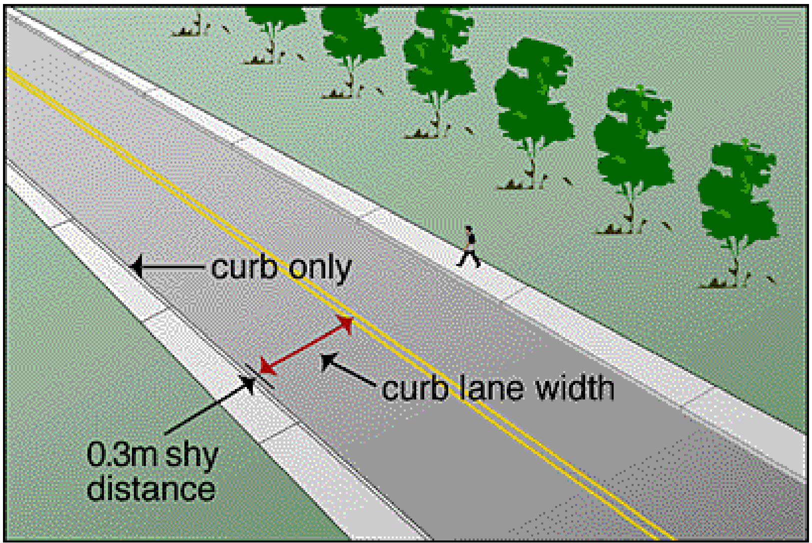
As with any applied model, the output is only as good as the input. Therefore, it is very important that the user of the BCI model understand the variable definitions and assumptions provided below, and that there will always be specific situations requiring their best judgment as to what would be most appropriate for the model. For example, one of the decisions that must be made by the user of the BCI model is which hour of the day to use for evaluating bicycling conditions. It has been assumed throughout this document that the peak hour will be the hour of choice. However, depending on the route being examined, the operational conditions may change with time of day. For example, while traffic volumes may be significantly greater during the peak hour compared with the rest of the day, travel speeds may be significantly lower due to the volumes. On other streets, on-street parking may be prohibited during the peak hour. Thus, the off-peak parking lane becomes the peak-hour curb lane for motor vehicle and bicycle travel. While in most cases the peak-hour analysis will be the "worst-case" scenario and will serve as a good measure of bicycle compatibility for a given roadway irrespective of time of day, the user of the model should be aware that differences in operating conditions such as those described here can significantly change the outcome and can result in different levels of compatibility on the same route. It is recommended that, for those routes or segments where dramatic changes in operating conditions are expected at different times of the day, the analysis be conducted for all scenarios that apply.

Defined below are the variables required for the BCI model:

· Lane Configuration - ***number of through motor vehicle lanes in one direction and the presence or absence of a bicycle lane or paved shoulder***. The number of lanes is used in the workbook to determine lane volumes from the average annual daily traffic (AADT).



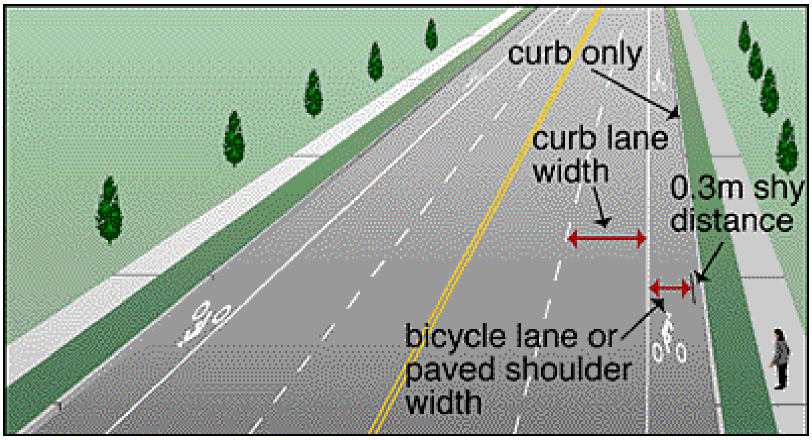
when gutter pan is present



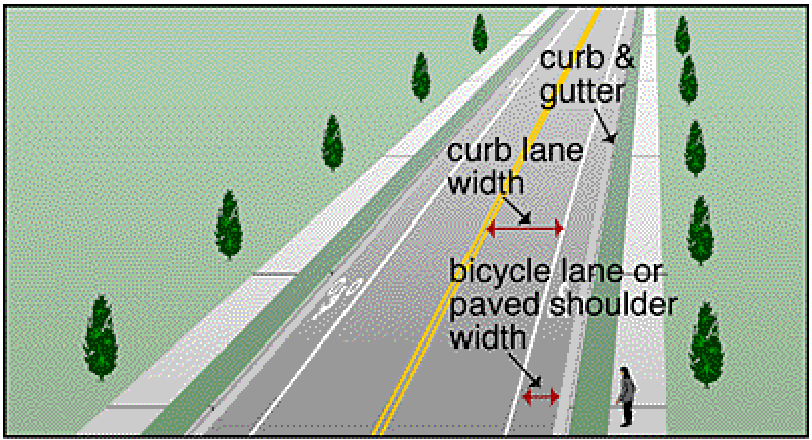
when no gutter pan is present

Figure 2. Curb lane width measurement when there is no bicycle lane, paved shoulder, or on-street parking lane.

· Curb lane width - ***width of the motor vehicle travel lane closest to the curb***, measured to the nearest tenth of a meter. If there is no bicycle lane, paved shoulder, or parking lane present, this distance is measured from the center of the lane line or center line to the joint or seam between the pavement edge and the gutter pan as shown in figure 2. If no gutter pan is present, the curb lane width is determined by measuring the distance from the center of the lane line or center line to the curb face and then subtracting 0.3 m from that distance. The 0.3-m value accounts for the space bicyclists will typically leave between themselves and a curb (i.e., the "shy" distance). This value also reflects the difference in bicycle lane design widths recommended by the American Association of State Highway and Transportation Officials (AASHTO), i.e., 1.5 m when no gutter pan is present versus 1.2 m when a gutter pan exists.[6] This scenario is also illustrated in figure 2.



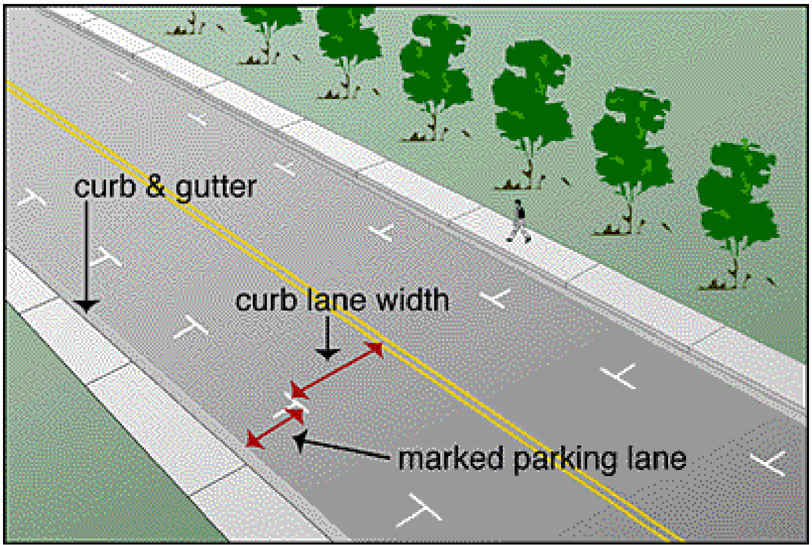
when no gutter pan is present



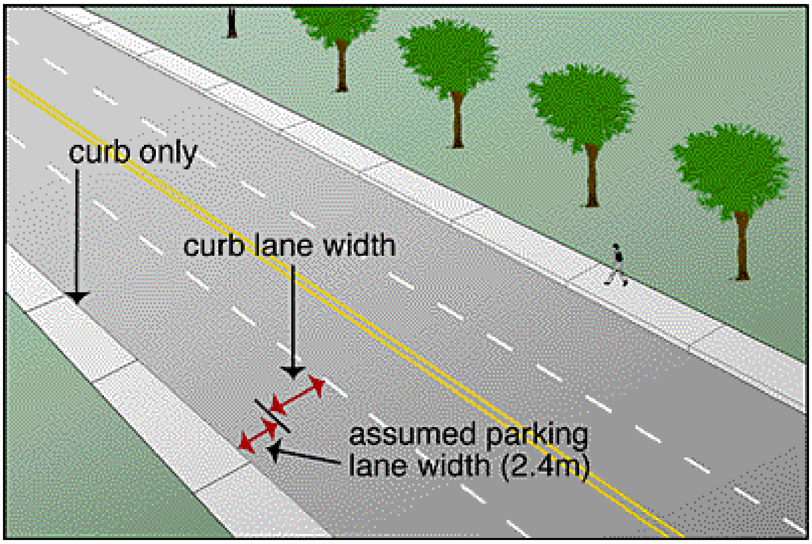
when gutter pan is present

Figure 3. Curb lane and bicycle lane (paved shoulder) width measurements when there is no on-street parking

