HIGHWAY USER INVESTMENT STUDY

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A discussion of the highway user investment study, a detailed highway user economic analysis combined with an investment level analysis, and associated computerized models are presented. The purpose of this paper is to point out data and procedures necessary for analyses of this nature and areas needing improvement. In a national application, data collected by individual states for the 1972 National Highway Classification and Needs Study were used as input. However, a large number of data necessary for the study were not provided by the needs study, and the methods of handling these data deficiencies are discussed. A summary of the national study results is presented, which shows that the proposed 1970-1990 investments in arterial and collector highways yield a benefit-cost ratio of 2.1 and reduce the total expected number of fatal accidents by 32,703. Finally, recommendations are made on areas needing research, and conclusions are drawn on the general applicability of the computer models to similar studies at the state level.

•THE HIGHWAY user investment study (HUIS), a support study for the 1972 National Highway Needs Report to Congress, was developed to satisfy two objectives: (a) to provide Congress with explicit information on the effectiveness of future highway investments in achieving Department of Transportation goals of economic efficiency and safety in transportation and (b) to develop analysis models that, in addition to use in national studies, could be adapted to state-level economic analyses of highways and investments.

This paper discusses HUIS and its computer programs (1) and, in doing so, points out the data and procedures necessary for economic analyses of this nature and those data and procedural areas needing improvement in either quality or quantity (Table 1). Because this is the first detailed highway user investment study to be developed for national application, highway departments will find it interesting and useful.

HUIS consists of economic and investment analyses. Each of these is discussed below.

ECONOMIC ANALYSIS

The Model

The economic analysis model incorporates the more or less typical approach to highway economic analysis in that each highway section proposed for improvement is defined in terms of vehicle operating costs, travel time, and accident parameters in both the before and after conditions. The savings resulting from the proposed improvement are compared to the capital cost of the improvement to determine the relative worth of the investment. However, there are at least three points about this analysis that are noteworthy: (a) large numbers of deficient highway sections can be processed (approximately 200,000 were processed for the national study); (b) many parameters are used to define the before and after conditions on these sections; and (c) both benefit-cost and cost-effectiveness approaches are used.

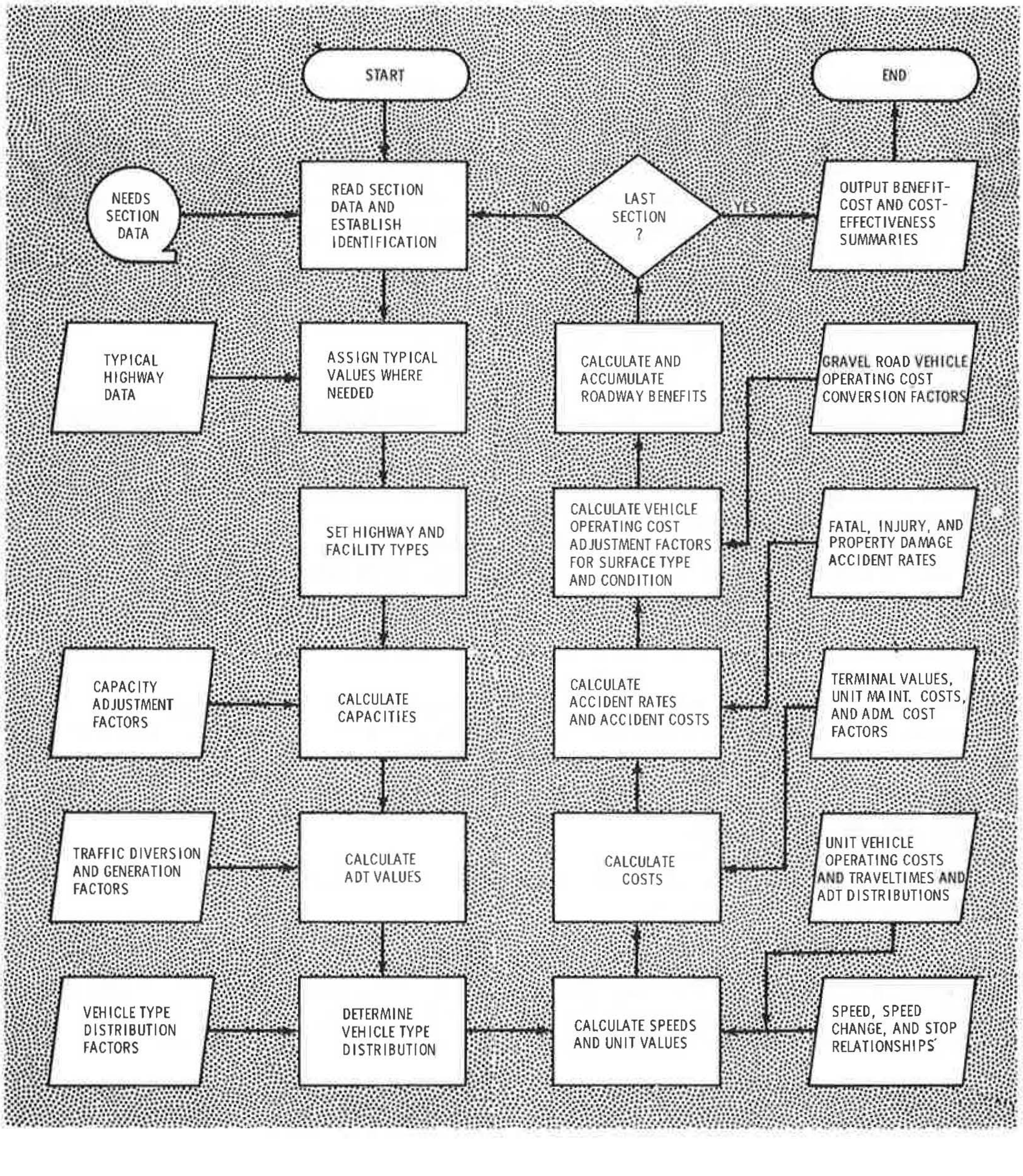
In both the benefit-cost and cost-effectiveness approaches, user savings are calculated for a section for each of the 21 years from the year of improvement through the design year to account for the effects of changing ADT. Annual user savings are calculated from the following formulas:

