Sensitivity of a Highway Safety Resource Allocation Model to Variations in Benefit Computation Parameters

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Resource allocation models aid highway safety planning decisions by setting priorities for projects based on their costs and benefits. In this study, a sensitivity analysis was conducted to see how project selection is affected by failure to adjust the accident database for underreporting and, separately, by the choice of discount rate and accident cost methodology used in computing accident cost and the present value of future benefits. The analysis used the INCBEN model developed by the Texas Transportation Institute for the FHWA. At a budget of $300,000 to $600,000, the highway safety and a few other countermeasures in the optimum solution were overwhelmingly better than other countermeasures. Consequently, even large changes in the discount rate, accident costs, and degree of adjustment for accident underreporting had virtually no effect on what projects were in the optimum solution or on the benefits obtained. At a budget of $1.2 to $1.5 million, the solution was much less stable; 20 to 30 percent of the benefit associated with the last $400,000 worth of countermeasures added, or as much as $900,000 in benefits, could be lost through the wrong choice of discount rate or accident cost methodology or through a failure to adjust reported accident data to include estimated underreporting. The effects were particularly notable when the discount rate was less than 2 percent or greater than 8 percent; when the threshold for accident reporting was reporting only of tow-away, injury, and fatal accidents; or when the method of calculating accident costs was changed.

An important aspect of highway safety planning is the allocation of limited resources to alternative countermeasures in a way that maximizes benefits net of costs. Resource allocation models can be used to aid with the establishment of project priorities after hazardous locations have been identified, appropriate accident countermeasures at each location specified, and the accident reduction factors and costs of each countermeasure estimated. Selection of the discount rate, the method used for computing accident costs, and assumptions about the reporting of motor vehicle accidents can have a major impact on the project priority order, because all three are used to calculate accident reduction benefits. This article reports the results of a sensitivity analysis that examined the magnitude of these impacts.

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RESOURCE ALLOCATION MODEL USED

The resource allocation model used in this study was the INCBEN model developed by the Texas Transportation Institute under a contract with the FHWA *(1)*. INCBEN chooses between alternative highway safety countermeasures based on their benefit-cost ratios. INCBEN is superior to other models in that it permits selection of a project that is not the one with the highest benefit-cost ratio at a given location if this will result in a higher benefit-cost ratio for the aggregate set of countermeasures. This could occur, for example, when the second-best countermeasure at a location builds incrementally on the first, creating substantial additional benefit.

The INCBEN model was applied sequentially to test the impacts of variations in the unreported accident rates, discount rates, and accident costs used in computing countermeasure benefits.

PAST SENSITIVITY ANALYSES

Sensitivity analyses of highway safety resource allocation models have been conducted by the Texas Transportation Institute *(2)*, JHK and Associates *(3)*, the state of Wisconsin *(4)*, and the state of Maryland *(5)*. These sensitivity analyses did not address the impact of unreported accidents or of different accident cost methodologies, and their results with regard to discount rates were flawed because they rediscounted the stream of future benefits but not the accident costs used in benefit computation. These studies suggest the following:

- Discount rates have an impact on project feasibility and priority.
- Large discount rates tend to favor projects with short service lives.
- Calculated benefits from all alternatives tend to get smaller as the discount rate increases (although the same set of countermeasures obviously still yields the same benefit in reality).
- Low discount rates favor projects with benefits that increase over time.
- Low discount rates favor projects that reduce a large proportion of accident costs for more severe accidents.

UNREPORTED ACCIDENTS

Accident rates are one of the major inputs into resource allocation models. Their accuracy and completeness can have a major impact on the outputs of any resource allocation model. Because accident reporting laws and practices differ widely among states and local jurisdictions, both in legal reporting requirements and actual police reporting practices, it is difficult to determine the scope and magnitude of data error. However, the existence of severe underreporting of accidents, particularly property damage only (PDO) accidents, is widely recognized as a threat to data validity. Other types of error, including errors in the location of accidents, accident severity, time of day, and light conditions, also threaten the validity of the accident data. Data deficiencies can result in the improper identification of high-accident sites, thereby compromising the accuracy of the budget allocation process. The different reporting thresholds used by states also affect the accuracy of project priority order generated by a resource allocation model, because the higher the state's threshold, the fewer accidents it reports. The influence of different thresholds is systematic in that increasing thresholds decrease the reporting of low-speed, low-severity accidents first. This may tend to result in more underreporting of urban accidents.

