Revision of the Highway Investment Analysis Package Methodology for Estimating Road-User Costs

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The Highway Investment Analysis Package (HIAP) released by the Federal Highway Administration in 1976 was revised so that the methodology for estimating operating speeds and costs would be consistent with the results of recent research. The HIAP procedure for accounting for fluctuations in the daily distribution of traffic was first modified to more accurately reflect flow conditions during the busiest hours of the year. The procedure for estimating average travel time under a given congestion level was then revised to be compatible with the 1985 *Highway Capacity Manual* methodology. Finally, vehicle operating cost data were updated, and the cost estimating procedures were modified to be more sensitive to changes in highway alignment. The new FORTRAN code was then validated and tested.

The Wisconsin Department of Transportation (WisDOT) has been performing economic evaluations of alternative highway improvement projects with the Highway Investment Analysis Package (HIAP), a computer model released by the Federal Highway Administration (FHWA) in 1976 for use as a policy planning tool (*1*). The model incorporates procedures for estimating vehicle operating speeds and costs as part of an economic analysis methodology. Since the 1976 release of the model, new capacity analysis procedures and vehicle operating cost data have been developed and published (*2, 3*). In 1979 FHWA published a modified version of HIAP that facilitates the input of highway needs study data and the updating of vehicle operating cost tables (*4*). However, the basic data and procedures for estimating vehicle operating speeds and costs remained intact.

For the HIAP model to remain a useful tool for highway planning purposes in Wisconsin, it was determined that the methodology for estimating operating speeds and costs should be updated to reflect the results of recent research. The objectives of this research were therefore to

1. Revise the HIAP model by incorporating current highway capacity analysis procedures and recalibrating the methodology for estimating vehicle operating speeds and travel time and
2. Evaluate recently published data on vehicle operating costs and revise the HIAP operating cost data base and estimating procedures.

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The research essentially followed the HIAP travel time and vehicle operating cost computational sequence; each step was critically evaluated and modified as appropriate. Subsequent tasks involved the programming of the recommended modifications and the validation of the revised software. Replacement pages were prepared for insertion into the HIAP Technical Manual, Computer User's Guide, and Programmer's Guide.

FINDINGS

The HIAP uses a capacity analysis–based procedure for estimating travel time and vehicle operating costs as part of an overall process for assessing the economic desirability of proposed highway improvement projects. Travel times are calculated as a function of the volume-to-capacity (V/C) ratio during six different periods of an average day. The average speeds associated with these six congestion levels are used to estimate vehicle operating costs for an assumed representative highway alignment. In general, the HIAP should be sensitive to changes in the factors that are input parameters to a highway capacity analysis. A limitation of the model in its original format is that it cannot be used to assess the impact of

1. Improvements to specific horizontal or vertical curves,
2. Improvements to intersections, or
3. Improvements that do not influence average speeds.

The HIAP methodology for estimating travel time and vehicle operating costs for a given set of traffic and roadway conditions involves three components: (a) accounting for the daily distribution of traffic, (b) estimating average travel time under a given congestion level expressed in terms of V/C ratio, and (c) calculating vehicle operating costs for each congestion level. The findings of this research will be discussed in the context of these three components.

Daily Distribution of Traffic

The HIAP model distributes average daily traffic (ADT) into six segments that cover the daily range of congestion levels found on a typical highway. The original data were developed by FHWA from 1971 traffic recorder data supplied by several states. Concern had been expressed by some WisDOT officials that the model was not adequately accounting for conditions during the hours of the year that have the highest traffic volumes. A critical review of the HIAP methodology revealed that this concern was well founded.

The original HIAP methodology assumes that the distribution of traffic during a typical day can be stratified into six congestion levels. Each congestion level is defined in terms of the duration of that congestion level in hours and the fraction of the ADT flowing during those hours. Both of these parameters are specified as a function of the ratio of average daily traffic volume to the hourly capacity of the highway section (ADT/C). A sample average daily traffic distribution is shown in Figure 1. The V/C ratio is calculated as

$$V/C = (ADT/C)\ (FRADT)/(DUR) \qquad (1)$$

where

- ADT/C = ratio of average daily traffic to hourly capacity,
- $FRADT$ = fraction of the average daily traffic flowing during the given hours, and
- DUR = total hours of an average day during which the flow condition is assumed to exist.