Table 1. Input data from needs study.

General	Existing Condition	Improvement	Cost
Section identification 1968 and 1990 functional classes Rural/urban connector class[a] Roadway deficiency type Roadway and structure deficiency periods Section length	No. of lanes Lane, median, and shoulder width Degree of access control Average highway speed Passing sight distance[b] Terrain type[b] Type of development No. of signalized intersections Type of signalization[a] Typical percentage of green time Peak-hour parking and directional operation[a] 1969 and 1990 ADT Percentage of trucks Capacity Surface type and condition No. and type of railroad crossings No. of structures	Type and year made Functional class design standard No. of lanes Degree of access control No. and type of railroad crossings No. of new structures Improvement and design year ADT	Right-of-way Grading and drainage Surface and base Structures Other Unit maintenance cost Administration cost factor

[a]Urban only. [b]Rural only.

Figure 1. Economic analysis process for roadway improvements.



$$\text{Benefit-cost savings} = (\text{value}_E - \text{value}_I)(\text{effective ADT}_I) + (\text{value}_E - \text{value}_{EAI})(\text{effective ADT}_{EAI})$$

$$\text{Cost-effectiveness savings} = (\text{value}_E)(\text{ADT}_E) - (\text{value}_I)(\text{ADT}_I) - (\text{value}_{EAI})(\text{ADT}_{EAI})$$

where E, EAI, and I = data associated with the existing, existing-after-improvement, and improved conditions of a section.

Value is the annual unit user value (e.g., vehicle operating cost, number of fatal accidents) for a specific year and a specific highway condition. Effective ADT is the average daily traffic for a specific year and highway condition reduced by an amount equal to one-half the diverted and generated ADT. The reduced ADT effectively gives diverted and generated ADT one-half the savings realized by the original ADT and thus accounts for consumer surplus.

In the benefit-cost approach the following annual unit values are considered:

1. Vehicle operating costs, travel times, and travel time costs for speed change cycles, stopping and idling, and curves and grades; and
2. Numbers of fatal, injury, and property-damage-only (PDO) accidents and associated costs.

In this approach all benefit and cost components are discounted (an interest rate of 10 percent was used in the national study) from the year in which they occur back to 1970 to convert all future dollars to present dollars. Benefits consist of annual user cost savings plus annual savings in maintenance and administration costs. The sum of these benefits for the study period is compared to the difference between the initial capital investment and the end-of-study-period terminal value to give the relative worth of a proposed highway improvement.