Estimates of the percentage of accidents reported by severity and state reporting threshold are presented in Table 1. This range of accident reporting categories was developed to test the effect on resource allocation of failure to adjust accident data for underreporting. These estimates are averages and may vary widely from the actual situations in states that do not adhere closely to the nominal reporting thresholds.

Project selection by the resource allocation model was not affected to any great extent by changes in the unreported accident rate at a budget level of $300,000 (Table 2). The results at a $900,000 budget level were similar to those at $300,000, in that one switch in a few projects occurred as the underreporting rate rose. The $900,000 solution for Reporting Categories 3, 4, and 5 had 41 countermeasures and for Reporting Categories 1 and 2, 40 countermeasures. The solutions for Reporting Categories 3 to 5 had two projects with capital costs of $15,000 and $45,000, respectively. Both were urban sites with benefit-cost ratios of 4.4 and 6.1, respectively. Solutions for Reporting Categories 1 and 2 replaced those two projects with a $60,000 rural project with a benefit-cost ratio of 5.04. Notably, the projects that appeared in the solution at $900,000 in addition to those already in the $300,000 solution were projects that had high capital costs, ranging from $35,000 to $200,000 (with the exception of a $15,000 project, which also was larger than most projects in the optimum at $300,000).

At budget levels of $1.2 and $1.5 million, the resource allocation was sensitive to the unreported accident rate. At a budget of $1.2 million, 46 projects were in the optimum solution with full reporting (Reporting Category 5). The same solution would have occurred if raw accident data had been adjusted to eliminate the effects of underreporting. Four of these projects dropped out, and two others entered when accident estimates were based on Reporting Categories 2 to 4, with insignificant loss in benefits of less than $4,000. For Reporting Category 1, reporting of fatal and injury accidents only, the optimum solution contained two projects that were not in the full reporting solution. Three projects from that solution were dropped. This resulted in the loss of almost $97,000 in benefits. (The benefits realized with full reporting are reality.)

At a budget of $1.5 million (Table 3), the optimum solution remained stable for reporting Categories 3 through 5. With Reporting Categories 1 or 2—a reporting threshold that only requires reporting of tow-away, injury, and fatal accidents—three large projects entered the solution inappropriately, with one very large and five small optimum projects being dropped for a net loss of over $225,000, or 21.6 percent of the total benefit of the six projects. All three projects that entered inappropriately were rural, whereas three of the six projects that exited were urban.

The experience with larger budgets suggests that it is extremely important to adjust the accident rate for underreporting when reporting requirements include only tow-away, injury, and fatal accidents. Failure to make this adjustment can result in severe underestimates of the benefits associated with highway safety countermeasures.

DISCOUNT RATES

A dollar that must be spent at a future date, even later in the same budget, is less valuable than a dollar that must be spent today, because it can be invested and earn a return until it must be spent. This return is an additional benefit that reduces the present value of the expenditure. For example, if $5,000 in maintenance can be done now or put off for a year without any loss in benefits, it would be better to spend the $5,000 on another improvement now, thus earning an immediate return, rather than doing the maintenance now and making the other improvements next year.

Discount rates are numbers used to compute the present value of future costs and benefits. The appropriate discount rate is based on an estimate of the rate of return on investments net of inflation. Sometimes, discount rates include premiums earned as part of the return because these investments are risky and because they tie up assets for many years, eliminating the

TABLE 1 ASSUMED PERCENT REPORTED ACCIDENTS FOR VARIOUS REPORTING THRESHOLDS BY THE MAXIMUM ABBREVIATED INJURY SCALE

		Percent of Accidents Reported						
						PDO		
Accident Category	Description	Fatal	MAIS of 4–5	MAIS of 2–3	MAIS of 1	Tow-away, No Injury Involved	Other PDO (>$50)	ALL PDO
1	Reporting of fatal and injury accidents	99	90	80	60	25	10	15
2	Reporting of towaway, injury, and fatal accidents	99	90	85	65	75	25	35
3	Reporting threshold of $300 to $500	99	95	85	75	80	50	55
4	Reporting threshold of $50 to $250	99	95	90	85	85	70	73
5	All accidents reported over $50 damage	100	100	100	100	100	100	100

TABLE 2 UNREPORTED ACCIDENT RATE RESULTS: PROJECTS PRESENT IN THE OPTIMUM SOLUTIONS FOR A $300,000 BUDGET AND A 5 PERCENT DISCOUNT RATE