The average hourly volume during any segment is expressed as

$$VOL = (FRADT)\ (ADT)/(DUR) \qquad (2)$$

The highest congestion level predicted by the HIAP is that associated with V/C Segment 6. Using as an example a two-lane rural highway with an ADT/C ratio of 3.5, the embedded traffic distribution data in the HIAP model indicate that the most congested hours of the year would have an hourly volume that was only 7.2 percent of the ADT and that these conditions would exist for 6.1 hr each day, or 2,227 hr every year. When similar calculations were performed for the remaining five congestion levels, a plot of these data as shown in Figure 2 revealed that the daily traffic distributions in the HIAP model do not reflect any significant peaking during the highest volume hours of the year. This is demonstrated in Figure 2 by the graph of hourly volume data from automatic traffic recorder stations

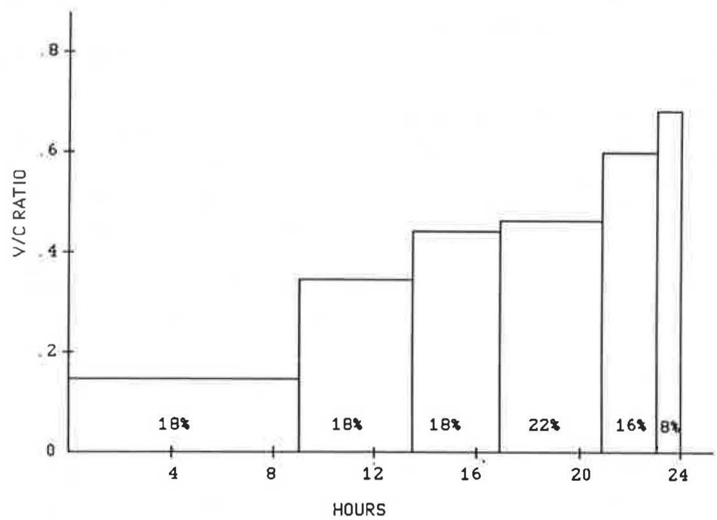

FIGURE 1 Sample distribution of ADT by congestion level and duration.

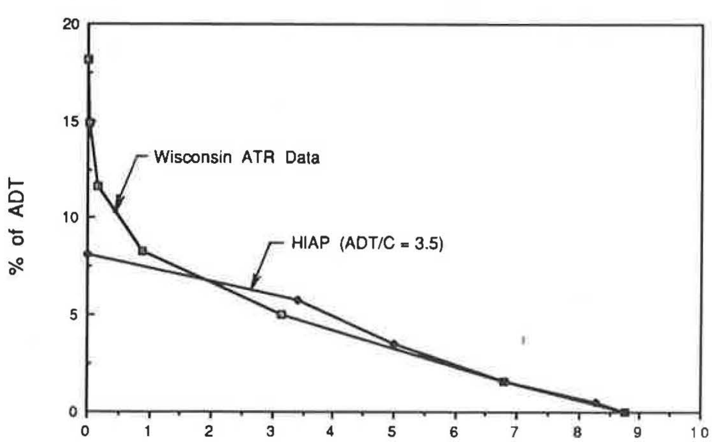

FIGURE 2 Comparison of highest hourly volume distributions: two-lane rural highways.

located on nonrecreational two-lane rural highways in Wisconsin. Similar results were observed for all of the embedded HIAP data.

The implication of these comparisons is that the HIAP model will underestimate the annual road-user costs for a given highway section because of its failure to account for the peaking conditions that occur during the highest volume hours of the year. To overcome this deficiency in the HIAP, the method for estimating the hourly volume and duration (on an average-day basis) of each of the six congestion levels was revised to reflect highest hourly volume distributions found on Wisconsin highways.

