Session 11-110, Negotiating Challenging Legal Issues in Planning

HUB-CAP, A-How-Tool to Meet Legal Challenges For Lane Rental during Construction

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Abstract - The Highway User Benefit-Cost Analysis Program (HUB-CAP) provides the Virginia Department of Transportation (VDOT) with a standardized method to quantify road user benefits/costs to the traveling public based on roadway geometric, traffic, and operating characteristics. Based on this information, the Department can determine the cost effectiveness of various alternatives including detours, temporary roadway or shoulder construction, off-peak hour day work, night work, and the most appropriate project delivery method (i.e., Incentive/Disincentive, A+B Bidding, etc.).

HUB-CAP provides valuable information to the designers, project managers and construction engineers when determining the most appropriate construction staging and final design. This application should be used early in the design process while there is still flexibility in the design. The optimal design will mitigate or avoid disruptions before they can occur. This application can also determine future highway user benefits-costs based on future improvement needs. By understanding the major factors influencing highway user benefits-costs, the analyst can take steps to minimize the effect of any future rehabilitation activities on roadway users.

This tool was developed after researching the methodologies and application used by five U.S. States' Department of Transportation, two Canadian and AASHTO's 2003 Highway User Benefit Analysis for Highway (The Red Book) as a starting point. HUB-CAP consists of four modules:

- Module 1A - Value of Time using daily traffic volumes
- Module 1B – Value of Time using hourly traffic volume with more features
- Module 2 - Accident Benefits-Cost analysis
- Module 3 - Operating and Ownership Benefits-Cost analysis

The HUB-CAP application has already been implemented at VDOT by area construction engineers and construction managers. This has resulted in several projects being delivered on time with substantial saving to the users and VDOT in construction duration, user costs and completion of the project on-time.

Executive Summary

Maintaining the roads in Virginia is a vital issue that the agency faces throughout the year. VDOT's districts (9) with congested roads tend to contract the highway improvements taking effect during the off peak hours and/or at night. Therefore, the contractor is required to have the rented lane(s) open during the AM (5:00-9:00) and PM (3:00 - 9:00) peak periods. The legal challenges that VDOT experienced dealing with the traffic issues that were caused by the contractors, has made the agency to develop the Highway User Benefit-Cost Analysis Program, HUB-CAP. The HUB-CAP, assist Virginia DOT project control divisions to cost out user's benefit or lost for the before, during and after construction of a project. Whether it is a lane marking, paving, lane addition or reduction, the project managers can calculate the user's benefit-cost, B-C, for the project. With minimum data entry, the product of the HUB-CAP will assist project managers to determine the incentive or disincentive clauses of a contract. The use of HUB-CAP will significantly reduce the potential legal challenges that were raised before due to contractor failure to meet the agreement. The spreadsheet program HUB-CAP has four modules that estimate: *Daily* and *Hourly* Value of Time B-C, *Accident* B-C and *Operation & Ownership* B-C for before and after project. HUB-CAP has been well received by the Department's Attorney General Office Staff and State's Construction and Project Control Divisions. Since utilization of this program; the Benefit-Cost for the Department has been tremendous in terms of staff time and expenses. This application can handle unit conversion for the modules' inputs, and best of all, most of the data inputs are readily available statewide and/or nationwide.

Introduction

The Road User Cost Guidelines Manual was developed to find the work zone delay costs to highway users resulting from construction, maintenance, or rehabilitation activities. The Guidelines are function of timing, duration, frequency, scope, and characteristics of the work zone; the volume and operating characteristics of the traffic affected; and the dollar cost rates assigned to vehicle operations and delays. This manual will familiarize the analyst with work zone and traffic characteristics, explain the possible work zone related road user cost components that can occur, and provide a step-by-step procedure to determine road user costs.

The Road User Cost application HUB-CAP, plays an important role in computing Liquidated Damages. The contractor's failure to complete a contract or reopen a lane of traffic on time results in additional impact damages in terms of time delay and any associated cost to the traveling public and to the Department. The procedures in the VDOT User Cost Guidelines Manual utilize MS-Excel software called HUB-CAP in order to calculate theses damages. This program can be utilized for both planning and operation analysis.