Projects In Optimum Solution	Project Cost	Project Service Life	Maintenance Costs	Rural/ Urban Location	Base Case Benefits	Base Case Benefit-Cost Ratio	Is Project Present in the Optimum Solution Using the Following Assumed Levels of Unreported Accidents? Categories*				
							5*	4	3	2	1
4601	$25,000	10	$200	U	$239,010	9.56	I**	I	I	I	I
4761	10,000	10	250	R	114,712	11.47	I	I	I	I	I
4791	12,000	10	350	R	389,477	32.46	I	I	I	I	I
5091	40,000	10	500	R	489,289	12.23	I	I	I	I	I
5211	5,000	2	300	U	26,223	5.24	I	O	O	O	O
5221	15,000	1	4,000	U	152,684	10.18	I	I	I	I	I
5391	20,000	15	2,000	R	165,290	8.26	I	I	I	I	I
5431	15,000	15	1,000	U	186,385	12.43	I	I	I	I	I
5491	20,000	15	2,000	R	194,046	9.70	I	I	I	I	I
5571	1,500	10	100	R	10,768	7.18	I	I	I	I	I
5581	1,200	5	100	R	7,395	6.16	I	I	I	I	I
5591	1,200	5	100	R	7,395	6.16	I	I	I	I	I
5601	1,200	5	100	R	8,061	6.72	I	I	I	I	I
5611	1,800	5	100	R	13,635	7.58	I	I	I	I	I
5621	1,500	5	100	R	18,856	12.57	I	I	I	I	I
5641	2,000	5	100	R	228,581	114.29	I	I	I	I	I
5651	2,700	8	100	R	24,162	8.95	I	I	I	I	I
5661	2,500	5	100	R	8,286	3.31	I	I	I	I	I
5681	1,500	5	200	R	288,365	192.24	I	I	I	I	I
5691	1,800	5	100	R	12,442	6.91	I	I	I	I	I
5761	8,000	8	200	R	1,273,073	159.13	I	I	I	I	I
5771	25,000	10	200	R	607,709	24.31	I	I	I	I	I
5911	6,000	5	300	R	424,448	70.74	I	I	I	I	I
5941	1,500	5	100	R	44,286	29.52	I	I	I	I	I
6081	1,500	10	300	U	121,049	80.70	I	I	I	I	I
6121	15,000	10	200	U	290,698	19.38	I	I	I	I	I
6131	5,000	5	100	R	67,945	13.59	I	I	I	I	I
6171	4,000	5	100	R	78,059	19.51	I	I	I	I	I
6321	50,000	10	200	U	503,887	10.08	I	I	I	I	I
6551	2,800	5	200	R	206,161	73.63	I	I	I	I	I
5111	3,000	5	200	U	15,511	5.17	O	I	I	I	I
5671	2,200	5	100	R	7,395	3.36	O	I	I	I	I

* See Table 1 to define reporting categories.

** I = In the solution; O = Out of the Solution

TABLE 3 UNREPORTED ACCIDENT RATE RESULTS: PROJECTS PRESENT IN THE OPTIMUM SOLUTIONS FOR A $1.5 MILLION BUDGET AND A 5 PERCENT DISCOUNT RATE