The WisDOT Division of Planning and Budget had developed highest hourly volume distributions for six functional highway classifications using automatic traffic recorder data (5). For each distribution, such as that shown in Figure 3, the highest hourly volume expressed as a percentage of ADT was divided into six uniform increments. The midpoint of each increment was defined as the average hourly volume for all hours represented by that increment. Total hours in each increment were determined graphically as shown in Figure 3. The resulting total hours were then factored to an average-day basis to maintain compatibility with other elements of the HIAP model. The complete set of annual traffic volume distribution factors is given in Table 1.

The HIAP source code was then revised to use the Table 1 data as the basis for estimating both the hourly volume and the duration of each of the six congestion levels. The user must specify only the ADT and the factor group that represents the highway under study.

Travel Time

Average travel time on a highway section for each of the six congestion levels that occur throughout a typical day is calculated by the HIAP for each of three vehicle classifications: passenger car, single-unit truck, and multiunit truck. Procedurally, the model calculates the average running speed for automobiles as a function of V/C ratio, the functional classification of the highway, and other design data. This requires that the capacity of each section be either specified by the user or determined internally by the program. Speeds are then modified to reflect added time due to speed changes, stops, and idling. Finally, speeds for other types of vehicles in the traffic stream are estimated on the basis of statistical correlations developed by FHWA in the early 1970s. The resulting speeds are then used to calculate travel time and vehicle operating costs.

Default Calculation of Capacity

Review of the methodology for estimating average running speed revealed that it was developed using data from the 1965 *Highway Capacity Manual* (HCM). The default calculation for the capacity of a rural facility or urban freeway or expressway was

$$C = N \times W \quad (3)$$

where

C = capacity in equivalent passenger cars per hour;
N = 2,000 for a two-lane road,
= 4,000 for a three-lane road, and
= 2,000 × number of lanes for a multilane road; and
W = adjustment factor for lane width and lateral clearance.

For other urban facilities, additional multiplicative factors, given in Table 2, were used.

Because the new 1985 HCM incorporates a number of significant changes to the procedures for calculating the capacity of various types of highways, the HIAP methodology was revised. The new procedures for calculating the capacity of extended sections of freeways, multilane highways, and two-lane highways were included in their entirety with several exceptions. The adjustments for driver population were excluded because their selection must be based on specific local knowledge, and this would be an inappropriate factor in a default calculation. The passenger car equivalencies for buses and recreational vehicles (RVs) were averaged and then used as representative values for the HIAP-defined single-unit truck. The passenger car equivalencies for trucks were used for the HIAP-defined multiunit truck classification.

The HIAP methodology for estimating the capacity of an urban facility was only approximate. Because of the need for a

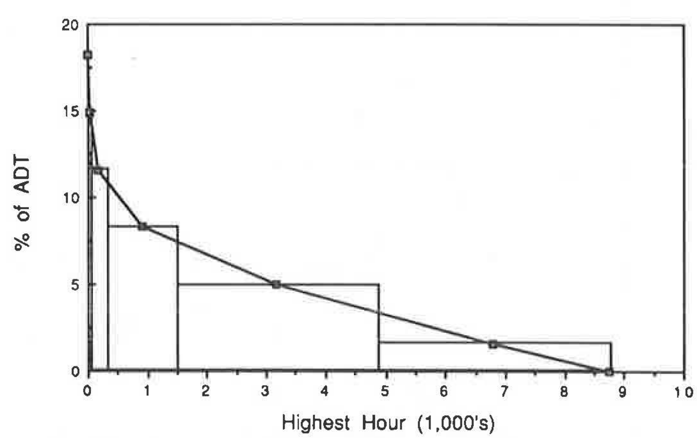

FIGURE 3 Sample annual traffic distribution: Factor Group IV.