Methodology

With the help of AASHTO Red Book, *"User Benefit Analysis for Highways, August 2003"*, three modules were selected from Chapter 5 and modified to create four modules in the "Highway User Benefit-Cost Analysis Program", HUB-CAP. The HUB-CAP program consists of input and output. The first part of the program input consists of inputs that are shared among

all four modules; they are facility: *name*, *type*, *area*, *directional number of lanes*, *vehicle class*, *ADT, closing length, percent detour and construction year*. Part two of the input is module specific. Module 1A requires input to calculate daily value of time that highway users gained or lose as a result of the road project. This module provides three methods of calculating the benefit or cost. For the Module 1B, hourly traffic rates (hourly volume divided by 24-hour volume) are required to compute the hourly users' benefit or cost for the project. Modules 1A and 1B is primarily used for the effect of lane reduction or addition and is subject to hourly traffic volume up to twenty four (24) hours. Module 2 allows various methods of calculation for crash rate prediction and associated benefit or cost. Module 3 calculates out-of-pocket user costs. As necessary, a lookup table is provided to assist the user for values that are not available for the project. More details on these modules are provided below.

The Before (Existing) and After (When existing condition changes) travel time (TT) is calculated using **BPR** and **Modified BPR** formulations that convert original free flow travel time into restrained travel time using volume-to-capacity (v/c) ratio.

BPR (Bureau of Public Road) Volume-Delay Function = 1 + a (v/c) ^{b} (Eq. 1)

The *Free-Flow* speed is calculated using following 85th percentile equation.

F-F Speed = 7.675 + 0.98 x Posted Speed (Eq. 2)

The parameters ***a*** and ***b*** change by the facility type, area type and speed. See Table 1 for ***a*** and ***b*** values.

Table 1 – BPR and Modified BPR *Parameters a* and *b*

Model	Parameter ***a***		Parameter ***b***	
	Freeway	Multi-la-hwy	Freeway	Multi-la-hwy
BPR	0.150		4	
Updated BPR UnSig.	0.200		10	
Updated BPR Sig.	0.050		10	
Collector	0.075		10	
FHWA= 0.87 + a(v/c)^{b}	0.130		4	
HCM 70 mph	0.88	1.00	9.80	5.40
HCM 60 mph	0.83	0.83	5.50	2.70
HCM 50 mph	0.56	0.71	3.60	2.10

Module 1A – Daily Value of Time

This module will estimate user benefits or cost using value of time by vehicle class (Auto and Truck) applying Delay, Operation or Posted Speed method using following inputs.

- Percentage of Hourly Compensation
- Average Hourly Wages in dollar

- Average Vehicle Occupancy Rate
- Average Daily Traffic (ADT) Volume
- Seasonal Factor (ADT/AADT)
- Capacity per hour per lane
- Percent Truck as percent of ADT
- Directional Number of Lanes
- Delay (min.), Operation or Posted Speed (mph or kph)

Once these inputs are entered, the **Output Table** provides following data for the Before and After conditions including:

- Operating Speed, mph or kph, where Delay or Posted Speed Method is applied
- Auto and Truck vehicle miles of travel, VMT
- Auto and Truck Travel Time and Delay, min.
- Auto and Truck User Hourly Value of Time per VMT, $
- Auto and Truck estimated Benefit or Cost, $