In the cost-effectiveness approach the following annual unit values are considered:

1. Travel times for speed change cycles, stopping and idling, and curves and grades;
2. Numbers of fatal, injury, and PDO accidents; and
3. Number of speed change cycles and stop cycles.

In this approach the savings are not discounted. User savings for the study period are compared to the initial capital investment to assess the relative effectiveness of the highway improvement. This approach provides the decision-maker with the means to evaluate the estimated numerical changes (e.g., fatal accidents eliminated) resulting from the proposed highway improvement.

Finally, the model aggregates the benefit-cost and cost-effectiveness data for all sections into summaries by state, interstate location, 1990 functional highway class (hereafter referred to as functional class), rural-urban connector designation, deficiency time period, and initial deficiency type. The model results are reported on an aggregated basis inasmuch as the general nature of some of the input data precludes reporting on a section basis.

The economic analysis model requires highway section data (Table 1) of the type and in the format of the section data reported by individual states as a requirement of the National Highway Classification and Needs Study (2) (hereafter referred to as the needs study); the model also requires supplemental data as follows:

1. Regional listing of states,
2. Vehicle type distributions,
3. Typical existing highway data for new location improvements,
4. Capacity adjustment factors,
5. Urban area sizes,
6. Traffic diversion and generation factors,
7. Typical percentage of improved highway with passing sight distance ≥ 1,500 ft,
8. Typical average highway speeds for improved highways,
9. Percentage ADT and v-c ratio for 6 ADT segments for HUIS facilities,

10. Speed, speed change, and stop equations,
11. Vehicle operating costs and travel times,
12. Vehicle operating cost adjustment factors for surface type and condition,
13. Daily train frequencies,
14. Capital cost terminal values,
15. Total accident, injury, and fatality rates, and
16. Accident conversion factors for injuries and fatalities.

Control parameters such as interest rate, values of automobile and truck travel time, and costs of fatal, injury, and PDO accidents are also necessary.

Needs Data

As an initial step of the needs study, a 1990 highway functional classification plan, including both existing roads and streets and proposed highways, was developed based on projected 1990 population, land use, and travel.

Needs for the arterial and collector classes were determined by using randomly sampled homogeneous sections and by comparing the conditions of existing roads and streets to appropriate minimum tolerable conditions. Those sections not meeting the tolerable conditions in 1970 were identified as backlog needs. The future adequacy of sections tolerable as of 1970 was examined in 5-year increments to 1990, and the sections becoming deficient in one of the 5-year periods were identified. In addition, the adequacy of existing structures and at-grade railroad crossings was determined.

After deficient sections were identified, necessary improvements and improvement years were established. Coincident with establishing needed improvements, the corresponding cost of the improvements was established.

Figure 1, a flowchart of the economic analysis process for roadway improvements, shows the major computational areas and related supplemental data inputs.

For HUIS the main identification parameters are state, location, functional classification, rural-urban connector class, deficiency time period, and initial deficiency type. Each deficient section identified is processed in one of four improvement categories: normal, railroad crossing, spot, or major structure.

Normal Improvements

New location, reconstruction of existing alignment, major widening, minor widening, resurfacing, and resurfacing plus shoulder improvements are considered normal roadway improvements.

Typical Highway Data—Although most of the required data were reported in the needs study, data on the existing condition are supplemented for sections requiring location improvements for which no existing condition data are reported and for low-volume collector sections. The reported improvement data are supplemented for those sections requiring improvements that change the existing average highway speed (AHS) and percentage of highway with passing sight distance (PSD) greater than or equal to 1,500 ft. Typical rural, small urban, and urbanized values were developed through an in-house study of existing roads and streets.

For new location improvements in which no data on existing highway condition exist, the following typical data are assigned based on functional class, area characteristics, and proposed improved highway type:

1. Number of lanes,
2. Highway type,
3. Surface type and condition,
4. AHS,
5. PSD, and
6. ADT-capacity ratio.

For low-volume collector sections typical existing AHS, PSD, and ADT-capacity ratio are assigned based on existing highway type (and, in urban areas, location and population). Typical AHS and PSD are assigned to the appropriate improved highway conditions based on improvement design standard and rural terrain type respectively.

Highway and Facility Types—Highway types are established for the existing and improved conditions of a section based on the number of lanes, median width, and degree of access control associated with the conditions. Because similar highway types have similar geometrics and speed characteristics, facility types for (a) selecting unit vehicle operating costs and travel times and (b) determining automobile running speeds also are established.