TABLE 1 ANNUAL TRAFFIC VOLUME DISTRIBUTION

	Factor Group[a]					
Segment	I	II	III	IV	V	VI
1						
Percentage of ADT	10.3	13.2	14.6	18.2	18.5	18.6
Hours	250	25	25	25	25	25
2						
Percentage of ADT	8.4	10.8	12.0	14.9	15.1	15.2
Hours	750	175	75	25	85	65
3						
Percentage of ADT	6.5	8.4	9.3	11.6	11.8	11.8
Hours	1,550	950	825	225	365	310
4						
Percentage of ADT	4.7	6.0	6.6	8.3	8.4	8.5
Hours	2,150	2,550	2,025	1,225	975	1,000
5						
Percentage of ADT	2.8	3.6	4.0	5.0	5.0	5.1
Hours	1,950	3,150	2,525	3,300	2,975	3,100
6						
Percentage of ADT	0.9	1.2	1.3	1.6	1.7	1.7
Hours	2,110	2,960	3,285	3,960	4,335	4,260

[a]Factor groups are defined as follows: I = urban Interstate, II = urban arterial, III = rural Interstate, IV = rural highway, V = Interstate (recreation), and VI = rural highway (recreation).

TABLE 2 URBAN HIGHWAY ADJUSTMENT FACTORS

	Basic Adjustment	Percentage Green Time Adjustment
Urban central business district	.75	.50
Other urban	.90	.75

procedure that was sensitive to traffic control and geometric design features of stop sign– and signal-controlled intersections typically found within major urban highway projects, a new computational procedure was developed to permit a more realistic estimate of the impact of these facilities on both travel time and vehicle operating costs. The new procedure requires that a signalized intersection capacity analysis be performed by the user before the HIAP model is run. It was determined that the complexity of the new intersection capacity analysis procedures made them inappropriate for incorporation into the HIAP, an already complex model the fundamental purpose of which was to evaluate the economic desirability of proposed highway improvement projects. Directly inputting the performance estimates from the level-of-service analysis into HIAP eliminated the need for coding a default intersection capacity analysis capability. The procedure for accomplishing this will be discussed subsequently.

Average Speed

The HIAP calculates the average running speed of automobiles as a function of V/C ratio. A set of curves is available for a variety of highway facilities. These curves were adapted from the 1965 HCM curves relating operating speed to V/C ratio (*6*). Average running speed as used in the HIAP was defined as the average speed of vehicles on a highway section free of the detrimental effects of internal or external stops or speed change cycles. Because the HCM operating speed was defined as the highest overall safe speed at which a driver can travel on a given highway, it was assumed that the HCM operating speeds were equivalent to the 85th percentile speed and that average operating speeds could be estimated as 90 percent of the 85th percentile speeds. Ratios of running speeds to average operating speeds developed through in-house research by the FHWA were then applied to the new average operating speed curves. The effects of curves and grades, stops, and speed change cycles were estimated separately and then added to the running speed component to obtain the overall average travel speed.

Because the 1985 HCM notes that the curves relating speed to V/C ratio are much flatter than those found in the 1965 HCM, it was decided that the HIAP speed curves should be revised. A factor that also had a significant influence was the use of average speed instead of operating speed in the new HCM. The approach used for revising the speed curves was first to plot the average speed and V/C ratio values defined as the boundary conditions for the various levels of service (see Tables 3-1, 7-1, and 8-1 of the 1985 HCM). These curves were then adjusted at the low V/C ratios to reflect the approximate influence of the 55-mph speed limit. For V/C ratios greater than 1.0, a constant assumed speed for forced flow conditions was established.

Figure 4 shows a comparison of the original HIAP running speed curves for two-lane rural highways with 60-mph design speeds and the revised average speed curves for similar highways. Although the speed values from the old curves would be adjusted to reflect the influence of curves and grades, stops, and speed change cycles, it is evident that there is a significant difference between the two sets of curves. Sensitivity analyses performed using typical data revealed that the revised curves produced results judged to be more realistic and representative of conditions observed on Wisconsin highways. When the revised curves developed for other highway types were compared with the original HIAP curves, patterns similar to those in Figure 4 were also observed.