Figure 1 – Modules general inputs

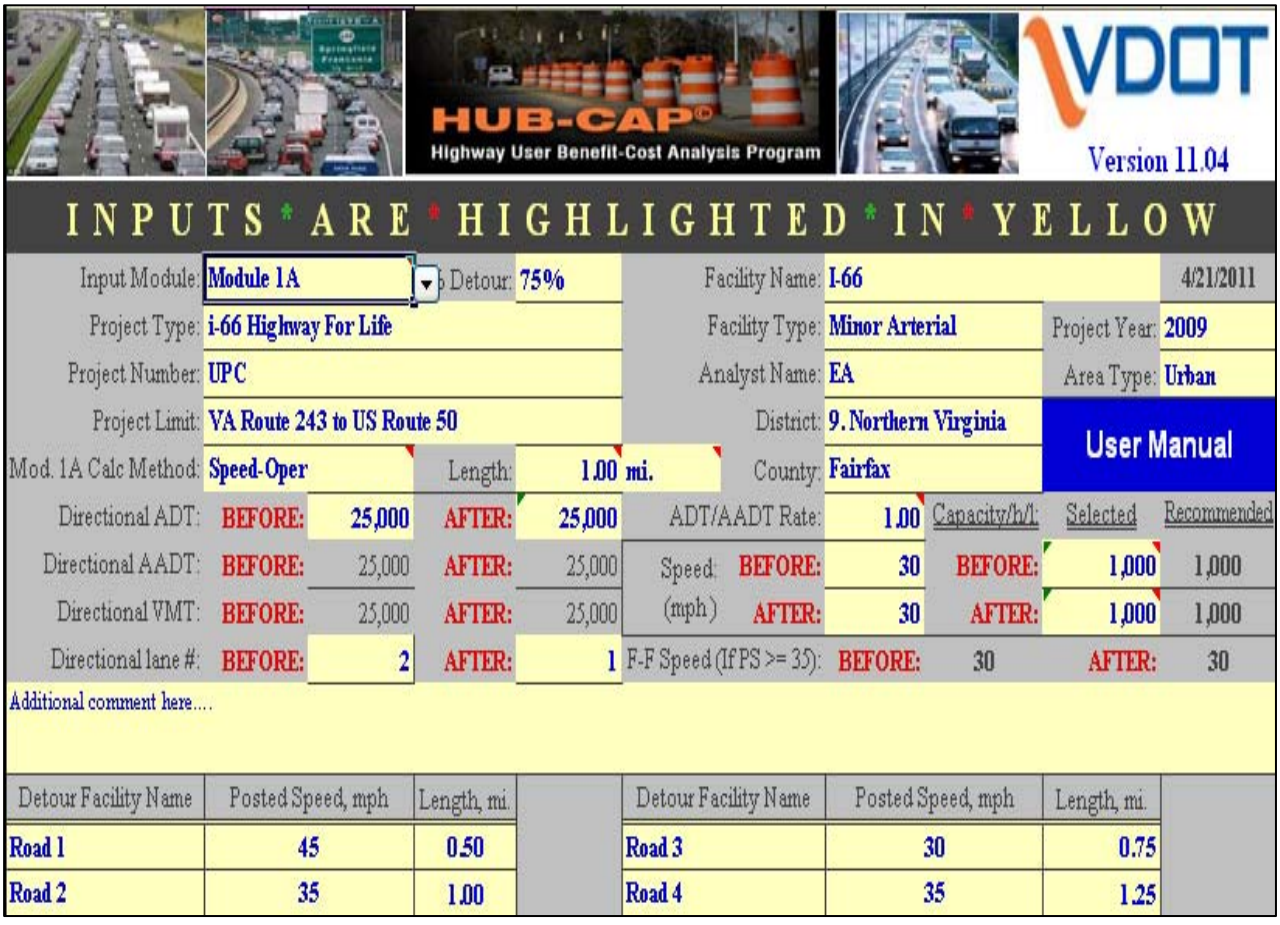
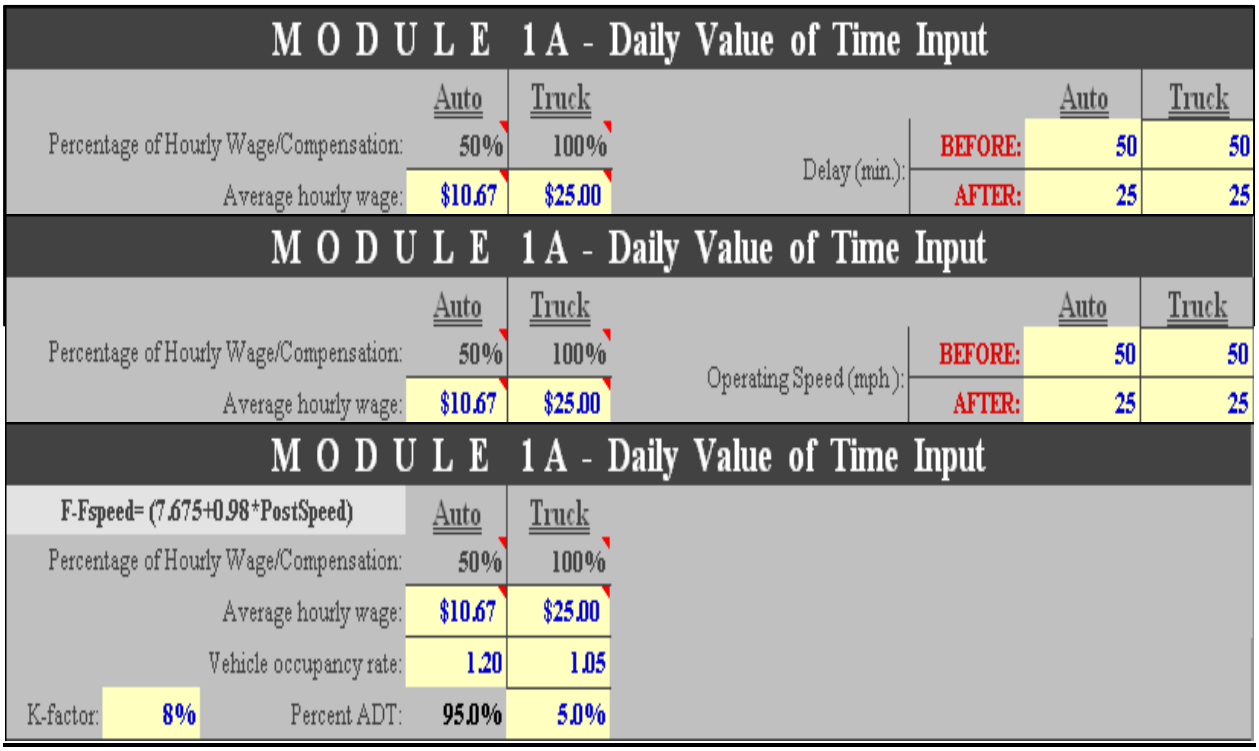