Highway Capacity—Existing (1970) capacity was reported for all sections except low-volume collectors and new location improvement sections for which no existing condition data were reported. An existing capacity for these sections is calculated as a function of the assigned typical ADT-capacity ratio and the 1990 ADT.

Highway capacity after improvement is calculated for each section by using modified Highway Capacity Manual (3) procedures and can be no less than the existing capacity with the exception that resurfacing improvements are assumed to produce no change in the existing capacity.

ADT—Two, three, or four ADTs were reported for each deficient section. The HUIS model uses these ADTs to establish an ADT growth function, defined by improvement year and design year ADTs and an annual ADT growth rate or increment, for each before and after condition. The possible ADT growth curve combinations range from a single linear, positive exponential or negative exponential curve, representing the ADT growth on all section conditions, to independent linear or positive exponential curves for each section condition. The final number of curves for a given section depends on the number and logicality of the reported ADTs and whether the reported improvement year and design year ADTs included diverted or generated traffic.

For a new location improvement the determination of ADT growth patterns is complicated by the fact that the existing highway may not be abandoned after the improvement is made. For HUIS the existing highway is assumed to be kept in service if the improved ADT is lower than the corresponding existing ADT.

The amount of diverted and generated traffic for each "after" improvement condition is also determined through use of diversion curves and fixed percentage generated ADT factors for the existing-after-improvement condition.

Maximum Allowable ADT—A maximum allowable ADT is calculated for each existing highway condition and any improved highway condition not specifically designed to carry design year traffic. The need for this maximum allowable ADT is based on the fact that projected ADTs often exceed the reasonable daily capacity of a highway, which, because of the nature of travel, is often much less than the theoretical daily capacity of 24 times the hourly capacity. Any traffic exceeding the maximum allowable ADT for a given highway condition is assumed to use alternative routes and to experience operating conditions and costs similar to those on the section being analyzed. These maximum allowable ADTs are calculated as a function of the appropriate capacity and a maximum ADT factor. Maximum ADT factors were developed for several categories of rural and urban facility types by using automatic traffic recorder data from several states.

Vehicle Types—The traffic stream for each section comprises five vehicle types—4-kip passenger vehicle; 5-kip commercial delivery truck; 12-kip single-unit truck; 40-kip gasoline powered, multiunit truck; and 50-kip diesel-powered, multiunit truck. A vehicle type distribution is defined by using the percentage of trucks furnished on a section basis and individual state truck weight study data.

Speeds, Speed Change, and Stop Cycles and Unit Operating Costs and Travel Times—Speed data, unit vehicle operating costs, and unit travel times are determined for both the improvement and design years for each highway condition for each section. Unit values are obtained for each remaining year in the analysis period by interpolation between these end point values.

Average automobile running speeds, the theoretical average running speeds at which an automobile can cruise under given traffic conditions without experiencing significant fluctuations in speed due to internal or external interference, are calculated by using modified Highway Capacity Manual (3) operating speed relationships. Average running speeds for single-unit and multiunit trucks are calculated as functions of the automobile speed.

The number and magnitude of speed change cycles per vehicle-mile are calculated for automobiles, single-unit trucks, and multiunit trucks (trucks experience speed change cycles only if their initial speed is greater than the speed slowed to by an automobile during its speed change). The number of stops per mile for each vehicle is calculated as a function of the number of automobile speed changes. The speed change and stop relationships were developed from raw, unreported data collected by Claffey (4).

Unit vehicle operating costs and travel times for curves and grades, idle engine, and speed change and stop cycles are developed for the five vehicle types. The basic source of these values was Winfrey's vehicle operating cost and travel time data (5) updated to 1969 and modified to reflect the effects of curves and grades.

Varying operating conditions throughout a day were accounted for by developing ADT distributions for several rural and urban facility types from state automatic traffic recorder data and by dividing them into six unequal segments with homogeneous operating conditions. Average running speeds, speed change and stop cycles, and related vehicle operating costs and travel times are determined for each segment. Finally, the data for each ADT segment are weighted to obtain daily values.

Initial Capital Investment and Terminal Values—The initial capital investment is the sum of right-of-way, grading and drainage, surface and base, structures, and other miscellaneous costs. All capital expenditures for a section are assumed to be made on the first day of the improvement year. Terminal value is calculated as a function of the individual cost items.