Projects In Optimum Solution	Project Cost	Project Service Life	Maintenance Costs	Rural/ Urban Location	Base Case Benefits	Base Case Benefit-Cost Ratio	Is Project Present in the Optimum Solution Using the Following Assumed Levels of Unreported Accidents? Categories* 5-3**	2-1
4601	$25,000	10	$200	U	$239,010	9.56	I**	I
4761	10,000	10	250	R	114,712	11.47	I	I
4791	12,000	10	350	R	389,477	32.46	I	I
4881	110,000	20	600	R	635,930	5.78	I	I
4931	75,000	10	500	U	308,996	4.12	I	I
4991	50,000	20	400	R	198,510	3.97	I	I
5011	30,000	10	1,000	R	147,073	4.90	I	I
5091	40,000	10	500	R	489,289	12.23	I	I
5111	3,000	5	200	U	15,511	5.17	I	I
5131	175,000	15	1,000	R	927,362	5.30	I	I
5181	15,000	1	4,000	U	65,985	4.40	I	O
5211	5,000	2	300	U	26,223	5.24	I	I
5221	15,000	1	4,000	U	152,684	10.18	I	I
5232	200,000	10	1,000	U	937,195	4.69	I	O
5391	20,000	15	2,000	R	165,290	8.26	I	I
5431	15,000	15	1,000	U	186,385	12.43	I	I
5491	20,000	15	2,000	R	194,046	9.70	I	I
5531	75,000	10	2,000	R	392,362	5.23	I	I
5571	1,500	10	100	R	10,768	7.18	I	I
5581	1,200	5	100	R	7,395	6.16	I	I
5591	1,200	5	100	R	7,395	6.16	I	I
5601	1,200	5	100	R	8,061	6.72	I	I
5611	1,800	5	100	R	13,635	7.57	I	I
5621	1,500	5	100	R	18,856	12.57	I	I
5641	2,000	5	100	R	228,581	114.29	I	I
5651	2,700	8	100	R	24,162	8.95	I	I
5661	2,500	5	100	R	8,286	3.31	I	O
5671	2,200	5	100	R	7,395	3.36	I	O
5681	1,500	5	200	R	288,365	192.24	I	I
5691	1,800	5	100	R	12,442	6.91	I	I
5711	45,000	10	200	R	333,678	7.42	I	I
5761	8,000	8	200	R	1,273,073	159.13	I	I
5771	25,000	10	200	R	607,709	24.31	I	I
5871	60,000	20	300	R	302,533	5.04	I	I
5911	6,000	5	300	R	424,448	70.74	I	I
5941	1,500	5	100	R	44,286	29.52	I	I
6081	1,500	10	300	U	121,048	80.70	I	I
6101	45,000	10	750	U	276,986	6.13	I	I
6121	15,000	10	200	U	290,698	19.38	I	I
6131	5,000	5	100	R	67,945	13.59	I	I
6171	4,000	5	100	R	78,059	19.51	I	I
6251	200,000	20	250	R	2,180,848	10.90	I	I
6321	50,000	10	200	U	503,888	10.08	I	I
6371	35,000	10	150	U	242,528	6.93	I	I
6401	35,000	10	150	U	261,263	7.46	I	I
6511	35,000	10	100	U	208,706	5.96	I	I
6541	2,000	5	100	R	6,393	3.20	I	O
6551	2,800	5	200	R	206,161	73.63	I	I
6661	7,500	10	500	U	30,581	5.08	I	O
4781	120,000	20	350	R	431,402	3.60	O	I
5701	28,000	10	300	R	107,403	3.84	O	I
5862	80,000	12	600	R	288,683	3.61	O	I

* See Table 1, to define reporting categories.
** I = In the solution
O = Out of the solution

ability to reinvest if a higher return becomes available. For highway safety resource allocation, an appropriate discount rate also should include a small risk premium because the return on investment will decrease when economic conditions are bad and increase when they are good.

A discount rate of 4 percent is recommended for highway safety projects with service lives of 5 years or less. Adding a risk premium because investment capital is tied up leads to recommendation of a 5-percent discount rate for projects with service lives of 10 to 30 years. If one discount rate will be used for all projects, a 5 percent discount rate is recommended.

Substantial uncertainty exists in discount rate estimates. Most economists would agree that the most appropriate value of the discount rate lies between 3 and 7 percent. However, some discount rate theorists and the Federal Office of Management and Budget feel that the discount rate for public-sector projects should approximate the pretax rate of return on corporate investment, which is estimated to be between 8 and 12