Figure 2 – Module 1A inputs



MODULE 1A - Daily Value of Time Input

	Auto	Truck
Percentage of Hourly Wage/Compensation:	50%	100%
Average hourly wage:	$10.67	$25.00

Delay (min.):	Auto	Truck
BEFORE:	50	50
AFTER:	25	25

MODULE 1A - Daily Value of Time Input

	Auto	Truck
Percentage of Hourly Wage/Compensation:	50%	100%
Average hourly wage:	$10.67	$25.00

Operating Speed (mph):	Auto	Truck
BEFORE:	50	50
AFTER:	25	25

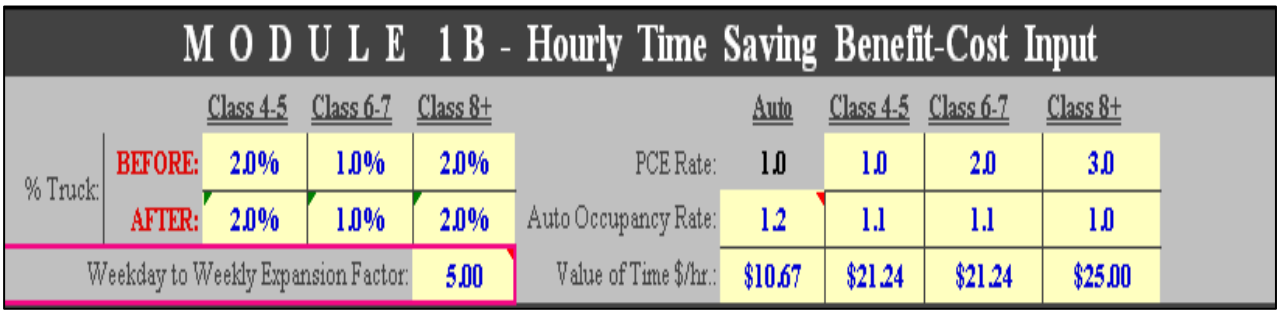
MODULE 1A - Daily Value of Time Input

F-Fspeed= (7.675+0.98*PostSpeed)	Auto	Truck
Percentage of Hourly Wage/Compensation:	50%	100%
Average hourly wage:	$10.67	$25.00
Vehicle occupancy rate:	1.20	1.05
K-factor: 8% Percent ADT:	95.0%	5.0%

Module 1B – Hourly Value of Time

This module will estimate user benefit by calculating hourly time saving given that hourly volume is available for the Before and After conditions. This module requires inputs similar to the Module 1A, for auto but three classes of trucks (2X/6T, Single Unit & Tractor Trailer). In addition to the aforementioned inputs, Passenger Car Equivalency (PCE) rate and Weekday-to-weekly Expansion Factor are needed.

