U.S. Department of Transportation
Federal Highway Administration

Highway Safety Manual Case Study 3: Using Predictive Methods for Alternative Selection in Florida

HSM Reference

The American Association of State Highway and Transportation Officials' (AASHTO's) *Highway Safety Manual* (HSM) Part C Predictive Method (Chapters 10-12) estimates crash frequency and severity. The predictive method uses equations known as Safety Performance Functions (SPFs) to estimate the predicted average crash frequency as a function of traffic volume and roadway characteristics (e.g., number of lanes, median width, intersection control, etc.). The HSM provides SPFs for rural two-lane, two-way roads; rural multilane highways; and urban and suburban arterials. The predictive method enables informed decision making throughout the project development process, including the selection of alternative roadway designs.

Description

The Florida Department of Transportation (FDOT) *Plans Preparation Manual* (PPM) establishes design criteria and guidance for FDOT new construction, major reconstruction, and resurfacing projects on state maintained roadways. The FDOT's PPM criteria are generally based on the more conservative side of ranges in AASHTO's *A Policy on Geometric Design of Highways and Streets* – also known as the Green Book – to accommodate Florida's conditions and place an emphasis on safety.[1] With the recent publication of the HSM, FDOT initiated a pilot project to investigate the differences in project cost based on FDOT PPM standards compared to Green Book standards to use as a tool for decision making and alternative selection during the project development process, with specific emphasis on the evaluation of safety costs utilizing the HSM predictive method.

Discussion

FDOT District 7 (Tampa area) decided to analyze a corridor widening project on State Road (SR) 574 using the HSM predictive method. At the western end of the study area, the corridor currently tapers from a six-lane section to a two-lane section, and the project involves widening SR 574 through the study area from a two-lane road segment to a four-lane divided section with center median to relieve congestion. Additionally, the section will be designed to include four-foot designated bike lanes and a sidewalk on the north side of the highway. The critical pinch point of widening this section is a busy signalized intersection located near the project's western terminus. At this intersection, the right-of-way (ROW) necessary to accommodate the planned cross-section is constrained by railroad ROW paralleling the alignment on the south

[1] Designs not meeting PPM standards are considered design variations, whereas, a design not meeting minimum AASHTO standards and PPM standards requires a design exception.

and the presence of a post office on the northwest corner. No ROW can be obtained from the railroad, and affected ROW at the post office, requires acquisition of not only land but several parking spaces from the post office parking lot. Early in the design (while preparing the typical section package), a study was conducted to evaluate a design variation from PPM standards, which narrowed the project at this intersection to minimize the impact on the post office property as much as possible.

The typical PPM design standard for widening this type of roadway is to construct a raised or restrictive median. To accommodate a left turn lane on the eastbound approach of SR 574 at the intersection, the required median width for this alternative is 19.5 feet wide. In total, this alternative would require a right-of-way acquisition of seven feet wide and 2,000 feet long and result in a loss of parking spaces from the post office parking lot. The right-of-way acquisition for this design was estimated to be $2.2 million. Although a variation from standard policy, in situations where the project is so constrained by right-of-way, it is permitted to consider an alternative five-lane section with a continuous two-way-left turn lane (16.5 feet wide). While this alternative five-lane section (including the four-foot bike lanes and sidewalk) would still require the acquisition of right-of-way from the post-office of over four feet wide, it was determined that it would retain the use of the parking spaces, which was the driving cost factor in the ROW cost estimation. The right-of-way cost for this section was estimated to be $600,000, which is $1.6 million less than the restrictive median section.

While research and practice have shown the restricted median section is generally the safer alternative, per past practices, FDOT would have used the $1.6 million difference in right-of-way costs to help justify the selection of the five-lane section. However, with the recent publication of the HSM, FDOT was able to use the predictive method to quantify the difference in predicted crash frequency and compare the two design alternatives.

FDOT used the predictive method for urban and suburban arterials (Chapter 12) to evaluate the predicted safety performance of each alternative over a 20-year horizon. They used the urban arterial SPFs (refer to HSM equation and tables) and adjusted for the proposed geometric conditions based on the crash modification factors (CMFs) for median width provided in the HSM (Table 12-22). Florida is currently in the process of developing local calibration factors (using the procedure outlined in HSM Part C, Appendix A); therefore, a default calibration factor (C_r) of 1.0 was used in Equation 12-2 for this analysis.