For urban and suburban facilities where intersection delay and speed limits constitute the principal controls on average

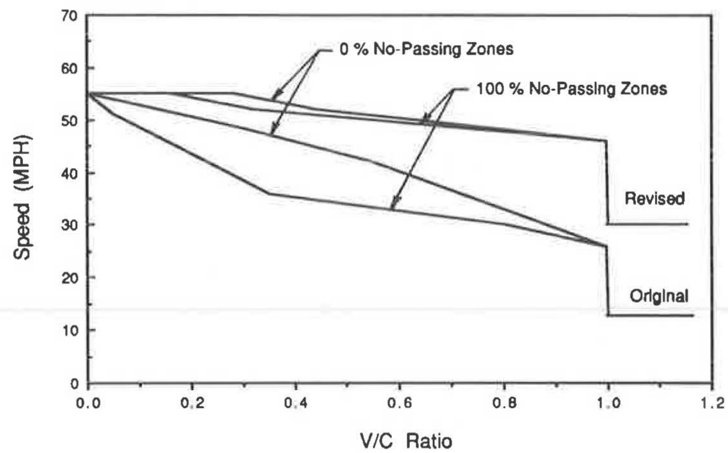

FIGURE 4 Comparison of original and revised speed curves: two-lane rural highway, 60-mph design speed.

speed, there was still a need to be able to account for the effect of the interaction of traffic volume and geometrics on midblock speeds. This was accomplished by using the speed curves appropriate to the cross-sectional characteristics of the urban facility (two lane and multilane divided or undivided) and comparing the resulting value with the user-supplied speed limit. The lower value would be used as the representative midblock average speed.

The original HIAP model also includes two regression equations for estimating truck running speeds as a function of automobile running speeds. Because the revised procedure for estimating speeds begins with a direct estimate of average speed, and because the 1985 HCM makes no distinction among the average speeds of various types of vehicles within a traffic stream, it was assumed that the average speeds from the new curves would apply to all vehicle types. Therefore the regression models for truck running speeds were not retained in the revised procedure.

Curves and Grades

The original version of the HIAP includes a multiplicative adjustment factor to be applied to average running speed as a means of accounting for the effects of average profile and curvature of the type of highway under study. Because the new speed curves were already defined in terms of average speed, the curves and grades adjustment factor was deleted in the revised HIAP methodology.

Speed Change Cycles

The original HIAP model calculates the estimated number of speed change cycles for automobiles, single-unit trucks, and multiunit trucks with a set of regression models developed by the FHWA using a quite limited data base (*7*).

The regression models were formulated by relating automobile speed changes per mile to running speeds. Another model was also developed to relate the magnitude of the speed change to the running speed.

The speed change models for trucks were developed from data that indicated that speed changes varied linearly with truck weight (*8*). The truck data were extrapolated to an assumed 4-kip automobile weight, and ratios between the speed changes for each of the truck classes (single unit and multiunit) versus that for the assumed 4-kip automobile were used as adjustment factors to be applied to the regression models for automobile speed changes.

The resulting set of speed change cycle models is used in the HIAP to calculate an excess travel time that is added to the travel time associated with the previously defined average running speed (as adjusted for the effects of curves and grades). The speed change estimates are also used in the calculation of vehicle operating costs.

Because the new speed curves developed from the 1985 HCM data provide average speed estimates that are assumed to include the effect of speed changes due to traffic stream friction, the speed change models were not used as a component of the revised procedure for estimating the average speed of vehicles under a given set of roadway conditions. However, they were retained for the purpose of estimating vehicle operating costs, with average speed instead of running speed used as the input variable. This was judged to be a reasonable adjustment given that there was substantial dispersion in the original FHWA data.

Stop Cycles

The HIAP model also includes an expression that relates stops per vehicle-mile to automobile speed changes per vehicle-mile. The coefficients in the model vary according to the type of highway facility. Because of the approximate nature of the model and the limited data base used in its development, a revised procedure was designed to more explicitly address conditions that would typically create the need for vehicles to stop.