Figure 3 –Module 1B inputs for Hourly User Benefit-Cost Analysis



MODULE 1B - Hourly Time Saving Benefit-Cost Input

% Truck:	Class 4-5	Class 6-7	Class 8+
BEFORE:	2.0%	1.0%	2.0%
AFTER:	2.0%	1.0%	2.0%

Weekday to Weekly Expansion Factor: 5.00

	Auto	Class 4-5	Class 6-7	Class 8+
PCE Rate:	1.0	1.0	2.0	3.0
Auto Occupancy Rate:	1.2	1.1	1.1	1.0
Value of Time $/hr.:	$10.67	$21.24	$21.24	$25.00

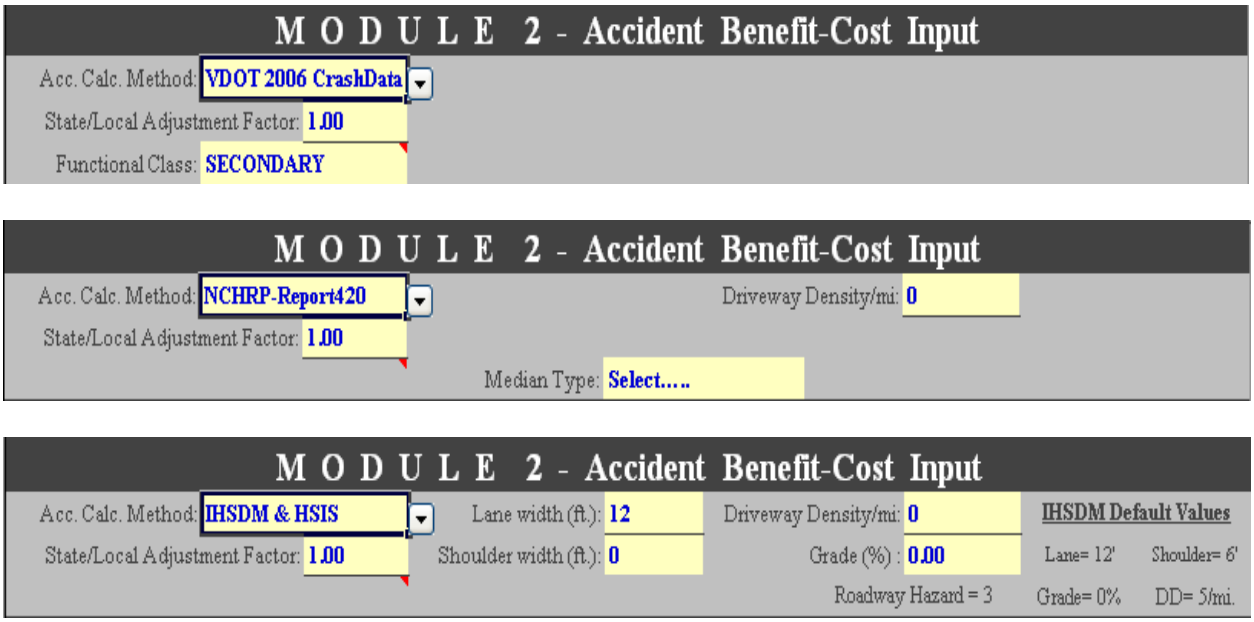
The hourly traffic rates, hourly traffic volume divided by ADT, for up to twenty four hours are needed to determine the hourly user's benefit-cost. By changing the After condition's input, a series of user benefit-cost scenarios can be developed.

Module 2 – Accident

This module will estimate accident portion of user's benefit-cost given average daily traffic for the Before and After of the project by selection of accident prediction method for the fatal, injury, and property damage only accident types. Following Figure 4, depicts inputs requires for the calculation of user's accident benefit or cost with subsequent methods.

- VDOT average 10 years and one-year crash data
- NCHRP Report 420
- IHSDM 2-lane highway, Interactive Highway Safety Design Model
- HSIS, Highway Safety Information System

Figure 4 – Module 2 inputs for Accident Benefit-Cost Analysis



For the VDOT method, the accident rates are computed by facility type (Freeway, Primary and Secondary) for both statewide combined 10 years accident data and by the districts' latest available data. The NCHRP Report 420 includes accident calculation by ADT and Access Density with consideration of median type (Undivided, TWLTL and Non-traversable). The accident prediction accident rates are referenced to the AASHTO Red Book Tables 5-12, 5-13 and 5-14. The predicted accident rate increases as the traffic volume or access point increases.