Maintenance and Administration Costs—For the cost-benefit comparison, annual maintenance costs for the existing and improved section conditions are calculated as a function of an average annual per mile maintenance cost that varies by highway type and functional class (and pavement type for two-lane roads or streets).

The annual administration cost for the improved condition is calculated as a function of annualized roadway costs, annual maintenance cost, and an administration cost factor that varies by functional class and location (and, in urban areas, population). The annual administration cost for the existing condition is calculated as a function of the annual maintenance and administration costs of the improved condition and the annual maintenance costs of the existing condition.

Roadway Accident Rates—Relationships between total accident, fatality, and injury rates and ADT for several facility types were developed by using existing accident data. These relationships and the number of fatalities and injuries per fatal and injury accident per state are used to determine the fatal, injury, and PDO accident rates for the before and after conditions of a section in both the improvement and design years.

Pavement Condition Adjustment Factors—To more accurately reflect vehicle operating costs, we calculate annual adjustment factors to convert unit vehicle operating costs, developed for high types of pavements in good condition, to unit operating costs on the existing and improved highway conditions. These factors are calculated as a linear function of Winfrey gravel and stone surface vehicle operating cost conversion factors (5), running speed, pavement type, pavement life, remaining pavement life, improvement year, and study period year.

For the existing highway condition, the pavement life is set based on the existing surface type, and the remaining pavement life as of 1970 is set based on the existing surface type and its condition in 1970. Pavement life and remaining pavement life for the improved highway condition are equal. They start as of the improvement year and are set based on the proposed improvement and an assumed improved pavement type.

Benefits—When benefits (described previously) are calculated, if the maximum allowable ADT is reached on a given highway condition, unit values are held constant from that year through the design year. In addition to benefits from roadway improvements, benefits associated with concurrent railroad crossing improvements are additive and are calculated by using the procedures described below.

Railroad Crossing Improvements

Railroad crossing improvement benefits consist of accident reductions and resulting accident cost savings and vehicle operating cost, travel time and travel time cost savings resulting from reductions in the number of speed change and stop cycles.

The same procedures used to determine unit values and benefits for normal improvements are used to determine unit values and benefits for railroad crossing improvements. However, annual maintenance and administration costs for railroad crossings are calculated as a function of the number of crossings and their protection types. One other procedural difference is that ADT growth on both the existing and improved highway conditions of the section is linear and is defined by the 1969 and 1990 ADTs with maximum allowable ADT constraints being applicable.

Railroad Crossing Operating Conditions—Vehicles required to stop at railroad crossings consist of those stopping for trains, based on the time a train occupies a crossing, train frequencies, and non-Poisson vehicle queuing theory, and those required to stop because of (a) state laws requiring all vehicles to stop at at-grade railroad crossings, (b) stop signs at crossings protected by crossbucks, and (c) legal requirements concerning trucks carrying hazardous materials. Idling times for vehicles required to stop for trains are based on the number of vehicles stopped and the vehicle arrival and departure rates. Because of the roughness of many railroad crossings those vehicles that do not have to stop are assessed a speed change cycle with a magnitude of one-tenth of the initial vehicle speed.

Accident Rates—Improvement and design year fatal, injury, and PDO accident rates are based on the expected annual numbers of vehicle-train and nontrain-vehicle accidents at each crossing type.

Spot Improvements

Spot improvements are defined as reconstruction of a minor (less than 41 percent) portion of a highway section. Thus it is assumed that the operating conditions before and after the improvement are the same, the only benefits deriving from accident reductions. Accident benefits are calculated by assuming linear ADT growth, defined by the 1969 and 1990 ADTs for a collector section or the improvement and design year ADTs for an arterial section, and by using normal improvement accident benefit procedures.

If concurrent railroad crossing improvements are being made to the section, the benefits are additive.

Major Structure Improvements

Major structure improvements are assumed to be necessary only where a restriction to travel, such as a major river, exists. The vehicle operating cost, travel time, and accident benefits from this type of improvement result from reduced travel distance, which is assumed to be 2 miles in an urban area and 20 miles in a rural area. Benefits are calculated by using a constant rural or urban speed and normal improvement procedures.