For purposes of this research, it was assumed that stop cycles occur as a result of the presence of stop sign– or signal-controlled intersections. Neither of these highway features were directly modeled in the original version of the HIAP. This is perhaps the most serious limitation of the original model applied to the evaluation of an urban project. As a result, the HIAP expression for stops per vehicle-mile was only retained for use as one of the required input variables in the equations for estimating truck speed change cycles (discussed in the previous section).

Modeling the number of stops at intersections is a relatively complex procedure. Current methodology is presented in the 1985 HCM. Assuming that the purpose of the HIAP is to estimate user costs and calculate measures of economic desirability, and not to serve as a tool for conducting preliminary design studies, a decision was made not to incorporate the HCM computational procedures directly into the HIAP. Instead, the user would simply input information on both approach delay and stops per vehicle based on capacity analyses or simulation studies conducted before running the HIAP.

In the revised procedure, the approach delay data are used to adjust the travel time derived from the curves relating speed to V/C ratio. The approach delay data are also used to calculate the stopped delay per vehicle, which then serves as the basis for estimating vehicle idling costs. Because the number of stops per vehicle is not normally calculated as part of a capacity analysis, Webster's equation for estimating stops is recommended as an appropriate procedure (*9*).

The influence of intersections on delay and stops depends on the flow conditions and, in the case of a signalized intersection, the traffic signal timing. There are commonly three signal control periods at urban intersections: a.m. and p.m. peak and off peak. During nighttime hours it is also common to have the signals operate in a flashing mode. On rural facilities, there may be only one timing plan, often for an actuated signal controller. To accommodate the HIAP structure of six daily congestion levels, an assumed equivalency between these congestion levels and the possible signal control periods had to be established.

Factor Groups I, III, and V represent various types of Interstate highway, and thus signal control would be nonexistent. For the remaining factor groups, it was assumed that the a.m. and p.m. peak periods each last 2 hr per weekday, that the off peak lasts for 14 hr per weekday and 18 hr on weekend days, and that the signals operate on flash during the remaining 6 hr of each day. Because of the highly directional nature of peak-hour flows, and the need to express the HIAP data on the basis of an average day, it was decided to aggregate the a.m. and p.m. peak data into a single peak period. The values for delay and stops would then be internally calculated by the HIAP as the average of the respective a.m. and p.m. peak-period values. It was further assumed that under flash operation there would be no stops or delay of traffic on the arterial. If cross-street approaches were to be considered, the user would have to code them as separate highway segments.

The resulting distribution of signal control periods is

1. Peak period: 1,043 hr/year,
2. Off-peak period: 5,527 hr/year, and
3. Night period: 2,190 hr/year.

The delay and stop values for these periods are weighted within the HIAP model in accordance with the distribution of hours by V/C segment for the given factor group (Table 1). The weighted values representing each V/C segment are then used to adjust travel time and vehicle operating costs to reflect the presence of stop sign– and signal-controlled intersections. Input coding is restricted to at most one stop sign– and one signal-controlled intersection per highway segment. All vehicle types are assumed to incur the same delay and stops per vehicle.

Idling

The HIAP data for the fraction of time spent idling was discarded so that values consistent with the revised procedure for estimating stops could be used. As discussed previously, data on approach delay per vehicle are available for each V/C segment. Using the methodology of the 1985 HCM, these data are divided by 1.3 to yield an estimate of stopped delay per vehicle. This is then used as the estimated idling time incurred by all traffic on the highway section.

Railroad Crossings

Railroad crossing delays are calculated as the sum of three components:

1. Delays due to trains,
2. Delays due to legally required stops, and
3. Delays due to crossing surface roughness.

A review of the methodology indicated that the estimated relationships for delays due to trains and crossing surface roughness were generally reasonable, although highly approximate. Therefore no changes were made.

However, it was determined that some revisions were justified in the case of delays due to legally required stops. The model for estimating the number of stops included a provision that 24 percent of all crossings equipped with crossbucks were also equipped with stop signs. This assumption was judged to be unrealistic and was therefore omitted. The revised model accounts only for the estimated delay and stops due to trains and to legally required stops by vehicles transporting hazardous cargoes.