When there is a bicycle lane or paved shoulder, the curb lane width is measured from the center of the lane line or center line to the center of the edge line as shown in figure 3. If there is a marked parking lane present, the curb lane width is measured in a similar manner as shown in figure 4. If the parking lane is unmarked, the curb lane width can be determined by measuring from the center of the lane line or center line to the curb face (including the gutter pan if present), and then subtracting 2.4 m from this distance (*see figure 4*). The 2.4-m value accounts for the fact that vehicles occupy, on average, approximately 2.1 m of space when parallel parking and typically park within 0.15 to 0.3 m of the curb.7



when parking lane is marked



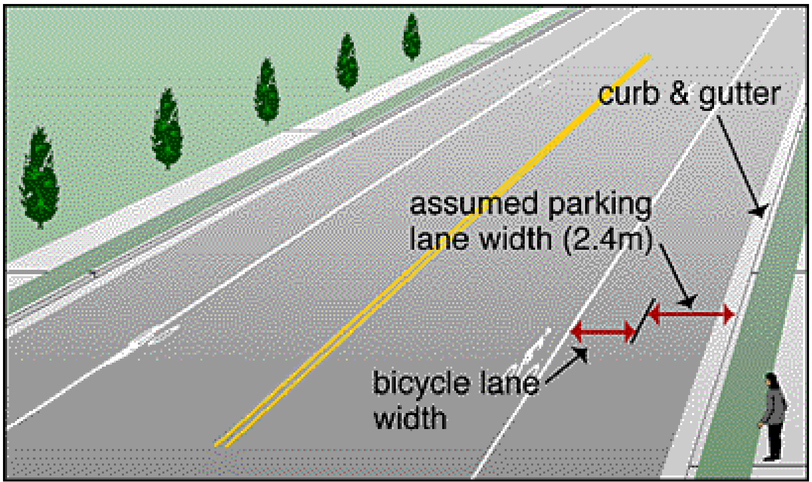
when parking lane is not marked

Figure 4. Curb lane width measurement when there is a parking lane present

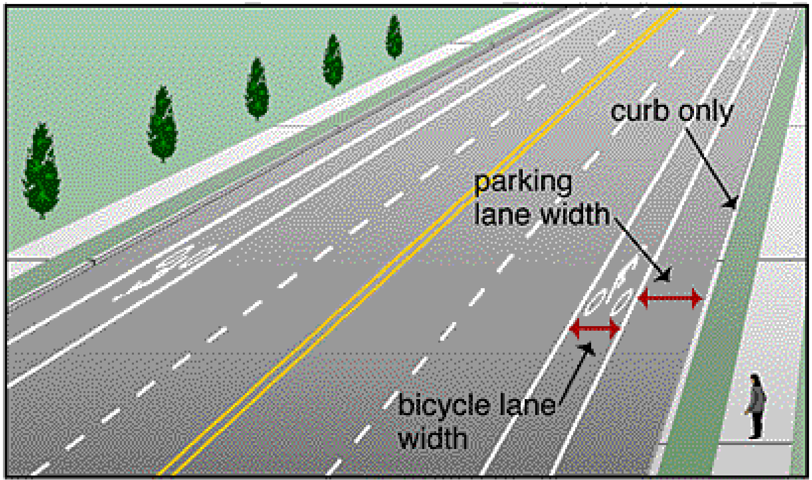
The other scenario common on residential streets is to have no lane markings at all. In this case, the total cross section width can be measured from curb to curb (or gutter pan seam to gutter pan seam) and divided by the number of lanes (typically two) to determine the curb lane width. If parking is also present on this type of unmarked street, the parking lane widths (usually 2.4 m) should be subtracted from the total cross-section width prior to dividing by the number of lanes.

· Bicycle lane (paved shoulder) width - ***width of the bicycle lane or paved shoulder (if present)***, measured to the nearest tenth of a meter. Note that a paved shoulder is treated the same as a bicycle lane in the BCI model since recent research has shown that these two types of facilities result in virtually identical operational behaviors by motorists and bicyclists.8 If there is no parking lane present, the bicycle lane (paved shoulder) width is measured from the center of the edge line separating the bicycle lane from the motor vehicle travel lane to the joint or seam between the pavement edge and the gutter pan as shown in figure 3. If no gutter pan is present, the distance is measured from the edge line to the curb face, and then 0.3 m is subtracted from that distance to account for the space bicyclists will typically leave between themselves and a curb (i.e., the "shy" distance). This scenario is also illustrated in figure 3.

If a marked parking lane is adjacent to the bicycle lane, the bicycle lane width is measured from the center of the edge line (separating the motor vehicle travel lane and bicycle lane) to the center of the parking lane line separating the bicycle lane and the parking lane as shown in figure 5. If the parking lane is not marked, as would be the case in a shared parking/bicycle lane, the bicycle lane width can be determined by measuring the distance from the center of the edge line to the curb face (including the gutter pan if present) and then subtracting 2.4 m from that distance to account for the width of the parking lane. This scenario is also illustrated in figure 5.



when parking lane is marked



when parking lane is not marked

Figure 5. Bicycle lane width measurements when there is a parking lane present

As noted in all of the possible configurations described above and shown in the figures, the curb lane width and bicycle lane (paved shoulder) width measurements either did not include gutter pan widths or included them but subtracted a value to account for the "shy distance" of the bicyclist. The BCI model was developed using sites that either had no gutter pan or had gutter pans ranging from 0.3 to 0.6 m in width. Many communities have gutter pans that are wider than 0.6 m and provide space that can be utilized by a bicyclist. In fact, some communities designate this space as a bicycle lane. In those cases, it is recommended that the practitioner determine if the extra wide gutter pan does indeed provide adequate space for the bicyclist to ride. If so, this space should be added to the curb lane width or bicycle lane width as appropriate.

· Motor vehicle speed - ***85th percentile speed of traffic***, in km/h. This value can be obtained from manual or automated speed data collection efforts; for more information on collecting speed data, refer to the Manual of Transportation Engineering Studies.9 However, if the data are unavailable or the resources to collect speed data do not exist, it is recommended that 15 km/h be added to the posted speed limit as a surrogate measure for the 85th percentile speed. Prior research has shown that 85th percentile speeds for vehicles traveling on many urban and suburban streets (including arterial, collector, and local classifications) generally exceed the speed limit by 10 to 23 km/h.10

· Traffic volume - ***hourly traffic volume by lane in one direction of travel.*** While hourly counts may be available in some locations, it is more likely that AADT counts (collected for continuous 24-hour periods) will be the source of traffic volume information. Converting these data into hourly counts requires knowing the percentage of daily traffic traveling on the roadway during the hour of interest. In most cases, the hour of interest will be the peak hour. This volume can be determined using the following equation:

$$PHV = AADT \times K \times D$$

where:

PHV = peak-hour directional volume,

$AADT$ = average annual daily traffic (vehicles per day)

K = peak-hour factor (the proportion of vehicles traveling during the peak hour, expressed as a decimal), and

D = directional split factor (the proportion of vehicles traveling in the peak direction during the peak hour, expressed as a decimal).

The K- and D-factors are usually determined on the basis of regional or route-specific characteristics. Generally, the K-factor ranges from 0.07 to 0.15 while the D-factor ranges from 0.50 to 0.65 in urban and suburban areas.11 If these factors are unknown or cannot be easily determined, a default K-factor of 10 percent may be assumed (expressed as 0.10), and a default D-factor of 55 percent may be used (expressed as 0.55). Note also that for one-way streets, the D-factor becomes 1.0 since 100 percent of the traffic is traveling in the same direction.

Once the directional hourly volume of traffic is determined using the above formula, it is necessary to assign traffic volumes to the curb lane and other travel lanes if it is a multilane facility. The lane distribution on non-freeway facilities depends on a variety of factors, including number and location of access points, the type of development, traffic composition, speed, volume, and local driving habits. These factors result in very little uniformity from site to site with respect to how volumes are distributed across lanes.5,11 If counts are available by lane, the percentage of vehicles traveling in each lane can be easily determined. If such counts are not available and considering the lack of consistency in this variable across sites, it is recommended that the hourly volume be distributed equally across all through lanes using the following equations:

$$CLV = PHV/N \quad OLV = PHV - CLV$$

where:

CLV = hourly curb lane volume,

OLV = hourly volume in all through lanes except the curb lane,

PHV = peak-hour directional volume, and

N = number of through lanes in one direction.

· Presence and density of on-street parking - ***presence of an on-street parking lane and percentage of spaces occupied***. The simple presence of an on-street parking lane may not adversely impact the comfort level of the bicyclist. During the development of the BCI model, it was shown that at least 30 percent of the spaces had to be occupied before the parking lane impacted the bicyclistsÕ comfort level. Thus, it is necessary to collect occupancy data for the hour being evaluated to determine if this 30 percent occupancy threshold is being met.

· Type of development - ***type of development or land use adjacent to the roadway***. For purposes of the model, only two classifications are required, "residential" and "other." The residential development type proved to be significantly different from all other types of development and was shown to positively impact the comfort level of bicyclists.

· Large truck volume - ***hourly large truck volume in the curb lane***. For purposes of the BCI model, large trucks are simply defined as all vehicles having six or more tires. This definition captures most single unit trucks and all combination unit trucks and buses. Most vehicle counters used today provide vehicle classification, and thus the percentage of trucks in the traffic stream is readily available if traffic count data are available. The volume of large trucks in the curb lane can then be determined as follows:

$$CLTV = PHV \times HV \times T$$

where:

$CLTV$ = curb lane truck volume,

PHV = peak-hour directional volume (all vehicles),

HV = the proportion of all vehicles in the traffic stream that can be defined as large trucks (expressed as a decimal), and

T = curb lane truck factor (proportion of large trucks traveling in the curb lane, expressed as a decimal).

On a two-lane roadway (one lane of travel in each direction), the T-factor, or proportion of large trucks traveling in the curb lane, is 1.0 since 100 percent of the trucks will be traveling in the curb lane. On a multilane roadway, however, the T-factor must be calculated or assumed. If traffic counts are collected by lane of travel, the T-factor can be directly determined. If such data are not available, it is recommended that a default value of 0.80 be used for this factor on multilane roadways, indicating that 80 percent of the large trucks on the roadway are traveling in the curb lane. This value is based on collected data for freeways showing that up to 89 percent of the trucks travel in the curb lane.5 While comparable statistics were not available for arterials and other types of surface streets, the distribution of large trucks by lane of travel is believed to be similar.