The last method of accident prediction is taken from the FHWA Report *"Prediction of the Expected Safety Performance of Rural Two-lane Highway"*. This model is one of series that was developed for the IHSDM, Interactive Highway Safety Design Model manual. The base model assumes: *12-foot lane width, 6-foot shoulder width, roadside hazard rating of 3, Access density of 5 per mile, No horizontal and vertical curvature and Level grade*. The following accident prediction models are shown for the IHSDM Base Model for 2-lane highway and the HSIS Model, respectively.

IHSDM = (AADT x 365 x 0.6148 x Length)/1,000,000 (Eq. 3)

HSIS = Exp (-3.6323)(Length) $^{0.7182}$ (AADT) $^{0.5722}$ (Eq. 4)

The predicted accident rate calculated by the NCHRP Report 420, IHSDM or HSIS method; then distributed for the type of accident using selected VDOT's district rates.

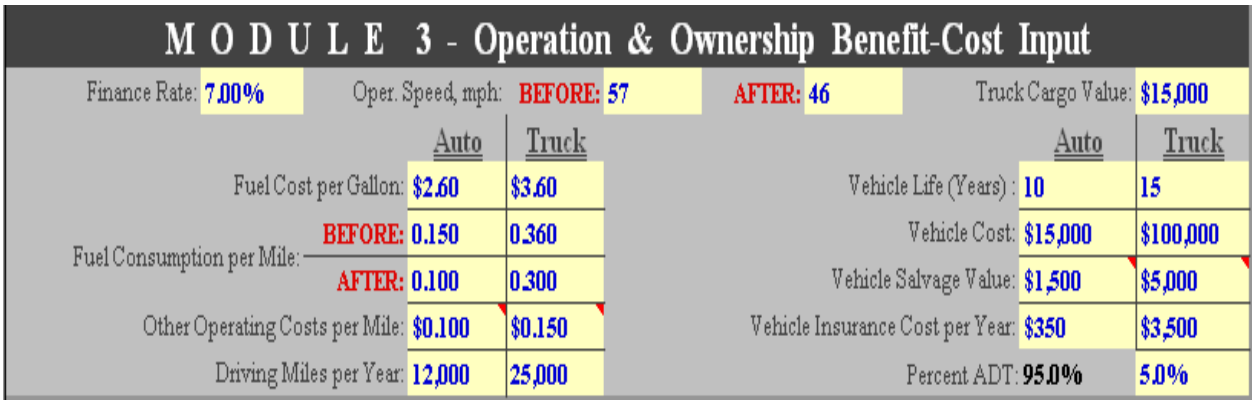
Module 3 – Operating and Ownership

This module will estimate operating and ownership cost portion of user benefits given average daily traffic and percentages of trucks for the Before and After conditions. The focal point of these calculations is the operating costs that are apparent by the user as out-of-pocket expenses. These costs will have a direct effect on driving behavior, and include driving expenses such as fuel costs and insurance premiums. The operating and ownership costs involve the following cost essentials:

- **Operating Costs**: Fuel/oil, Maintenance, and Tires.
- **Ownership Costs:** Insurance, license and registration fees and taxes, Economic depreciation, and Finance charges. In special cases, the inventory includes cost of the cargo on the vehicle.

The module's output calculates fuel cost per vehicle miles of travel (VMT) for both before and after the Project, total operating and ownership cost per VMT for both before and after the Project. Finally, total operating and ownership cost savings as a result of the Project are calculated.

Figure 5 – Module 3 inputs for Operating and Ownership Benefit-Cost Analysis



Measure of Effectiveness (MOE) Matrix

The calculated user benefits or cost can be adjusted using MOE Matrix. The user can adjust the cost by selecting variables for the project. Figure 6 pictures the MOE Matrix inputs.

Figure 6 –MOE Matrix for Adjustment of Hourly Travel Benefit-Cost Analysis

ROAD USER COST MOE-MATRIX OUTPUT			
Facility Type	◯ Interstate	◯ Primary	◯ Secondary
COST OF CONSTRUCTION ($1,000)	◯ ≤ 500	◯ 500 - 2,000	◯ 2,000 - 8,000
	◯ 8,000 - 15,000	◯ 15,000 - 45,000	◯ >45,000
LOCATION SETTING	◯ Urban	◯ Rural	◯ Suburbs
AADT	◯ ≤ 10K	◯ 10K to 50K	◯ > 50K
RISK	◯ High	◯ Medium	◯ Low
APPLICATION	◯ Lane Closure	◯ Interim Milestone	◯ Substantial / Final Completion dates
Note: The MOE Matrix results a 0 percent reduction in hourly User Cost value calculated in Module 1B.			