Improvements to the Economic Analysis Model

As a result of the experience gained from the development and use of the economic analysis model, certain desirable changes became apparent: improved input data and analysis procedures and new input data and analysis procedures. The amount and degree of change are somewhat dictated by the proposed use of the model. In other words if the model is to be used for system-level investment decisions (as was the case with the national HUIS analysis) only minimal change is needed. But, if the model is to be used to evaluate individual highway sections or projects, the amount of change required is maximized.

Improved Input Data and Analysis Procedures—Although the comprehensive procedures developed for this study have proved to be sound and adequate, there is room for improvement in the input data and analysis procedures. As constituted, this analysis does not consider changes in section length resulting from highway improvements. Though using the same length may be quite sufficient for a national- or state-level investment analysis, it is not sufficient when an individual highway improvement is evaluated.

A second area worthy of attention concerns information relating to ADT. In either a system or project economic analysis, ADT is one of the most significant inputs. Specific areas of concern include traffic projection, traffic assignment procedures, methods of calculating diverted and generated traffic, daily and yearly ADT distributions, temporal distributions of vehicle types, treatment of ADTs on intersecting roads and streets, and consideration of the system effects of individual project improvements.

Finally, attention needs to be given to those factors that affect vehicle speeds, vehicle operating costs, and accidents. Whereas the economic analysis data and procedures are adequate for system investment decisions, available data are rather limited. Data collection and analysis and research effort are needed in the following areas: road user effects of horizontal and vertical curvature, pavement type and condition, capacity, passing sight distance, average highway speed, and roadside obstacles and interferences; accident rates for roads, railroad crossings, and spot improvements; maintenance and administration costs; vehicle operating costs and characteristics for current model vehicles; methods of calculating user costs at intersections, railroad crossings, and structures and isolated reconstruction and resurfacing improvements; and relationships to estimate vehicle speeds and speed change and stop cycles.

New Input Data and Analysis Procedures—One area of needed new input data and associated analysis procedures is the socioeconomic effects of highway improvements. It is important that noise, air pollution, and relocations (people and businesses) be evaluated along with user costs.

New procedures also need to be developed to determine the optimum timing of construction, including stage construction projects. Procedures aiding decisions on when a construction project should be started to get the maximum benefit or whether to build the final product in one or more stages could maximize the taxpayer's return on each dollar invested in highways.

Finally, new input data and analysis procedures to measure the negative and positive effects of improving a highway section would be a desirable addition to models of this nature.

INVESTMENT ANALYSIS

The Model

The investment analysis model determines functional classes and deficiency areas (e.g., intolerable operating speed of v-c ratio or poor surface condition) associated with an administrative system in which to invest money in order to optimize benefits (e.g., user savings, fatal accident reductions, or total accident reductions) realized under different levels of investment constraints.

Assume, for example, that for specified functional classes and deficiency areas the benefit to be optimized is economic benefits. Sections associated with a given time period are ranked in descending order of benefit-cost ratio. Then within the maximum and minimum expenditure constraints the available funds are invested in consecutively lower benefit-cost projects until the funds for the time period are depleted. Those sections not funded in one time period are made a part of the next time period ranking.

The investment analysis model requires the following inputs:

1. Administrative systems consisting of one or more functional classes;
2. Data output from the economic analysis model consisting of initial capital investment, present worth of costs, present worth of benefits, total number of accidents eliminated, and number of fatal accidents eliminated for each deficient section on the administrative systems;
3. Maximum expenditures for each administrative system in each time period; and
4. Minimum expenditures for each functional class within an administrative system and for each deficiency area within each functional class.

Improvements to the Investment Analysis Model

The procedures for analyzing sections deferred from one time period to another need improvement, and the capacity of priority ranking of sections should be added. Further work in these areas would greatly enhance the capabilities of this model and would provide the decision maker with more meaningful investment-level analysis and priority programming tools.

NATIONAL HUIS RESULTS

Any interpretation of the national study results should be prefaced by the knowledge that (a) only costable user effects—i.e., vehicle operating cost, travel time, and accident savings—resulting from highway improvements were considered, leaving other, often significant, economic and noneconomic decision-influencing effects to be evaluated by other means; and (b) the results were generated based on what improvements were necessary to bring the highway sections up to a uniform national set of geometric standards, where the determination of improvement type was not necessarily the result of an economic evaluation. Thus it is important to recognize that the study results were not intended to be used as the sole criterion for making decisions. The great value of these results lies in the fact that a relatively uniform basis was used for all states in determining the economic consequences and cost-effectiveness of proposed highway improvements, thus making reliable interstate and intrastate comparisons possible.

