Iowa Design Exception Process: Application of Benefit-Cost Analysis for Restoration, Rehabilitation, Resurfacing, or Reconstruction of Secondary Roads

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The problem of providing a rational procedure for allowing exceptions to current design guides for secondary roads is discussed. Many paved secondary roads in Iowa are in need of considerable work, mostly as rehabilitation, resurfacing, and reconstruction. Some will need considerable investment to bring them up to current design guides, sometimes when the amount of investment cannot be economically justified. The Iowa Design Exception Process, a rational decision process for determining the bases for allowing exceptions to meeting current design guides, is described. Information is also included on how the process has worked in Iowa, and a case study is discussed to examine some of the issues arising during the application and review process. The procedure has proven to be a success. What remains lacking is a court test of the procedure. As of the date of writing, no tort claim has been made on the basis of exceptions granted to the current design guides.

In 1947, the Iowa General Assembly passed a farm-to-market (FM) road bill that authorized the designation and establishment of an FM system to include not more than 35,000 mi of secondary roads. Two years later, the assembly created a road use tax fund, with specific allocations to FM roads.

Development of the system proceeded slowly, beginning with designation of specific roads as FM roads. An earlier bill, passed in 1939, established the concept of FM roads and caused up to 10,000 mi to be so designated. In addition, progress on grading and surfacing from 1939 to 1947 was limited somewhat by the lack of funds caused by the depression of the 1930s and by the diversion of resources caused by national needs of World War II.

As the volume of work on secondary roads increased, the need for regular liaison between the State Highway Commission and county engineers became apparent to all. Therefore, the Secondary Road Department was established on April 7, 1953. (Its current title is Office of Local Systems.) In addition to its liaison function, the new department was able to act as a conduit to provide the services of all departments of the highway commission to the counties.

A year later, the highway commission adopted the 1954 Secondary Road Plan. The plan represented an agreement with the Bureau of Public Roads whereby the counties agreed to certain procedures, standards, and general operational rules for construction on the combined FM and federal aid secondary system. As conditions have warranted, the plan has been updated. Of particular interest was the requirement to meet the current FM road standards, beginning with the standards approved in January of 1954.

AASHO design standards were used as the basis for the 1954 Iowa standards, with some modifications to fit Iowa conditions. Width of roadbed was based on traffic volume, in vehicles per day (vpd). Maximum widths of roadbed were specified, based on average daily traffic (ADT) and ranged between 22 and 30 ft. A minimum of 2-ft shoulders was required for any pavement and an additional 2 ft of roadbed width was permitted where fills in excess of 6 ft were necessary. Foreslopes were to be 2:1 to 3:1 in cut or in fills of less than 4 ft and 1.5:1 or 2:1 in fills over 4 ft. Backslopes of 2:1 were permitted, but flatter slopes needed to be justified by the need of borrow material for adequate fills or when adjacent property owners requested flatter backslopes (provided they waived all right-of-way costs). New bridges could be 16, 20, or 24 ft in width, and nonpassing sight distance was based on an eye level at 4.5 ft above the road and at design speeds lower than currently used.

Most of the high-type surfacing on these roads was placed after 1954, with the bulk of the pavement being placed in the late 1950s and 1960s (see Figure 1). By 1963, 17 percent of the FM roads had been paved with higher type surfacing, and 81 percent had been surfaced with gravel or crushed stone.

Pavement was designed for a service life of about 20 to 25 years, which has proven to be reasonably accurate. Surfaces placed during the 1950s began needing significant reconstruction in the middle-to-late 1970s and, because the bulk of the pavement was placed in the 1960s, much of the paved FM mileage faced significant reconstruction or resurfacing needs in the late 1980s and will continue into the 1990s.

Since 1954, design guides have been upgraded several times, making a large portion of these roads nonconforming when compared to current design criteria. It is expected that significant improvements to these roads will be necessary as they are reconstructed or rehabilitated, to conform to current design guides. The last update was in 1985, based on the 1984