TABLE 4 DISCOUNT RATE RESULTS: PROJECTS PRESENT IN THE OPTIMUM SOLUTIONS FOR A $3 MILLION BUDGET

Projects In Optimum Solution	Project Cost	Project Service Life	Maintenance Costs	Rural/ Urban Location	Base Case Benefits	Base Case Benefit-Cost Ratios	Is Project in the Optimum Solution with The Following Discount Rates?		
							0, 2, 3 Percent	4, 5, 6, 7, 8 Percent	10, 12, 15 Percent
4791*	$12,000	10	$350	R	$443,789	36.98	I	I	I
5431	15,000	15	1,000	U	224,015	14.93	I	I	I
5571	1,500	10	100	R	11,488	7.66	I	I	I
5621	1,500	5	100	R	121,152	14.10	I	I	I
5641	2,000	5	100	R	245,259	112.63	I	I	I
5651	2,700	8	100	R	25,780	9.55	I	I	I
5681	1,500	5	200	R	309,402	206.27	I	I	I
5761	8,000	8	200	R	1,426,837	178.35	I	I	I
5771	25,000	10	200	R	693,581	27.74	I	I	I
5911	6,000	5	300	R	458,426	76.40	I	I	I
5941	1,500	5	100	R	47,101	31.40	I	I	I
6081	1,500	10	300	U	125,382	83.59	I	I	I
6121	15,000	10	200	U	331,414	22.09	I	I	I
6171	4,000	5	100	R	85,236	21.31	I	I	I
6251	200,000	20	250	U	2,740,235	13.70	I	O	O
6551	2,800	5	200	R	221,447	79.09	I	I	I
4601	25,000	10	200	U	272,745	10.91	O	I	I
4761	10,000	10	250	R	131,975	13.20	O	I	I
5091	40,000	10	500	R	556,779	13.92	O	I	I
5111	3,000	5	200	U	16,668	5.56	O	I	O
5221	15,000	1	4,000	U	146,215	9.75	O	I	I
5391	20,000	15	2,000	R	199,698	10.00	O	I	I
5491	20,000	15	2,000	R	233,386	11.67	O	I	I
5581	1,200	5	100	R	8,014	6.68	O	I	I
5591	1,200	5	100	R	8,014	6.68	O	I	I
5601	1,200	5	100	R	9,242	7.70	O	I	I
5611	1,800	5	100	R	15,299	8.50	O	I	I
5661	2,500	5	100	R	8,981	3.59	O	I	I
5671	2,200	5	100	R	8,014	3.64	O	I	O
5691	1,800	5	100	R	13,962	7.76	O	I	I
6131	5,000	5	100	R	73,311	14.66	O	I	I
6321	50,000	10	200	U	554,880	11.10	O	I	I
5211	5,000	2	300	U	26,176	5.24	O	O	I

TABLE 5 DISCOUNT RATE RESULTS: PROJECTS PRESENT IN THE OPTIMUM SOLUTIONS FOR A $1.5 MILLION BUDGET[a]

Projects In Optimum Solution	Project Cost	Project Service Life	Maintenance Costs	Rural/ Urban Location	Base Case Benefits	Is Project in the Optimum Solution with The Following Discount Rates?					
						0 Percent	2 Percent	3,4,5,6 Percent	7,8 Percent	10 Percent	12,15 Percent
4781	$120,000	20	$350	R	$903,472	In	In	In	In		
4931	75,000	10	500	U	586,334		In	In	In	In	In
4941	17,688	15	300	R	71,041						In
4991	50,000	20	400	R	416,564	In	In	In	In	In	
5111	3,000	5	200	U	18,935		In	In	In	In	In
5181	15,000	1	4,000	U	70,129				In	In	In
5211	5,000	2	300	U	29,295		In	In	In	In	In
5232	200,000	10	1,000	U	1,111,259					In	In
5661	2,500	5	100	R	10,236	In	In		In	In	In
5671	2,500	5	100	R	9,136		In		In	In	In
5701	28,000	10	300	R	140,292			In			In
5751	60,000	20	300	R	341,764	In	In				
5821	175,000	15	300	R	1,147,627	In					
5862	80,000	12	600	R	550,244		In	In	In		
6101	45,000	10	750	U	348,012			In	In		
6541	2,000	5	100	R	7,606		In		In	In	In
6661	7,500	10	500	U	36,472		In		In	In	In
Total Benefit in Base Case[b]						$2,819,662	2,910,057	2,993,147	2,986,434	2,295,966	2,090,735
% of Optimum Base-Case Benefits						94.2	97.2	100.0	99.8	76.7	69.8
Total Cost						$407,500	407,200	406,000	407,200	362,200	357,888
Benefit-Cost Ratio						6.92	7.15	7.37	7.33	6.34	5.84

a. Only projects included in the optimum at some, but not all, discount rates are shown. An additional 38 projects were in the optimum solution at all discount rates.

b. May not add exactly due to rounding error.

percent, with 15 percent as a clear upper bound. The sensitivity analysis evaluated discount rates of 0, 2, 3, 4, 5, 6, 7, 8, 10, 12, and 15 percent.

The sensitivity analysis revealed that the optimum solutions generated by the INCBEN model are relatively stable across discount rates (Table 4) at a low budget level. The model displayed some sensitivity to discount rates, in that low discount rates slightly favored projects with long service lives. The composition of projects in the solution, however, did not change much when the discount rate was varied. The few switches in optimum projects occurring in the sensitivity analysis on discount rates were among groups of projects that were so close in aggregate cost and benefit (within less than 1 percent when all are examined at a single discount rate) that they were equally desirable given the level of error in the effectiveness estimates.