If classification counts are not available, the user will have to input a truck percentage value (HV) believed to be appropriate for the type of roadway. In general, many urban streets will have very little or no truck traffic because of travel restrictions placed on such vehicles. An analysis of the FHWA Highway Safety Information System (HSIS) confirmed this fact for certain functional classifications. For the States of Illinois, Utah, and North Carolina, the mean percentage of traffic that was classified as trucks on local streets was less than 1 percent. On collectors, the mean truck percentage ranged from 0.4 to 2.6 percent, while on minor arterials, the range of means was 0.5 to 3.9 percent. The largest percentage of trucks was found on non-freeway principal arterials where the means ranged from 1.4 to 5.4 percent.12 On the basis of this analysis, it is recommended that the truck percentages shown in table 4 be used for the various functional classifications when the practitioner does not have the appropriate data and is not able to adequately determine the actual truck percentage.

- Parking time limits - ***parking time limits for on-street spaces***. Vehicles pulling into or out of on-street parking spaces were shown to adversely impact the comfort level of bicyclists. Thus, as the parking turnover along a street increases, the comfort level for bicyclists decreases. Since most locations will not have parking turnover data or the resources to collect such data, a surrogate measure of parking time limit is recommended. It should be noted, however, that there may be cases where the time limit does not adequately reflect the level of parking turnover. For example, a street in front of a local post office may have 60-minute parking stalls, but the people using these spaces may generally be there no more than 15 minutes at a time. In that case, the value for a 15-minute limit parking stall may be more appropriate.

Right-turn volumes - ***hourly volume of vehicles turning right into all driveways and intersecting streets along the midblock segment being evaluated***. For the BCI model, the adjustment factor is only applied when the hourly number of right turns is 270 or more. Knowing this information will assist in accounting for high-volume driveways or minor streets. Once the peak-hour volume is calculated, determining the number of right-turning vehicles can be done as follows:

$$RTV = PHV \times R$$

where:

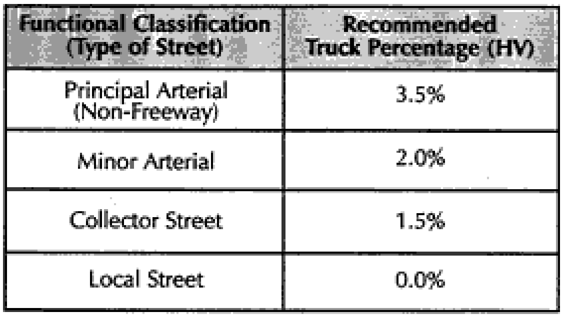
RTV = right-turn volume,

PHV = peak-hour directional volume,

R = proportion of vehicles in the traffic stream turning right into driveways or minor streets along the roadway segment, expressed as a decimal.

Knowledge of the proportion of vehicles turning right into driveways and minor intersection streets along a segment of roadway often may not exist. And since the adjustment factor in the BCI model and the relative impact on the overall bicycle LOS are small, it does not warrant spending resources to obtain this information. Instead, it is recommended that the practitioner use his/her judgment as to whether a specific midblock segment contains a high volume of right-turning traffic during the hour being evaluated. Examples of locations where right-turn volumes may be a factor during the peak hour include business and industrial entrances and minor streets used to cut through neighborhoods.

Table 4. Recommended truck percentages by functional classification for streets where such information is not available.



Functional Classification (Type of Street)	Recommended Truck Percentage (HV)
Principal Arterial (Non-Freeway)	3.5%
Minor Arterial	2.0%
Collector Street	1.5%
Local Street	0.0%

BCI & LOS workbook

The BCI model and the LOS criteria have been incorporated into a workbook to simplify using the model in real-world applications. The workbook is on the enclosed diskette in a Microsoft Excel file named BCI.xls (*see appendix A regarding the English units version*). The definitions, equations, and assumptions described in the previous section have been incorporated where appropriate. The default values used in the workbook are shown in table 5. The workbook includes three separate worksheets that are linked together to produce the BCI and LOS results. The first worksheet is the **Data Entry** form and allows the user to enter location information, geometric and roadside data, traffic operations data, and parking data (*see figure 6*). The location data allows the user to enter a name, number, or other item of information that identifies each midblock segment.

The **geometric and roadside** data elements include:

- Number of through lanes in one direction.
- Curb lane width to the nearest 0.1 meters.
- Bicycle lane or paved shoulder width to the nearest 0.1 meters. Leave blank if non-existent.

- Type of roadside development; specifically whether the development type is residential or not, expressed as ***y*** for yes or ***n*** for no.

The **traffic operations** data elements include:

- Posted speed limit in km/h.

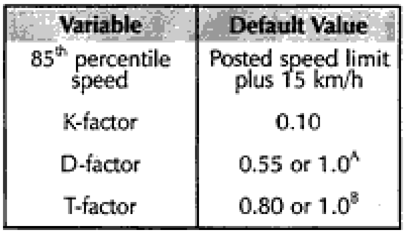
- 85th percentile speed in km/h. Leave blank if it is not known; the workbook will add 15 km/h to the posted speed limit to serve as an estimate of the 85th percentile speed. Note, this additive value can be modified by the user within the worksheet.

- AADT volume.

- Percentage of vehicles in the traffic stream that can be defined as large trucks, expressed as a decimal. See table 4 if this information is unknown.

- Percentage of vehicles in the traffic stream turning right into driveways or minor intersections along the midblock, expressed as a decimal.

Table 5. Summary of default values used in the BCI & LOS workbook.

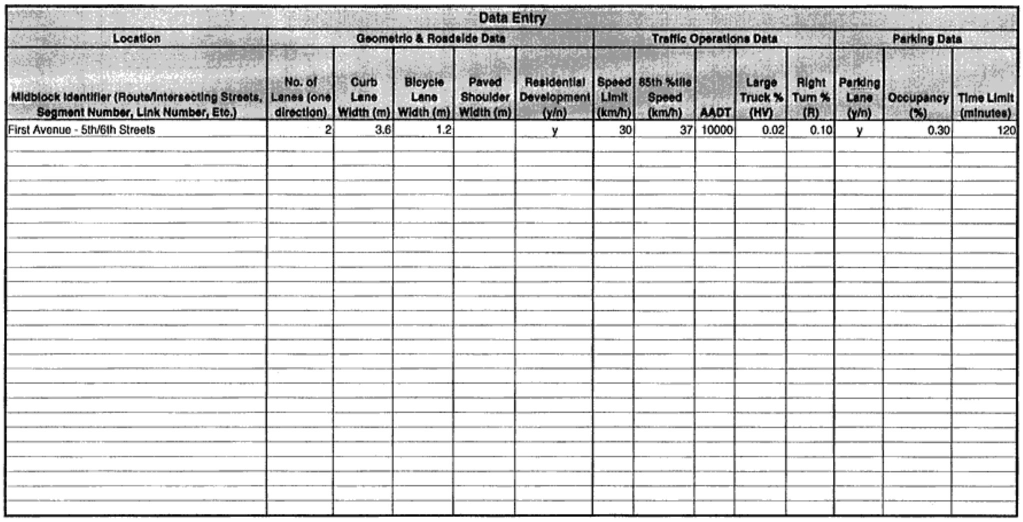


Variable	Default Value
85th percentile speed	Posted speed limit plus 15 km/h
K-factor	0.10
D-factor	0.55 or 1.0[A]
T-factor	0.80 or 1.0[B]

[A] 0.55 on two-way streets; 1.0 on one-way streets

[B] 0.80 on multilane streets; 1.0 on two-lane streets

[Click here to download the Excel Worksheets for FIGURES 6-8]



Data Entry													
Location	Geometric & Roadside Data					Traffic Operations Data					Parking Data		
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	No. of Lanes (one direction)	Curb Lane Width (m)	Bicycle Lane Width (m)	Paved Shoulder Width (m)	Residential Development (y/n)	Speed Limit (km/h)	85th %tile Speed (km/h)	AADT	Large Truck % (HV)	Right Turn % (R)	Parking Lane (y/n)	Occupancy (%)	Time Limit (minutes)
First Avenue - 5th/6th Streets	2	3.6	1.2		y	30	37	10000	0.02	0.10	y	0.30	120

Figure 6. Data Entry worksheet.

The **parking** data elements include:

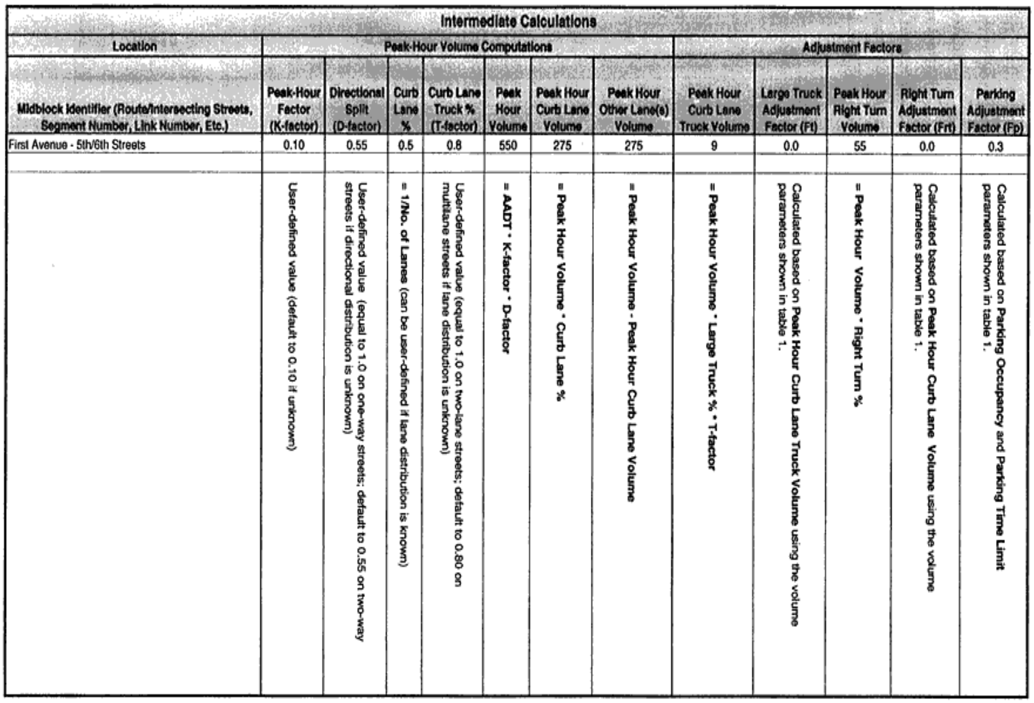
- Presence or absence of a parking lane, expressed as ***y*** for yes or ***n*** for no.