Keys to the HUB-CAP Output Sheets

The HUB-CAP application is accompanied with a user manual (Not the Guidelines Manual). It has been tested and used for several re-surfacing and capacity improvement projects including Interstates 66 corridor and 95 corridor HOT Lane in the Northern Virginia of the Washington Metropolitan Region. The HUB-CAP is designed to investigate different scenarios. The Lookup tables are referenced by the source and are suitable in the absence of local input data. By introducing Posted Speed in the Module 1A, an additional method for the calculation of user benefit-cost is a key if lacking delay or operating speed. For the Module 1B, an option of building up to five scenarios is available with a complemented comparison chart. Navigation is made easy by the linked buttons throughout the program. .

The travel time calculated in Modules 1A and 1B is averaged by using a minimum of two and a maximum of 5 volume-delay functions. For example, if the calculated free-flow speed of a multi-lane facility found to be between 55 mph, it averages travel time produced by BPR and updated BPR formulas for Signalized, FHWA, HCM Models for free-flow speed of 50 & 60 mph..

Module 2 is a good tool for the prediction of accident by the type of crashes and associated costs for the Before and After conditions. The Module 3, performs calculation of cost associated with out-of-pocket expenses. These hidden costs are called "*Operating and Ownership*" costs. The O&O costs will have a direct effect on direct expenses associated with the driving behavior. Some of the costs are volatile and changes by day(s) or by week(s) such as the price of fuel.

.Using the MOE Matrix, can calibration the estimated benefit or costs that are calculated by each module. The abbreviated terms in the HUB-CAP modules' input and/or outputs are as follow.

AADT= Annual Average Daily Traffic
AOR= Auto Occupancy Rate
Cap= Capacity
F-F= Free-Flow
FATAL= Fatality,
Ln= Lane
Mph, Kph= Mile, Kilometer per Hour
Para. B= BPR Parameter "b"
PCE= Passenger Car Equivalency rate
PDO= Property Damage Only
Pcphpl= Passenger Car per Hour per Lane
Phpl= Per Hour per Lane
PH, PP= Peak Hour, Peak Period
PS, OS= Posted Speed, Operating Speed
O&O= Operating & Ownership
Oth= Other
TT= Travel Time
VMT= Vehicle Mile of Travel
Vphpl= Veh. Per Hour per Lane
VOT= Value of Time $

Conclusion and Recommendation

The Highway User Benefit-Cost Analysis Program, HUB-CAP, complement the Road User Cost Guidelines Manual in providing the Department with a standardized method to quantify road user costs to the traveling public based on operating and time delays. Based on this information, the Department can determine the cost effectiveness of various alternatives including detours, temporary roadway or shoulder construction, off-peak hour day work, night work, and the most appropriate project delivery method (i.e., Incentive or Disincentive). The road user costs incurred by the traveling public for cases when the contract provisions for allowable working hours and completion dates are not adhered, grows exponentially and cause the peak period to extend beyond normal time.

Application of the user-friendly HUB-CAP, requires minimum inputs which mostly are readily available instate or nationwide. The outputs provide engineers and planners a tool test various scenarios using a scientific method. Mainly, it assists project control managers to cost out the user fees to be implemented in the contracts.

The use of HUB-CAP requires no training and it is an easy self-learning program. To unleash the power of HUB-CAP, some fixed data could be opened for additional data entry. The LOOKUP sheet offers tables of data gathered from different sources to put the information at a click of finger. The use of this program requires some engineering knowledge and experience; otherwise, the program can be applied incorrectly. It is recommended to update nationwide rates and factors used in the program that are periodically changed. This program is free and can be obtained for use. Requests can be made to the program author at:

ED.AZIMI@VDOT.VIRGINIA.GOV.

Resource Documents

1. National Cooperative Highway Research Program (NCHRP) Report 133: Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects (1972).

2. American Association of State Highway and Transportation Officials (AASHTO): A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (2003).

3. Transportation Research Board (TRB) & National Research Council (NRC) Special Report 209: Highway Capacity Manual, Edition ().

4. Federal Highway Administration (FHWA) Pavement Divisions Interim Technical Bulletin: Life Cycle Cost Analysis in Pavement Design (1998).

5. California, Kentucky, Maryland, New Jersey and Texas Department of Transportation User Cost Manuals.

6. Transport Canada and Victoria Transport Policy Institute User Cost Manual/Policy.