FDOT developed a spreadsheet to perform the HSM analysis. The predicted average crash frequency for urban and suburban roadway segments is calculated by summing the predicted average crash frequencies for multiple-vehicle non-driveway collisions, single-vehicle crashes, and multiple-vehicle driveway-related collisions (see Figure 1). First, SPFs were applied to the forecasted traffic volumes to calculate the predicted number of total, fatal and injury (FI), and property damage only (PDO) multiple-vehicle non-driveway collisions for each year (Equation 12-10 and Table 12-3). The predicted crash frequency for the FI and PDO crashes were then adjusted based on a proportion to ensure the sum matched the total number of crashes predicted (Equations 12-11 and 12-12). The same process was used for calculating the single vehicle crashes (Equations 12-13, 12-14, 12-15; Table 12-5) and the multiple-vehicle driveway-related crashes (Equation 12-16; Table 12-7).

Once the predicted average crash frequencies were calculated, the next step was to determine the cost of crashes for the 20-year period. For this part of the analysis, FDOT used the crash costs provided in the HSM (Table 7-1), which are equal to $158,200 for FI crashes and $7,400 for PDO crashes. Crash costs were estimated for each year by multiplying the crash costs by the predicted average crash frequencies for each crash type. The annual crash costs were then converted to a present value using a four percent discount rate. The resulting crash costs for the two design alternatives over the 20-year horizon are provided in Table 1. Additionally, Table 1 provides the predicted FI crashes and PDO crashes for the 20-year period.

Based on these results, the four-lane divided alternative was predicted to have a crash cost savings of approximately $4.2 million compared to the five-lane with two-way left-turn lane alternative. A benefit-cost ratio was calculated by dividing the crash cost savings by the difference in ROW costs.[2] The resulting benefit-cost ratio was equal to 2.64, illustrating that the benefit obtained through improvement in crash costs more than offset the differential in ROW costs. The results of this analysis were used to justify the additional ROW costs of the four-lane divided section.

Predicted Total Average Crash Frequency for Road Segment Base Conditions (excludes vehicle crashes with bike/ped) (Equation 12-4)

$$N_{spf\,rs} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Where,

N_{brmv} = predicted average crash frequency of multiple-vehicle non-driveway crashes

N_{brsv} = predicted average crash frequency of single-vehicle crashes

N_{brdwy} = predicted average crash frequency of multiple-vehicle driveway-related crashes

Multiple-Vehicle Non-driveway Crashes (Equation 12-10)

$$N_{brmv} = \exp\left(a + b \times \ln(AADT) + \ln(L)\right)$$

Where,

AADT = annual average daily traffic (veh/day)

L = length of roadway segment (miles)

a, b = regression coefficients (Table 12-3)

Single-Vehicle Crashes (Equation 12-13)

$$N_{brsv} = \exp\left(a + b \times \ln(AADT) + \ln(L)\right)$$

Where,

a, b = regression coefficients (Table 12-5)

Multiple-Vehicle Driveway Related Collisions (Eqn. 12-16)

$$N_{brdwy} = \sum n_j \times N_j \times \left(\frac{AADT}{15{,}000}\right)^t$$

Where,

N_j = Number of driveway-related collisions per driveway per year for driveway type j (Table 12-7)

n_j = number of driveways within segment of driveway type j (both sides of road)

t = coefficient for traffic volume adjustment (Table 12-7)

Figure 1: HSM Equations

[2] Although there are differences in costs associated with construction, ROW was found to have the most significant impact, and therefore, ROW was the only cost considered in the economic analysis.

Table 1: Crash Costs and Predicted Crash Frequency for SR 574 Design Alternatives – 20-Year Horizon

CRASH TYPE	4 LANE, DIVIDED			5 LANE WITH TWLTL		
	Crash Costs	Predicted Crash Frequency		Crash Costs	Predicted Crash Frequency	
		FI	PDO		FI	PDO
Multi-Vehicle Non-Driveway	$1,492,000	12.8	34.3	$2,856,000	24.2	67.2
Single Vehicle	$155,000	1.2	5.4	$235,000	1.4	15.7
Multi-Vehicle Driveway-Related	$561,000	4.6	11.6	$3,337,000	27.3	74.1
Total	**$2,208,000**	19.6	51.3	**$6,428,000**	52.9	157.0

Training Needs

One of FDOT's staff members who is actively engaged in AASHTO's Highway Committee on Design, conducted training for District Engineers on the use of the predictive method. This training enabled the District 7 engineers to apply the predictive method to the SR 574 study.

Benefits

The HSM predictive method enables the design engineer to estimate quantitative safety impacts of various design alternatives and provide justification for their design decisions. For the SR 574 study in particular, the loss of parking at the post office necessary to construct the four-lane divided section, may have been difficult to justify to the post office and the public based on engineering judgment alone. However, the use of the predictive method provided the design engineer with quantifiable evidence on why the four-lane alternative is preferred based on the crash cost savings.

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