- Percentage of spaces occupied, expressed as a decimal.

- Parking time limit, expressed in minutes. Leave blank if there is no limit (e.g., on a suburban neigborhood street).

The second worksheet contains a series of **Intermediate Calculations**, which converts the AADT into hourly volumes and calculates the three adjustments factors contained in the BCI model (see figure 7). The equations associated with each of the cells in this worksheet are also shown in the figure while the Excel logic is provided in appendix B. The peak-hour factor (K), directional split factor (D), and proportion of large trucks in the curb lane (T-factor) are user-defined values in this worksheet. The assumed default values of 0.10, 0.55, and 0.80 (for a multilane two-way street) for K, D, and T, respectively, are shown in the figure. The proportion of all vehicles traveling in the curb lane (curb lane %) is currently calculated using the number of lanes; this value can entered by the user if the lane distribution is known.

The final calculations are made within the **BCI and LOS Computations** worksheet shown in figure 8. This worksheet contains the nine variables that make up the BCI model, the calculated BCI, and the bicycle LOS and compatibility level. No user inputs are required on this worksheet. All of the data needed will have been provided in the **Data Entry** worksheet or determined within the **Intermediate Calculations** worksheet. The equations associated with each of the cells in this worksheet are also shown in the figure while the Excel logic is provided in appendix B.



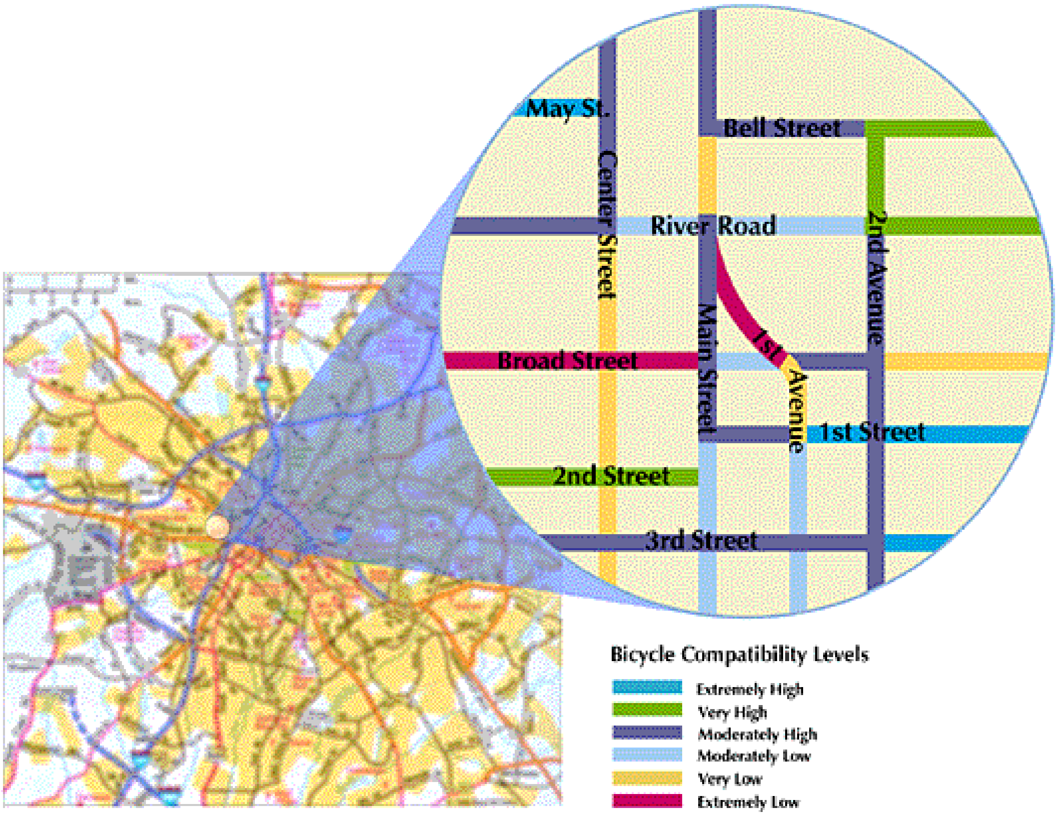
Intermediate Calculations												
Location	Peak-Hour Volume Computations							Adjustment Factors				
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	Peak-Hour Factor (K-factor)	Directional Split (D-factor)	Curb Lane %	Curb Lane Truck % (T-factor)	Peak Hour Volume	Peak Hour Curb Lane Volume	Peak Hour Other Lane(s) Volume	Peak Hour Curb Lane Truck Volume	Large Truck Adjustment Factor (Ft)	Peak Hour Right Turn Volume	Right Turn Adjustment Factor (Frt)	Parking Adjustment Factor (Fp)
First Avenue - 5th/6th Streets	0.10	0.55	0.5	0.8	550	275	275	9	0.0	55	0.0	0.3
	User-defined value (default to 0.10 if unknown)	User-defined value (equal to 1.0 on one-way streets; default to 0.55 on two-way streets if directional distribution is unknown)	= **1/No. of Lanes** (can be user-defined if lane distribution is known)	User-defined value (equal to 1.0 on two-lane streets; default to 0.80 on multilane streets if lane distribution is unknown)	= **AADT * K-factor * D-factor**	= **Peak Hour Volume * Curb Lane %**	= **Peak Hour Volume - Peak Hour Curb Lane Volume**	= **Peak Hour Volume * Large Truck % * T-factor**	Calculated based on **Peak Hour Curb Lane Truck Volume** using the volume parameters shown in table 1.	= **Peak Hour Volume * Right Turn %**	Calculated based on **Peak Hour Curb Lane Volume** using the volume parameters shown in table 1.	Calculated based on **Parking Occupancy** and **Parking Time Limit** parameters shown in table 1.

Figure 7. Intermediate Calculations worksheet.

Application examples

As previously noted, the BCI model is a tool that may be used in a variety of applications, including the evaluation of current operating conditions, proposed roadway designs, and long-range transportation plans. All applications involve either an evaluation of existing geometric and operational conditions or an evaluation of proposed or projected conditions. Evaluating existing conditions allows the practitioner to: 1) produce bicycle compatibility maps (*see figure 9*), which help bicyclists make informed decisions regarding route selection; 2) identify the most appropriate routes within corridors to designate as part of the community bicycle network; and 3) identify the "weak links" on the network and prioritize roadway improvement projects and subsequent funding to correct these deficiencies. Evaluating proposed or projected conditions allows one to: 1) assess the bicycle LOS and compatibility level of all roadway design projects (new or retrofit); 2) assess the impact of proposed developments or changes in land use that may change traffic volumes and/or patterns; and 3) provide input to long-range transportation plans regarding the need for roadway improvements to maintain or enhance bicycle compatibility levels.

Provided below are several examples illustrating how the model may be applied to real-world scenarios. The first set of examples looks at three existing roadway segments with very different geometric configurations. The second set examines three proposed roadway designs, and the final set illustrates how the model can be applied to a transportation planning problem. All of the worksheet entries and computations for the examples are shown in figures 11, 12, and 13.



Evaluation of existing conditions

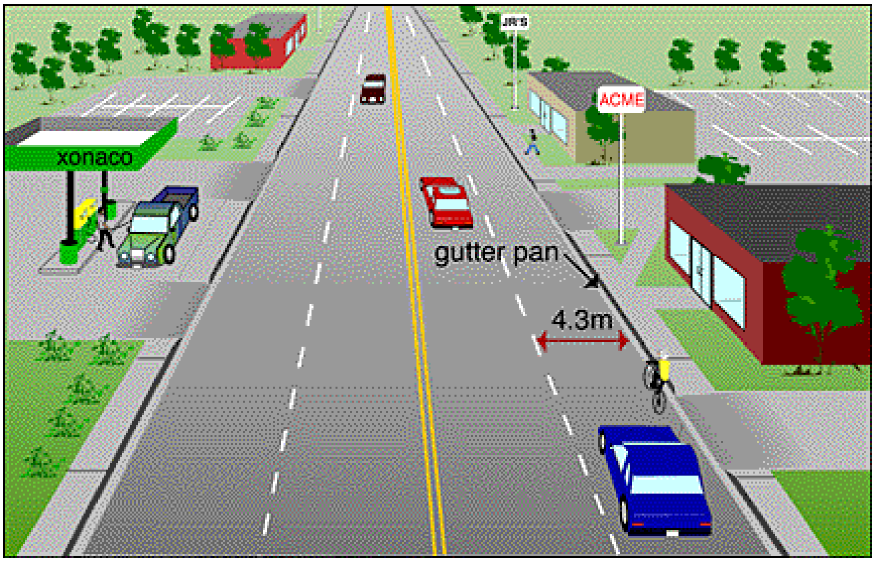
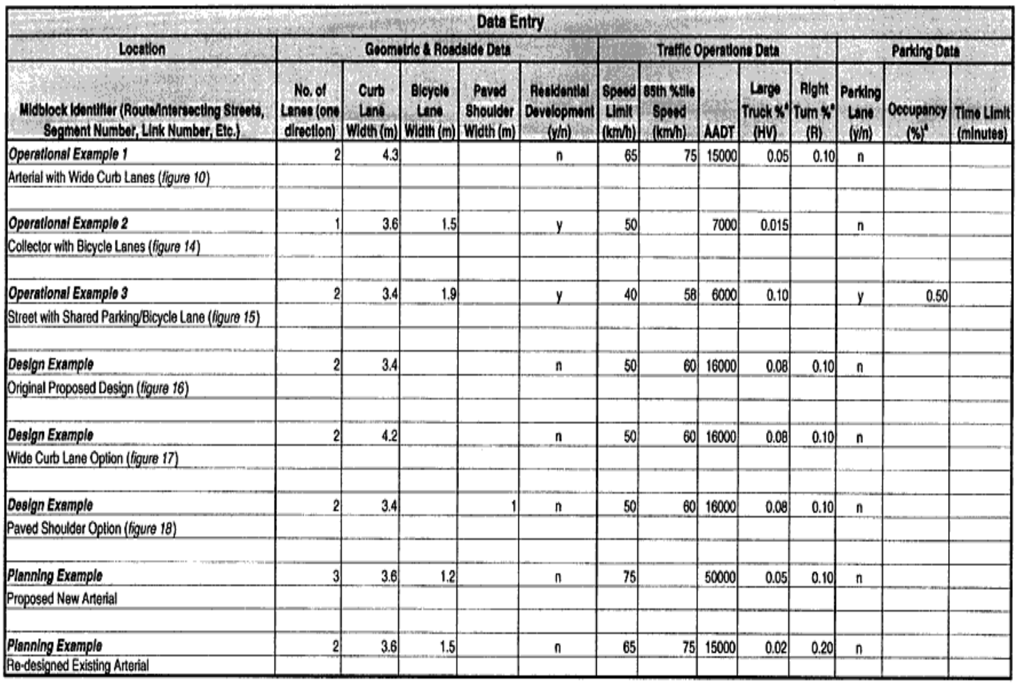


Figure 10. Operational example 1 - multilane wide curb lane street in retail/commercial area.