Economic Analysis

Benefit-Cost Results—Overall 1970-1990 highway investments in arterial and collector sections, given in Table 2, returned an average of $2.1 in benefits for each dollar invested. As might be expected, the urban investments tended to carry the rural investments with the average benefit-cost ratios for rural, small urban, and urbanized areas being 0.4, 1.9, and 4.0 respectively.

On a functional class basis Interstate investments yielded high b-c ratios (4.5 to 4.8) in all locations. Excluding the Interstate systems the b-c ratios on rural functional classes ranged from 0.2 to 0.5, whereas the b-c ratios on small urban functional classes ranged from 0.9 to 2.3 and on urbanized functional classes from 2.1 to 4.8. Four of the five rural functional classes had b-c ratios less than 1.0, whereas only one urban category, small urban collectors, had a b-c ratio less than 1.0. As expected, the b-c ratio decreased in going from arterials to collectors. It should be emphasized that these are average functional class b-c ratios, and, though most of the rural functional classes have b-c ratios less than 1.0, 20,977 (29 percent) of the 72,577 rural sections requiring improvement had b-c ratios greater than or equal to 1.0.

On a national basis the total benefit of $374.6 billion consisted of $263.6 billion in time savings, $112.1 billion in vehicle operating cost savings, $2.6 billion in accident savings, and a negative savings of $3.6 billion in maintenance and administration costs. As in most studies using discounting techniques, these results were sensitive to changes in the interest rate and, as can be seen from the results, to assumed values of time. The study results were rather insensitive to the value of a human life.

Cost-Effectiveness Results—Data given in Table 3 show that, if all the needs study improvements were made, fatal accidents would be reduced by 33,000, injury accidents by 4,259,000, and PDO accidents by 9,611,000. In terms of cost-effectiveness ratios, 0.1 fatal accident, 13 injury-producing accidents, and 30 PDO accidents would be eliminated for each million dollars invested. Proposed improvements in rural areas produced the greatest reduction in fatal accidents, whereas urban improvements produced the greatest reduction in nonfatal injury-producing and PDO accidents.

For each $1,000 invested $1,497 in vehicle operating cost savings and 1,230 hours of time savings were realized. In both cases urban area savings were greater than rural area savings.

Investment Analysis

Because of the rigid reporting dates associated with the 1972 Highway Needs Report to Congress only minimal use was made of the investment analysis model. However, the following general conclusions were reached after the results of the limited applications were evaluated:

Table 2. HUIS benefit-cost summary (present worth in millions of dollars).

1990 Functional Highway Classification	Benefits: Accident	Benefits: Unit Operating Cost	Benefits: Time	Benefits: Maintenance and Administration Cost	Benefits: Total	Costs	Net Present Worth	Benefit-Cost Ratio
Rural								
Interstate	-7	4,651	791	-34	5,401	1,123	4,278	4.8
Other principal arterial	690	-2,237	12,895	-788	10,560	24,748	-14,188	0.4
Minor arterial	224	393	11,029	-351	11,295	24,628	-13,333	0.5
Major collector	17	4,282	3,605	-169	7,735	19,377	-11,642	0.4
Minor collector	1	2,580	1,788	-439	3,930	21,546	-17,616	0.2
Subtotal	925	9,669	30,108	-1,781	38,921	91,422	-52,501	0.4
Small urban								
Interstate	-	210	56	-3	263	59	204	4.4
Other freeway and expressway	55	725	2,827	-34	3,573	1,532	2,041	2.3
Other principal arterial	24	3,765	6,407	-78	10,118	3,764	6,354	2.7
Minor arterial	2	1,799	2,649	-45	4,495	2,992	1,413	1.5
Collector	-2	854	1,168	-28	1,992	2,355	-363	0.9
Subtotal	79	7,353	13,107	-188	20,351	10,702	9,649	1.9
Urbanized								
Interstate	71	5,354	5,200	-43	10,582	2,389	8,193	4.3
Other freeway and expressway	1,281	37,952	105,737	-716	144,254	29,961	114,293	4.8
Other principal arterial	149	25,698	51,465	-339	76,973	18,419	58,554	4.2
Minor arterial	78	19,647	45,181	-402	64,504	18,630	45,874	3.5
Collector	-15	6,432	12,795	-148	19,064	9,119	9,945	2.1
Subtotal	1,564	95,083	220,378	-1,648	315,377	78,518	236,859	4.0
Total	2,568	112,105	263,593	-3,617	374,649	180,642	194,007	2.1

Table 3. HUIS cost-effectiveness summary.