At higher budget levels, the discount rate had a substantial effect on project selection. All of the solutions included a core of 38 projects. Table 5 presents other projects in the optimum solution for different discount rates; base-case benefits, costs, and benefit-cost ratios for the group of projects selected; and ratios of the benefits for the projects in the optimum solution at the given discount rate to the benefits of the projects that proved optimum in the base case.

Overall, 17 projects entered some but not all of the optimum solutions. Eight of these projects were in the optimum solutions for the base case. The project substitutions that occurred resulted in increasing amounts of lost benefits as the discount rate moved further from the base-case rate of 5 percent. At a discount of 0 percent, $178,485 in benefit was lost, or 5.8 percent of the benefits in the base case. Minimal differences in benefits occurred for discount rates between 2 and 8 percent. At a discount rate of 10 percent, $697,180 in benefits, or 23.3 percent of benefits in the base, were lost. At discount rates of 12 to 15 percent, $902,411 in benefits, or 30.2 percent of the benefits in the base case, were lost.

ACCIDENT COST COMPUTATION METHODS

Discount rates often are used in computing two components of accident costs, namely the medical costs of severe injuries and indirect accident costs, which represent the present value of productive human capital lost due to injury and death or the related value of a slight change in the probability of life and safety. A limited sensitivity analysis was conducted to examine the impacts of three different methods for calculating indirect accident costs: (a) based on the present value of human capital cost that society incurs due to a loss of productive labor, (b) based on willingness to pay for life and safety as measured by Blomquist *(6)* from analysis of seatbelt use for fatalities and human capital costs for nonfatal injuries, and (c) based on the willingness-to-pay estimates that Landefeld and Seskin *(7)* derived from the present value of human capital, as modified in Miller et al. *(8)*. Among the three methods, the least desirable is the use of inconsistent methods—human-capital costs for nonfatal injuries and willingness to pay for fatalities. The willingness-to-pay method is most consistent with economic theory and the value range of at least $1 million recently recommended by the U.S. Department of Transportation *(9)*. It is the best method, as explained further in Kragh et al. *(10)*. The human capital method is the most widely used in highway safety resource allocation modeling.

The sensitivity analysis revealed that the optimum resource allocation was sensitive to the choice of accident-cost methodology for some budget levels. When the budget level was $300,000, the sensitivity analysis revealed that the optimum resource allocation was insensitive to the choice of accident cost methodology for discount rates ranging from 4 to 8 percent, even though the value associated with a fatal accident varied by more than $100,000 between methods.

With a budget constraint of $1.5 million, the analysis showed that the optimum set of countermeasures determined using human-capital costs at a 5 percent discount rate contained 10 projects that were not in the optimum set determined using human-capital and willingness-to-pay values and omitted 3 projects that appeared in the human-capital and willingness-to-pay solution. The benefit realized with the same total expenditure was $629,730 less for the projects prescribed in the solution based on human-capital and willingness-to-pay costs, or 30.9 percent of the benefit attributable to the three projects in the solution based on human-capital and willingness-to-pay costs. At this same budget level, the solution based on human-capital and willingness-to-pay costs contained two projects that were not in the solution with values of life based on Blomquist's *(1)* work and omitted one project that was in that solution, with a net gain in benefit of $342,462, or 23.6 percent of the benefits attributable to the two projects in the solution based on human-capital and willingness-to-pay costs. Thus, the accident costs used can alter the project selection in a resource allocation model, with a large impact on the benefit realized.

CONCLUSION

At a budget of $300,000 to $600,000, the highway safety and a few other countermeasures in the optimum solution were overwhelmingly better than other countermeasures. Consequently, even large changes in the discount rate, accident costs, and degree of adjustment for accident underreporting had virtually no effect on which projects were in the optimum solution or on the benefits obtained. At a budget of $1.2 to $1.5 million, the solution was much less stable; 20 to 30 percent of the benefit associated with the last $400,000 worth of countermeasures added, or as much as $900,000 in benefits, could be lost through the wrong choice of discount rate or accident cost methodology, or through a failure to adjust reported accident data to include estimated underreporting. The effects were particularly notable when the discount rate was less than 2 percent or greater than 8 percent; when the threshold for accident reporting was reporting only of tow-away, injury, and fatal accidents; or when the method for calculating accident costs was changed.

ACKNOWLEDGMENT

The work reported herein was performed under contract to FHWA.

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The opinions expressed herein are strictly those of the authors, and should not be construed as the official positions of their agencies or organizations.

Publication of this paper sponsored by Committee on Planning and Administration of Transportation Safety.