Operational Example 1 shown in figure 10 is a multilane (two lanes in each direction) wide curb lane arterial that serves as a commuting bicycle corridor. The curb lane width is measured from the center of the lane line to the gutter pan seam and is 4.3 m. The AADT on this segment is 15,000 vehicles per day (vpd). The posted speed limit is 65 km/h, and a speed study showed the 85th percentile speed during the peak-hour to be 75 km/h. As indicated in the figure, there is no on-street parking and the development along the roadside primarily consists of retail centers and commercial businesses. The large truck volume on this route accounts for 5 percent of the traffic during the peak hour, while approximately 10 percent of the vehicles in the traffic stream turn right into driveways or onto minor streets. All of this information has been entered into the data entry form as shown in figure 11 for ***Operational Example 1 - Wide Curb Lane***. The peak-hour volume computations and calculation of adjustment factors are shown in figure 12. The results, shown in figure 13, indicate that this facility produces a BCI of 4.47, which results in a bicycle LOS E and a very low compatibility level for bicycling.

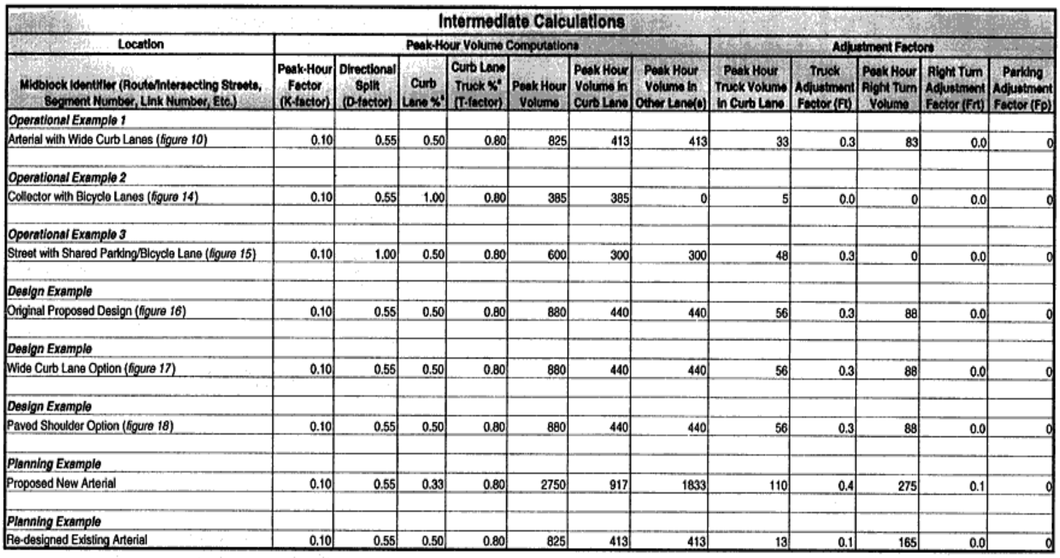
[Click here to download the Excel Worksheets for FIGURES 11-13]



Data Entry													
Location	Geometric & Roadside Data					Traffic Operations Data					Parking Data		
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	No. of Lanes (one direction)	Curb Lane Width (m)	Bicycle Lane Width (m)	Paved Shoulder Width (m)	Residential Development (y/n)	Speed Limit (km/h)	85th %tile Speed (km/h)	AADT	Large Truck %[a] (HV)	Right Turn %[a] (R)	Parking Lane (y/n)	Occupancy (%)[a]	Time Limit (minutes)
Operational Example 1	2	4.3			n	65	75	15000	0.05	0.10	n		
Arterial with Wide Curb Lanes (*figure 10*)													
Operational Example 2	1	3.6	1.5		y	50		7000	0.015		n		
Collector with Bicycle Lanes (*figure 14*)													
Operational Example 3	2	3.4	1.9		y	40	58	6000	0.10		y	0.50	
Street with Shared Parking/Bicycle Lane (*figure 15*)													
Design Example	2	3.4			n	50	60	16000	0.08	0.10	n		
Original Proposed Design (*figure 16*)													
Design Example	2	4.2			n	50	60	16000	0.08	0.10	n		
Wide Curb Lane Option (*figure 17*)													
Design Example	2	3.4		1	n	50	60	16000	0.08	0.10	n		
Paved Shoulder Option (*figure 18*)													
Planning Example	3	3.6	1.2		n	75		50000	0.05	0.10	n		
Proposed New Arterial													
Planning Example	2	3.6	1.5		n	65	75	15000	0.02	0.20	n		
Re-designed Existing Arterial													

[a] Percentages shown as a decimal or proportion

Figure 11. Data Entry worksheet for all application examples.

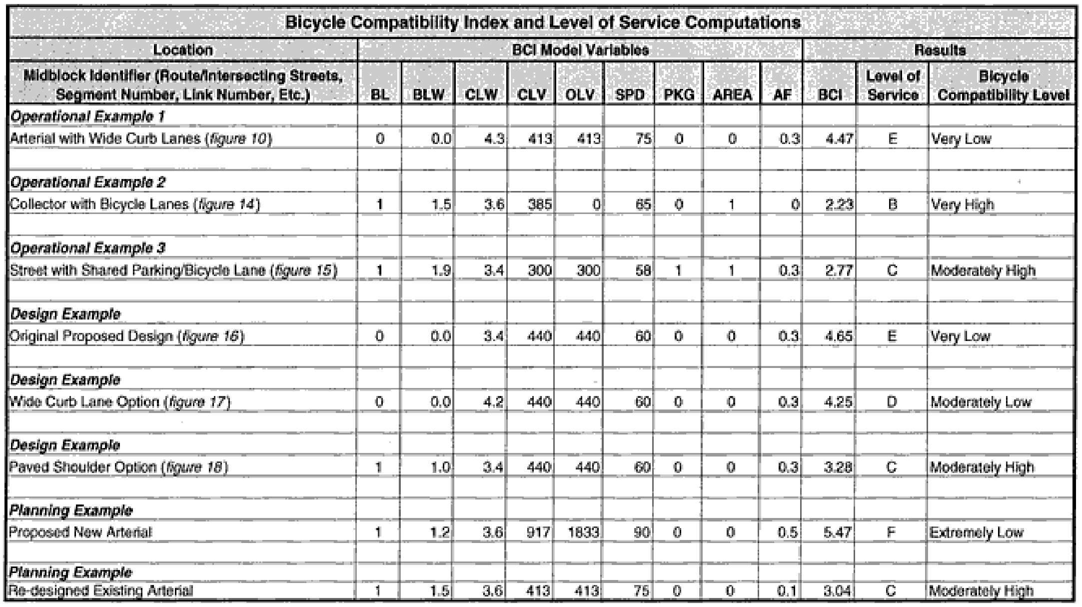


Intermediate Calculations

Location	Peak-Hour Volume Computations							Adjustment Factors				
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	Peak-Hour Factor (K-factor)	Directional Split (D-factor)	Curb Lane %[a]	Curb Lane Truck %[a] (T-factor)	Peak Hour Volume	Peak Hour Volume in Curb Lane	Peak Hour Volume in Other Lane(s)	Peak Hour Truck Volume in Curb Lane	Truck Adjustment Factor (Ft)	Peak Hour Right Turn Volume	Right Turn Adjustment Factor (Frt)	Parking Adjustment Factor (Fp)
Operational Example 1												
Arterial with Wide Curb Lanes (*figure 10*)	0.10	0.55	0.50	0.80	825	413	413	33	0.3	83	0.0	0
Operational Example 2												
Collector with Bicycle Lanes (*figure 14*)	0.10	0.55	1.00	0.80	385	385	0	5	0.0	0	0.0	0
Operational Example 3												
Street with Shared Parking/Bicycle Lane (*figure 15*)	0.10	1.00	0.50	0.80	600	300	300	48	0.3	0	0.0	0
Design Example												
Original Proposed Design (*figure 16*)	0.10	0.55	0.50	0.80	880	440	440	56	0.3	88	0.0	0
Design Example												
Wide Curb Lane Option (*figure 17*)	0.10	0.55	0.50	0.80	880	440	440	56	0.3	88	0.0	0
Design Example												
Paved Shoulder Option (*figure 18*)	0.10	0.55	0.50	0.80	880	440	440	56	0.3	88	0.0	0
Planning Example												
Proposed New Arterial	0.10	0.55	0.33	0.80	2750	917	1833	110	0.4	275	0.1	0
Planning Example												
Re-designed Existing Arterial	0.10	0.55	0.50	0.80	825	413	413	13	0.1	165	0.0	0

[a] Percentages shown as a decimal or proportion

Figure 12. Intermediate Calculations worksheet for all application examples.