Vehicle Operating Costs

Vehicle operating costs are computed in the HIAP over five vehicle types for each of the following components:

1. Running cost (including adjustments for curves and grades),
2. Excess cost of speed change cycles,
3. Excess cost of stop cycles,
4. Idling cost, and
5. Railroad crossing–related costs.

Three basic changes were made to the operating cost methodology. First, recent data developed by Zaniewski et al. (*3*) were used to update the costs to reflect 1980 prices and vehicle characteristics. Second, costs were accumulated over three vehicle classes instead of the original five vehicle types. And, finally, vehicle running costs were made more sensitive to the alignment of the highway section under study.

The Zaniewski data provided the following operating costs:

1. Total cost at constant speed on specific grades and on pavements with specific pavement serviceability indices ($/1,000 mi),

2. Excess cost of speed change cycles ($/1,000 cycles),
3. Excess cost on horizontal curves ($/1,000 mi), and
4. Idling cost ($/1,000 hr).

The data are stratified over three automobile types and five truck types. Because the HIAP methodology for estimating vehicle operating characteristics uses three vehicle classes (automobile, single-unit truck, and multiunit truck), the cost tables were consolidated to approximate the same set of vehicle classes. The weighting factors used in this process are summarized in Table 3 and reflect the average distribution of vehicle types found on Wisconsin highways. The constant speed cost data selected for incorporation in the HIAP were those reported for a pavement serviceability index of 3.0.

TABLE 3 WEIGHTING FACTORS FOR CONSOLIDATING VEHICLE OPERATING COSTS

HIAP Vehicle Class	Zaniewski Vehicle Class	Percentage
Automobile	Automobile	
	Small	26.2
	Medium	21.3
	Large	28.2
	Pickup trucks	24.3
Single-unit truck	Trucks	
	2A single unit	74.7
	3A single unit	24.3
Multiunit truck	Trucks	
	2-S2	10.9
	3-S2	89.1

The other major revision made in the estimation of vehicle operating costs was to incorporate a user-specified distribution of curves and grades for the highway section under study. The HIAP model as presently structured uses a constant assumed distribution of curves and grades for various types of facilities. The operating cost tables in the HIAP were created using these hypothetical alignments. This causes poor sensitivity to assumed modifications in design speed or percentage of highway with passing sight distance greater than or equal to 1,500 ft (both of which reflect the nature of the highway alignment). Although changes in these input parameters will cause a change in highway capacity, and therefore a change in average speed as reflected through the speed–V/C ratio curves, all traffic is still assumed to travel over the same hypothetical alignment for purposes of calculating vehicle operating costs.

In the revised methodology, the user specifies the percentage distribution of a highway segment that has curves and grades within the following four classes:

Class	*Degree of Curve*	*Percent Curve*
1	1–2	Level
2	3–5	± 1–2
3	6–10	± 3–4
4	> 10	> ±4

In this way, an assumed change in highway alignment can be directly accounted for through both the estimated change in average speed and a revised set of cost data to be used in estimating vehicle operating costs. The revised cost data are in the format of Tables 4 and 5. The basic running cost is expressed as

$$BCST = \sum_{i=1}^{p} (WGRD_i)\,(RGRD_i) \qquad (4)$$

where $WGRD_i$ is the fraction of the highway segment with grades within Class i and $RGRD_i$ is running costs at constant average speed on Grade Class i.