1990 Functional Highway Classification	Initial Capital Investment (millions of dollars)	Accident Reduction[a]: Fatal No.	Fatal Rate	Injury No.	Injury Rate	PDO No.	PDO Rate	Total No.	Total Rate	Vehicle Operating Cost Savings: Dollars (million)	Rate[b]	Time Savings: Hours (million)	Hours/ Thousand Dollars
Rural													
Interstate	3,747	-1	0	-25	-7	-46	-12	-72	-19	24,354	6,499	1,676	447
Other principal arterial	43,569	38	1	907	21	1,688	39	2,633	60	-16,427	-377	13,839	318
Minor arterial	40,432	12	0	247	6	578	14	837	21	-5,053	-125	11,923	295
Major collector	30,634	0	0	-24	-1	1	0	-23	-1	11,867	387	3,167	103
Minor collector	34,875	-1	0	-14	0	-25	-1	-40	-1	8,218	236	1,449	42
Subtotal	153,257	48	0	1,091	7	2,196	14	3,335	22	22,959	150	32,054	209
Small urban													
Interstate	172	0	0	6	32	14	84	20	116	1,383	8,040	153	892
Other freeway and expressway	3,011	0	0	108	36	252	84	360	119	2,957	982	4,256	1,413
Other principal arterial	6,966	-3	0	41	6	172	25	210	30	15,480	2,222	8,847	1,270
Minor arterial	5,823	-1	0	11	2	13	2	23	4	7,402	1,271	4,375	751
Collector	4,351	0	0	-5	-1	-21	-5	-26	-6	3,640	836	1,835	422
Subtotal	20,323	-4	0	161	8	430	21	587	29	30,862	1,519	19,466	958
Urbanized													
Interstate	5,730	5	1	194	34	497	87	696	122	30,113	5,255	8,831	1,541
Other freeway and expressway	61,262	10	0	2,448	40	6,342	104	8,800	144	187,017	3,053	181,096	2,956
Other principal arterial	31,638	-10	0	207	7	297	9	494	16	101,705	3,215	72,655	2,296
Minor arterial	34,857	-12	0	201	6	128	4	317	9	84,879	2,435	66,349	1,903
Collector	16,789	-4	0	-43	-3	-279	-17	-326	-19	27,203	1,620	18,022	1,073
Subtotal	150,276	-11	0	3,007	20	6,985	46	9,981	66	430,917	2,868	346,953	2,309
Total	323,856	33	0	4,259	13	9,611	30	13,903	43	484,738	1,497	398,473	1,230

[a]Numbers in thousands; rates in number per million dollars.
[b]Dollars saved for each $1,000 invested.

1. To maximize user benefits requires that the overall investment be reduced from the level sufficient to overcome all identified needs to the level that would exclude the funding of sections yielding negative user savings. The exact level of investment necessary to maximize benefits would depend on the systems being analyzed.

2. The relative investment in urban areas increased as the investment level was reduced from that necessary to overcome all needs, further illustrating that urban systems yield relatively higher user benefits.

3. Specifying that certain funds be invested in specific federal-aid systems yielded lower total benefits than allowing unconstrained investment in the economically "best" projects.

RECOMMENDATIONS AND CONCLUSIONS

Work is under way in the areas of indirect effects, priority programming of section improvements, and the application of the models to state use. Improvements in these areas should greatly enhance the usefulness of the present models.

It is recommended that research be done in the areas of indirect effects; priority programming; and speed, speed change cycle, and stop cycle factors. In addition, it is recommended that research be done on how to treat projects not funded at one point in time but deferred to another point in time, such as in the investment analysis model.

In conclusion, the HUIS models, making use of large amounts of field-inventoried data plus unreported supplemental data, provide one of the most detailed and comprehensive highway user investment analysis tools yet developed. The two HUIS models, in their present form, provide valuable tools to aid in (a) evaluating different investment levels and the consequences of limited budgets, (b) evaluating alternative systems, (c) realigning systems along functional or administrative lines, and (d) establishing matching funds ratios. Thus the current HUIS models are good investment analysis tools for state use. And with the recommended improvements in input data and procedures it is to be expected that the models will be even better national decision-making tools.

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