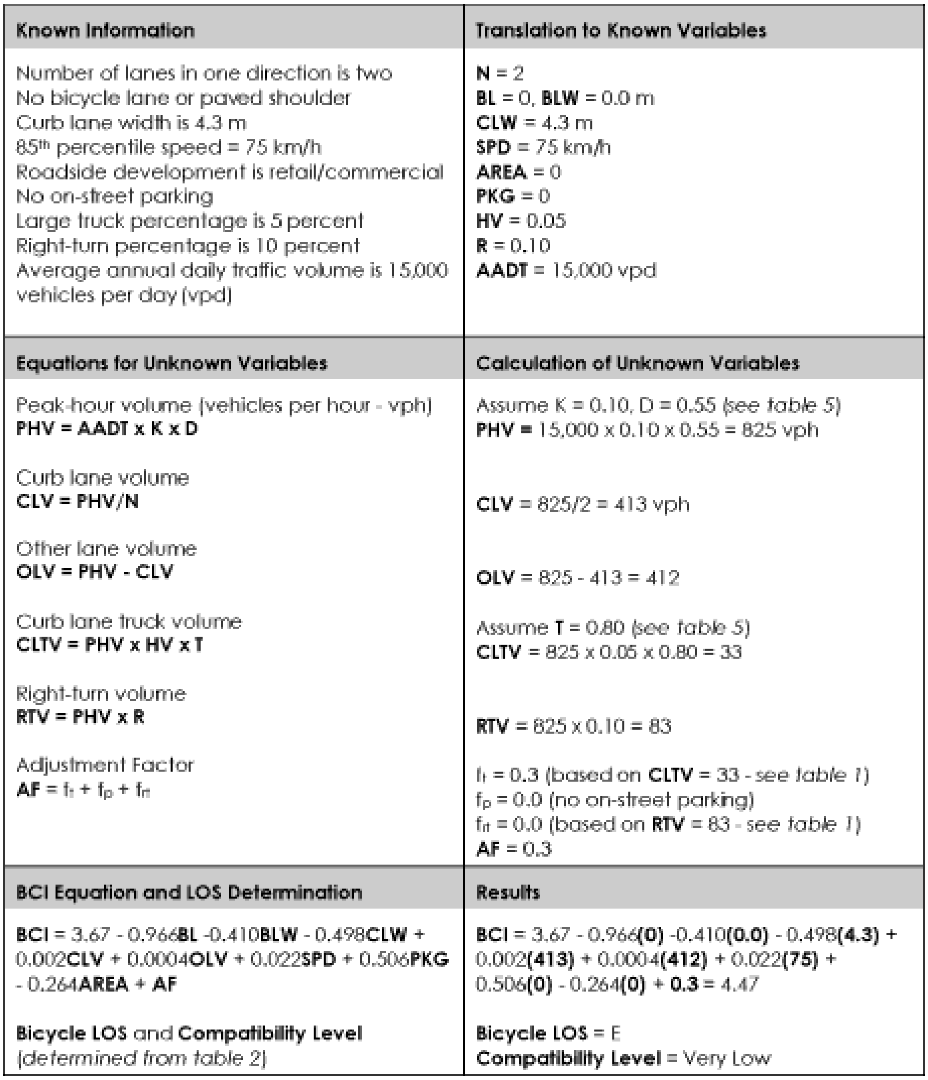


Bicycle Compatibility Index and Level of Service Computations

Location	BCI Model Variables									Results		
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	BL	BLW	CLW	CLV	OLV	SPD	PKG	AREA	AF	BCI	Level of Service	Bicycle Compatibility Level
Operational Example 1												
Arterial with Wide Curb Lanes (*figure 10*)	0	0.0	4.3	413	413	75	0	0	0.3	4.47	E	Very Low
Operational Example 2												
Collector with Bicycle Lanes (*figure 14*)	1	1.5	3.6	385	0	65	0	1	0	2.23	B	Very High
Operational Example 3												
Street with Shared Parking/Bicycle Lane (*figure 15*)	1	1.9	3.4	300	300	58	1	1	0.3	2.77	C	Moderately High
Design Example												
Original Proposed Design (*figure 16*)	0	0.0	3.4	440	440	60	0	0	0.3	4.65	E	Very Low
Design Example												
Wide Curb Lane Option (*figure 17*)	0	0.0	4.2	440	440	60	0	0	0.3	4.25	D	Moderately Low
Design Example												
Paved Shoulder Option (*figure 18*)	1	1.0	3.4	440	440	60	0	0	0.3	3.28	C	Moderately High
Planning Example												
Proposed New Arterial	1	1.2	3.6	917	1833	90	0	0	0.5	5.47	F	Extremely Low
Planning Example												
Re-designed Existing Arterial	1	1.5	3.6	413	413	75	0	0	0.1	3.04	C	Moderately High

Figure 13. BCI and LOS Computations worksheet for all application examples.

Should an individual or agency not have access to a computer or the software necessary to use the spreadsheet application, the computations would have to be made manually. The manual calculations for the operational example just described (***Operational Example 1 - Wide Curb Lane***) are shown in table 6. First, the known information and translation of this information into variables needed for the model or subsequent calculations is shown. Next, the intermediate equations and computations are provided, including the determination of the adjustment factor. Finally, the calculation of the BCI and determination of the bicycle LOS and compatibility level are illustrated.



Known Information	**Translation to Known Variables**
Number of lanes in one direction is two	**N** = 2
No bicycle lane or paved shoulder	**BL** = 0, **BLW** = 0.0 m
Curb lane width is 4.3 m	**CLW** = 4.3 m
85th percentile speed = 75 km/h	**SPD** = 75 km/h
Roadside development is retail/commercial	**AREA** = 0
No on-street parking	**PKG** = 0
Large truck percentage is 5 percent	**HV** = 0.05
Right-turn percentage is 10 percent	**R** = 0.10
Average annual daily traffic volume is 15,000 vehicles per day (vpd)	**AADT** = 15,000 vpd
Equations for Unknown Variables	**Calculation of Unknown Variables**
Peak-hour volume (vehicles per hour - vph) **PHV = AADT x K x D**	Assume K = 0.10, D = 0.55 (*see table 5*) **PHV =** 15,000 x 0.10 x 0.55 = 825 vph
Curb lane volume **CLV = PHV/N**	**CLV** = 825/2 = 413 vph
Other lane volume **OLV = PHV - CLV**	**OLV** = 825 - 413 = 412
Curb lane truck volume **CLTV = PHV x HV x T**	Assume **T** = 0.80 (*see table 5*) **CLTV** = 825 x 0.05 x 0.80 = 33
Right-turn volume **RTV = PHV x R**	**RTV** = 825 x 0.10 = 83
Adjustment Factor **AF** = $f_t + f_p + f_{rt}$	f_t = 0.3 (based on **CLTV** = 33 - *see table 1*) f_p = 0.0 (no on-street parking) f_{rt} = 0.0 (based on **RTV** = 83 - *see table 1*) **AF** = 0.3
BCI Equation and LOS Determination	**Results**
BCI = 3.67 - 0.966**BL** -0.410**BLW** - 0.498**CLW** + 0.002**CLV** + 0.0004**OLV** + 0.022**SPD** + 0.506**PKG** - 0.264**AREA** + **AF**	**BCI** = 3.67 - 0.966**(0)** -0.410**(0.0)** - 0.498**(4.3)** + 0.002**(413)** + 0.0004**(412)** + 0.022**(75)** + 0.506**(0)** - 0.264**(0)** + **0.3** = 4.47
Bicycle LOS and **Compatibility Level** (*determined from table 2*)	**Bicycle LOS** = E **Compatibility Level** = Very Low

Table 6

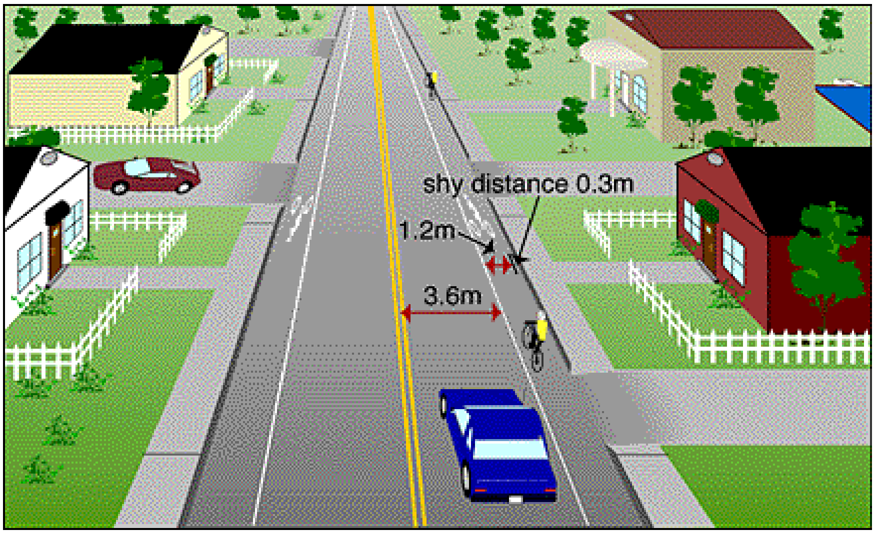


Figure14. Operational Example 2- two-lane collector street with bicycle lane in residential neighborhood

Operational Example 2 is shown in figure 14 and is a two-lane suburban collector street with bicycle lanes. The curb lane and bicycle lane widths are 3.6 m and 1.5 m, respectively. The AADT on this segment is 7,000 vpd, and the posted speed limit is 50 km/h. As shown in the figure, the development type along the roadside is residential, and there is no on-street parking. The volume of traffic turning right during the peak-hour is unknown but is assumed to be insignificant considering the development type. The 85th percentile speed of traffic is also unknown; thus, the default value in the program is being used that simply adds 15 km/h to the speed limit, resulting in an assumed value of 70 km/h. The composition of the traffic is another variable that is not known for this particular street. It is being assumed that the percentage of trucks on this route during the peak hour is only 1.5 percent (*see table 4*). These entries are shown in figure 11 for ***Operational Example 2 - Bicycle Lane***. The intermediate calculations are shown in figure 12 and the results in figure 13. The BCI for this roadway segment is 2.23, which results in a bicycle LOS B and indicates a very high bicycling compatibility level.