TABLE 4 RUNNING COST AT CONTANT SPEED: PASSENGER CARS ($/1,000 VEHICLE MILES)

		Average Speed (mph)													
Class	Grade (%)	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	level	188	171	151	134	129	126	125	125	128	131	135	141	150	160
2	± 1-2	195	176	153	140	132	127	130	128	130	132	137	142	152	162
3	± 3-4	216	193	168	154	141	132	130	129	132	134	142	148	157	167
4	> ± 4	264	231	201	183	172	161	161	156	158	159	161	163	170	179

TABLE 5 EXCESS RUNNING COST ON CURVES: PASSENGER CARS ($/1,000 VEHICLE-MILES)

		Average Speed (mph)													
Class	Degree of Curve	5	10	15	20	25	30	35	40	45	50	55	60	65	70
1	1-2	3.2	3.9	3.6	3.2	2.8	2.4	2.2	2.0	2.3	4.3	7.4	12.1	18.8	28.1
2	3-5	21.5	20.1	17.5	15.0	10.1	6.2	2.9	0.9	3.3	10.8	24.8	47.8	81.8	136.9
3	6-10	32.3	28.3	19.9	14.2	6.9	5.6	4.0	16.7	45.0	96.1	183.1	219.3	438.1	543.4
4	> 10	32.7	21.1	10.8	4.0	14.5	59.5	112.5	178.6	252.2	381.9	595	--	--	--

The excess cost of vehicle operation on horizontal curves (*ECST*) is

$$ECST = \sum_{i=1}^{p} (WCRV_i)(RCRV_i) \quad (5)$$

where $WCRV_i$ is the fraction of the highway segment with curves within Class i and $RCRV_i$ is excess running cost at constant average speed on Curve Class i.

Section Detail File

To enhance the usefulness of the HIAP output data, the section detail file was also revised to provide an expanded set of summary statistics for the distribution of the total travel time and operating costs associated with the given highway section. The revisions provide the distribution of these user costs over three classes of vehicle (automobile, single-unit truck, and multiunit truck) and over four operating modes (running, speed change cycles, stop cycles, and railroad crossings). Row and column totals for each 3 × 4 matrix are also provided.

MODEL VALIDATION AND EVALUATION

The new FORTRAN code for the revised HIAP methodology was tested by entering the HIAP computational algorithms into a spreadsheet program for a microcomputer and then comparing the spreadsheet results with those generated by the HIAP program for a set of systematically varied input data. When differences occurred, the FORTRAN code was checked and corrected as appropriate. Although not all table-lookup sequences were fully evaluated, each basic computational sequence was validated. If errors remain, they are probably associated with embedded data values rather than the computational logic.

After the revised HIAP methodology had been validated, the program was applied to five case study highway improvement projects under consideration by WisDOT. The results were then compared with those obtained using the 1979 version of the HIAP. In attempting to generalize the observations from the case study comparisons, it can be noted that the revised version of the HIAP tends to yield lower estimated travel time benefits but larger vehicle operating cost savings. However, this pattern does not hold in all cases. The revised model will produce economic feasibility results that differ from those produced by the old version, but no trend or pattern is apparent.

CONCLUSIONS AND RECOMMENDATIONS

The revisions to the HIAP methodology for estimating travel time and vehicle operating costs provide an improved tool for highway investment planning. The new methodology is now compatible with current state-of-the-art knowledge of traffic flow characteristics and vehicle operating costs. The procedure by which the model accounts for the annual hourly distribution of traffic volume is more consistent with observed data and permits a more reasonable accounting of those conditions that occur during the 100 highest volume hours of the year. These conditions often control the selection of proposed design improvements, especially in the case of highways serving areas with substantial outdoor recreation facilities.

The revised model is also more sensitive to the existing and proposed alignment specified by the user by virtue of the new required input data on the distribution of curves and grades. However, the model still remains insensitive to improvements at isolated locations such as individual curves or grades. Similarly, urban projects or any project that includes a stop sign– or signal-controlled intersection can now be more accurately and reliably evaluated because information on stops and delay is now a required input to the HIAP.

The revised FORTRAN source code has been validated and applied to five case study projects. The results appear to be reasonable. Users of the model are nevertheless encouraged to occasionally check selected calculations to further verify the model or identify elements that require additional testing and evaluation.

In conclusion, the revised version of the HIAP is considered ready for application. It should provide better and more reliable estimates of the economic desirability of alternative improvement projects involving changes in the alignment and cross-sectional design features of extended segments of rural or urban highways. A copy of the revised code and documentation is available from the authors.

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