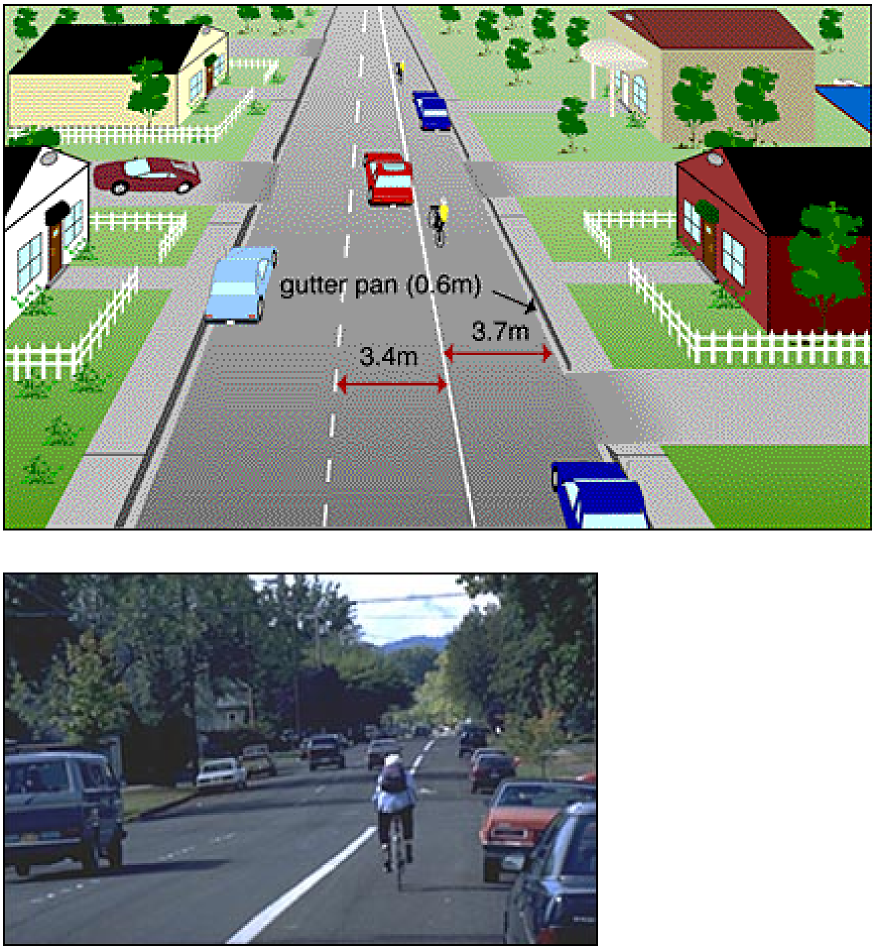


Figure 15. Operational Example 3 - one-way multilane street with a shared bicycle/parking lane in a residential area.

In figure 15, ***Operational Example 3*** is illustrated and includes a shared parking/bicycle lane shown on a one-way multilane street. The width of this shared lane is 3.7 m, measured from the center of the edge line to the gutter pan seam. The gutter pan is 0.6 m wide. Since there is no line separating the parking lane from the bicycle lane, an assumed parking lane width of 2.4 m is used and subtracted from the total width available (including the gutter pan) of 4.3 m, resulting in a bicycle lane width of 1.9 m. The curb lane width is measured from the center of the lane line to the center of the edge line and is 3.4 m. The AADT on this segment is 6,000 vpd, and the truck percentage during the peak hour is 10 percent. Since this location is a one-way street and 100 percent of the traffic on the roadway is now traveling in one direction, the directional split (D-factor) is 1.0.

The posted speed limit is 40 km/h, while the 85th percentile speed is 58 km/h. During the peak hour, approximately 50 percent of the available parking spaces are occupied. Finally, the development type is predominantly residential, and the right-turn volume is known to be very low during the peak hour. The intermediate calculations for ***Operational Example 3 - Shared Parking/Bicycle Lane*** are shown in figure 12, including the change in the directional split factor to 1.0. The results are shown in figure 13 and indicate that the BCI for this roadway segment is 2.77, which results in a bicycle LOS C, reflecting a moderately high compatibility level for bicycling.

Assessment of proposed design alternatives

Another practical employment of the BCI model is in the evaluation of proposed roadway designs. The following example illustrates how the BCI model can be used to achieve a design that is "bicycle friendly." A two-lane minor arterial with a two-way-left-turn lane (TWLTL) is being widened to a multilane roadway with a raised median and left-turn bays to accommodate the projected increase in traffic volume and improve safety along the corridor. The roadway currently has 1.2-m bicycle lanes and serves as an important link in the bicycle network. The roadway presently operates at bicycle LOS C, which indicates a moderately high compatibility level for bicycling. The projected traffic volume being used for the design is 16,000 vpd, with 8 percent of those vehicles being large trucks. The posted speed limit will be 50 km/h, and the 85th percentile speed is expected to be 60 km/h. The development along the route is mixed commercial, and there are no plans for on-street parking.

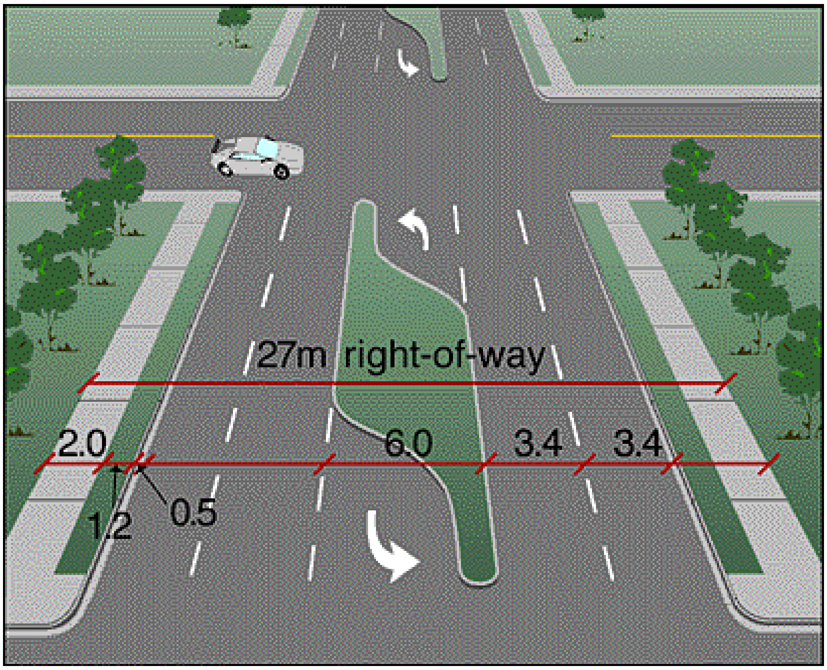


Figure 16. Design Example - original proposed design

The original proposed design was developed within a 27-m right-of-way (ROW) and is shown in figure 16. It consists of four 3.4-m travel lanes, a 6.0-m raised median with left-turn bays, a 2.0-m sidewalk on both sides of the street, a planting strip (1.2 m wide) on both sides separating the travel lanes from the sidewalk, and 0.5-m-wide gutter pans. These geometric data and the operational data provided above are shown in the data entry worksheet in figure 11 for ***Design Example - Original Proposed Design***. The intermediate calculations are shown in figure 12 and the results in figure 13. The BCI for this original design is 4.65, reflecting a bicycle LOS E and a very low compatibility level for bicycling.

Since this route is an important link within the bicycle network, this original design is unacceptable for bicyclists. The goal of the local bicycle coordinator is to maintain the bicycle LOS C, which is currently present on the two-lane facility. After discussing the problems with the roadway design engineers, an alternative plan within the same 27-m ROW is developed in which the median width is reduced from 6.0 m to 4.8 m and the planting strip is reduced from 1.2 m to 1.0 m on both sides of the roadway. The additional 1.6 m in width is added to the curb lanes to create 4.2-m-wide lanes as shown in figure 17. This new curb lane width was entered in the data entry worksheet as shown in figure 11 for ***Design Example - Wide Curb Lane Option***. The results, shown in figure 13, indicate that the BCI for this wide curb lane option is 4.25, which results in a bicycle LOS D and reflects a moderately low compatibility level for bicycling. While this design is an improvement over the original design, it still does not meet the goal of maintaining the existing level of compatibility for bicycling (i.e., LOS C).

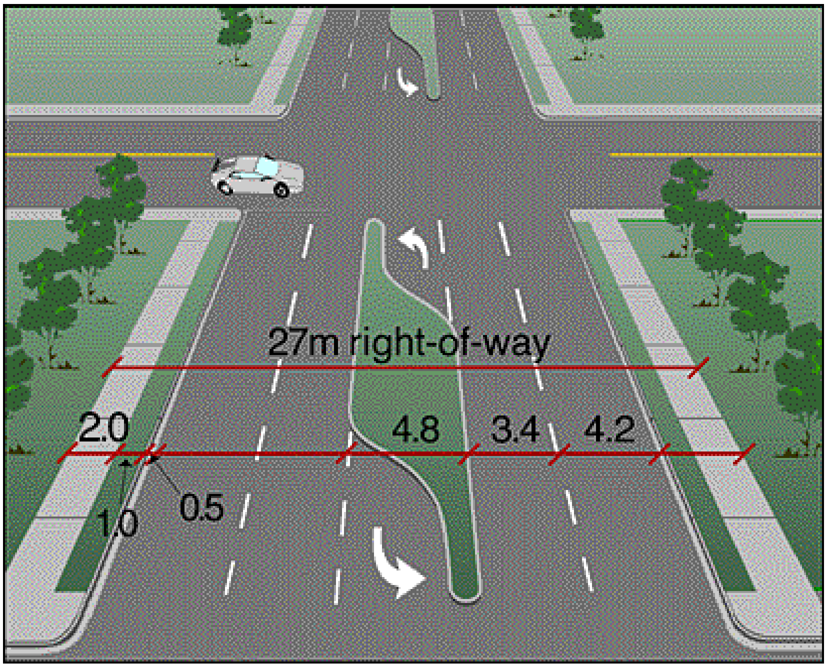
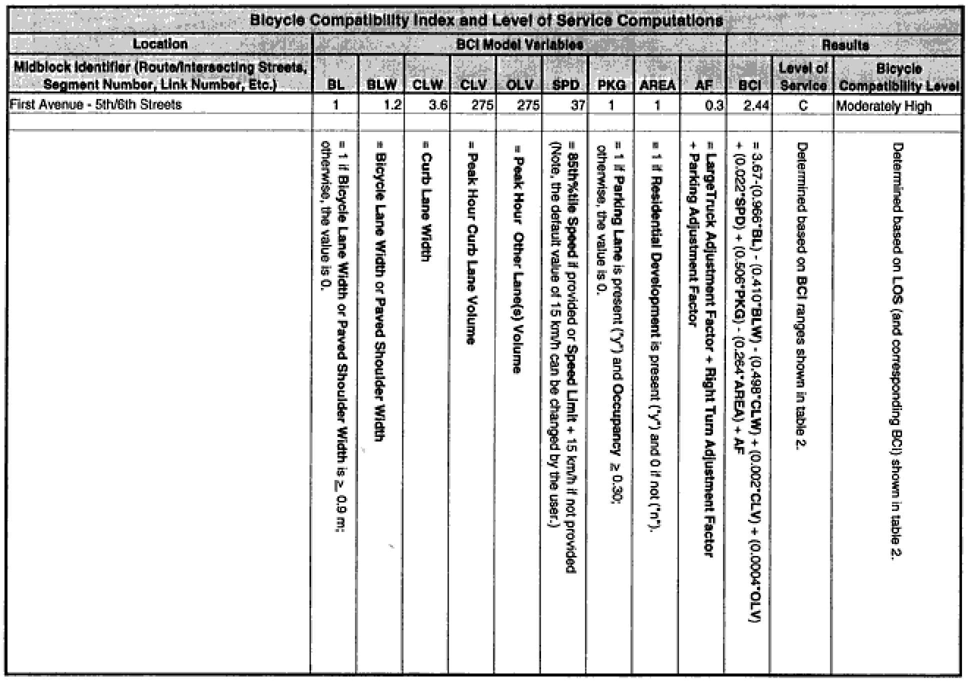


Figure 17. Design example - wide curb lane option

A third alternative was proposed within the existing 27-m ROW in which the median width remained at 4.8 m, the planting strips remained at 1.0 m, and the curb lanes returned to 3.4 m. The only remaining feature that the design engineers were willing to alter was the sidewalk. By reducing the width of the sidewalks from 2.0 to 1.8 m and combining this width gain with those previously achieved in reducing the median width and planting strip widths, a 1.0-m paved shoulder could be incorporated on both sides of the street as shown in figure 18. These new values were entered in the data entry worksheet as shown in figure 11 for ***Design Example - Paved Shoulder Option***. The results, shown in figure 13, indicate that the BCI for this option is 3.28, which corresponds to a bicycle LOS C, reflecting a moderately high compatibility level for bicycling. This design meets the goal of maintaining the present compatibility level for bicycling and is selected as the most desirable alternative.



Bicycle Compatibility Index and Level of Service Computations												
Location	**BCI Model Variables**									**Results**		
Midblock Identifier (Route/Intersecting Streets, Segment Number, Link Number, Etc.)	**BL**	**BLW**	**CLW**	**CLV**	**OLV**	**SPD**	**PKG**	**AREA**	**AF**	**BCI**	**Level of Service**	**Bicycle Compatibility Level**
First Avenue - 5th/6th Streets	1	1.2	3.6	275	275	37	1	1	0.3	2.44	C	Moderately High
	= 1 if **Bicycle Lane Width** or **Paved Shoulder Width** is ≥ 0.9 m; otherwise, the value is 0.	= **Bicycle Lane Width** or **Paved Shoulder Width**	= **Curb Lane Width**	= **Peak Hour Curb Lane Volume**	= **Peak Hour Other Lane(s) Volume**	= **85th%tile Speed** if provided or **Speed Limit** + 15 km/h if not provided (Note, the default value of 15 km/h can be changed by the user.)	= 1 if **Parking Lane** is present ("y") and **Occupancy** ≥ 0.30; otherwise, the value is 0.	= 1 if **Residential Development** is present ("y") and 0 if not ("n").	= **LargeTruck Adjustment Factor** + **Right Turn Adjustment Factor** + **Parking Adjustment Factor**	= 3.67-(0.966***BL**) - (0.410***BLW**) - (0.498***CLW**) + (0.002***CLV**) + (0.0004***OLV**) + (0.022***SPD**) + (0.506***PKG**) - (0.264***AREA**) + **AF**	Determined based on **BCI** ranges shown in table 2.	Determined based on **LOS** (and corresponding BCI) shown in table 2.

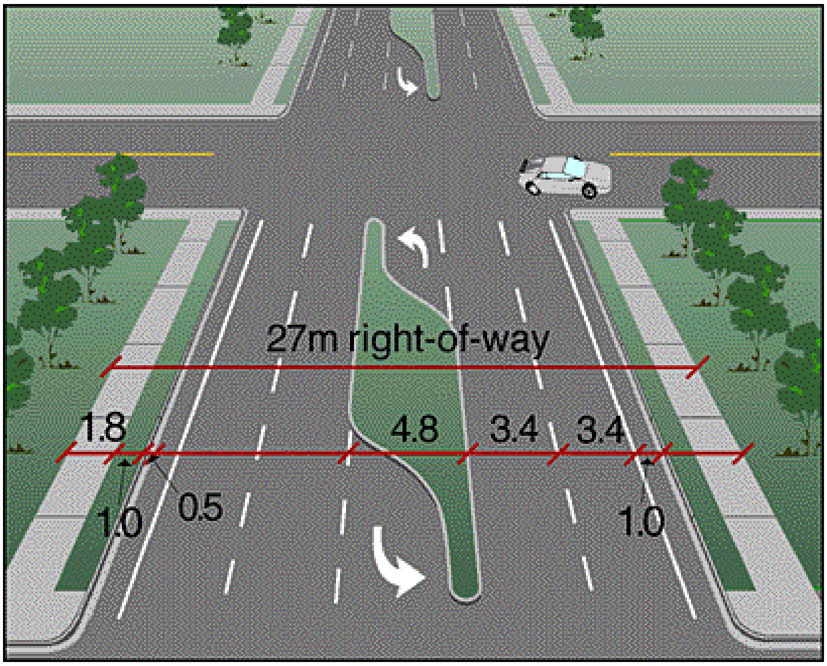
Figure 8. BCI and LOS Computations worksheet.

Planning to accommodate bicyclists

The BCI model can also be used to assess long-range transportation plans and the alternatives that may be proposed. The following example illustrates how the model can be used to plan for a bicycle corridor. A suburban area on the west side of the city is currently growing at an exponential rate and is expected to triple its population base within the next 10 years. Consequently, there is a need to either upgrade the major arterial that currently provides access between this area and the central business district or build a new roadway to accommodate the expected increase in traffic. The present arterial is a four-lane facility with a variety of retail and commercial development along the roadside with virtually no right-of-way for additional lanes.

Based on a cost-feasibility study, the decision was made to build a new roadway with a 1.2-m bicycle lane to accommodate bicyclists. Since there is no provision for bicyclists on the current arterial, this plan initially sounded like a major victory for bicycling commuters. The proposed roadway is a six-lane arterial with a projected traffic volume of 50,000 vpd and a posted speed limit of 75 km/h. The travel lanes will be 3.6 m wide, trucks are expected to comprise 5 percent of the volume, and 10 percent of the traffic is expected to turn right into driveways or onto minor streets. All of these data were entered in the data entry worksheet as shown in figure 11 ***for Planning Example - Proposed New Arterial***. The results, shown in figure 13, indicate that the BCI for this new proposed arterial will be 5.47. This value translates into a LOS F and indicates that the facility will be extremely incompatible for bicycling. So while the addition of a bicycle lane looked like a good idea, the reality is that the combination of other geometric and operational characteristics would create an unfriendly environment for bicyclists.

Since increasing the bicycle level of service to LOS C or better on the new proposed arterial could simply not be done within the right-of-way constraints, it was necessary to look for alternatives to provide a bicycle route within this same corridor. One alternative proposed by the local resident engineer consisted of removing the bicycle lane from the new facility and using the cost savings resulting from the reduced right-of-way needs to improve the old (existing) arterial to accommodate bicyclists. Once the new arterial is built, traffic on the existing roadway is expected to decrease to 15,000 vpd. The percentage of trucks is also expected to decrease to 2 percent while the percentage of traffic making right turns is expected to increase to 20 percent since a greater number of users of this roadway will now be individuals interested in patronizing one of the local businesses. The estimated 85th percentile speed is expected to remain at 75 km/h. The current configuration of lanes on this roadway is four 3.4-m through lanes (two in each direction) and a substandard 3.8-m two-way-left-turn lane (TWLTL). The proposed new configuration eliminates the TWLTL, increases the through lanes to 3.6 m in width, and includes 1.5-m bicycle lane on both sides of the roadway. This information was entered in the data entry worksheet in figure 11 for ***Planning Example - Re-designed Existing Arterial***. The results, shown in figure 13, indicate that the BCI for this new proposed arterial will be 3.04. This value translates into a LOS C and indicates that the bicycling compatibility level will be moderately high. Ultimately, these results indicate the need to revise the plans for the new arterial, including reducing the right-of-way required, and the need to plan on reconfiguring the existing roadway to create a more user-friendly roadway for bicyclists.



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