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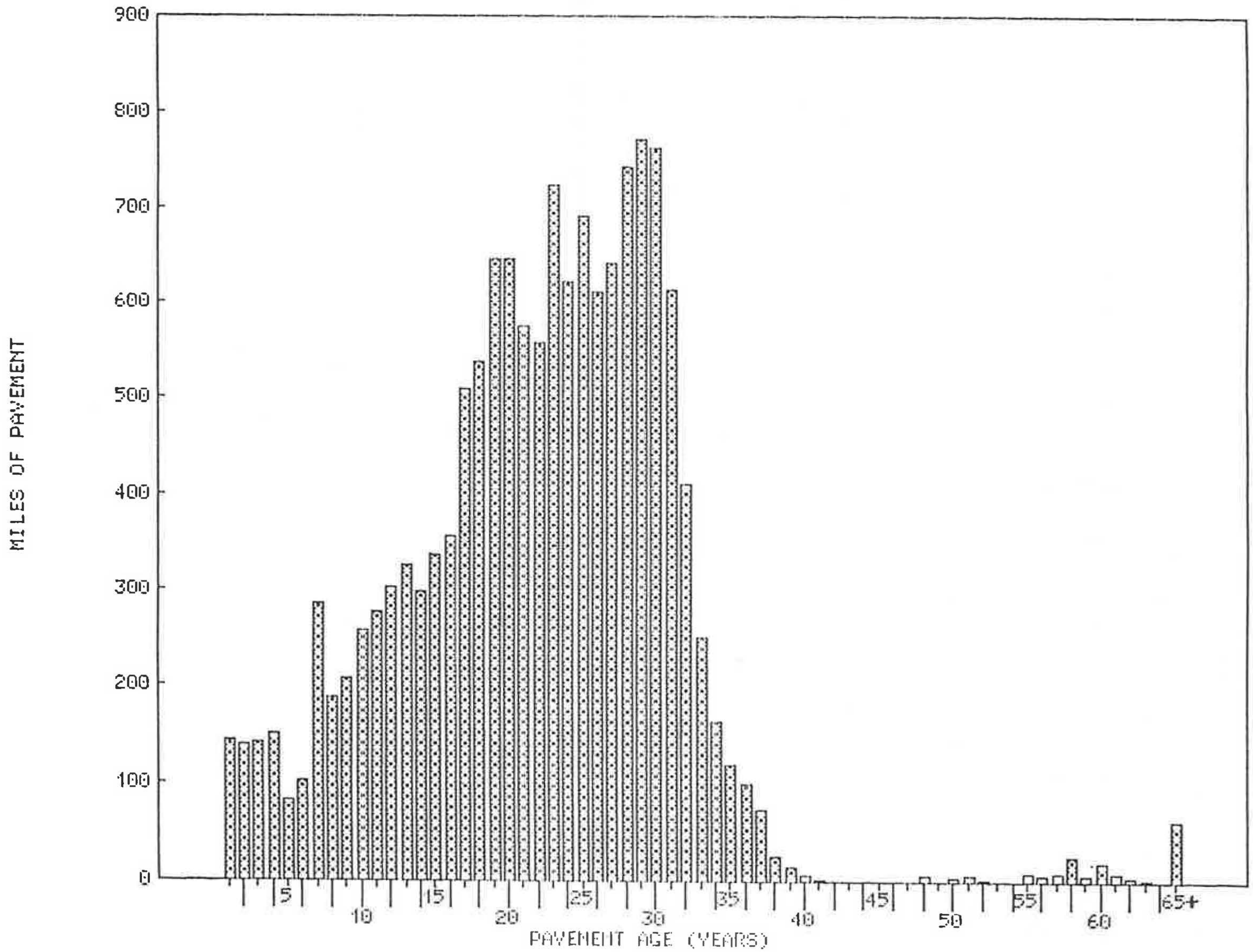

FIGURE 1 Age of secondary paved roads as of 1988.

AASHTO Green Book, "*A Policy on the Geometric Design of Highways and Streets*" (*1*). In many instances, the cost of upgrading a given road to current criteria may be quite high and not be cost-effective.

In addition to the higher costs, there was concern on the part of county engineers and boards of supervisors about the possibility of an accident's occurring on a road that had undergone some improvements without meeting current design guides and the potential for tort claims filed against the county citing failure to adhere to current design criteria (*1*). (In 1965, the Iowa legislature passed the Tort Claims Act, which is now part of Chapter 25A of the Code of Iowa. It waived governmental immunity for negligent acts on the part of the state. In 1967, the legislature passed the Tort Liability of Government Subdivisions Act, Chapter 613A, which waived immunity for any government subdivision.)

The concern seems quite valid, because recent judgments in tort liability cases have often resulted in some large awards and public agencies have been particularly hard hit. The issue of adherence to design criteria often arises during the legal proceedings. Although Iowa has an exception in the code on resurfacing projects, it may not apply to other resurfacing, restoration, or rehabilitation (3R) projects and does not apply to reconstruction projects.

Yet, it seems logical to consider the option of not upgrading entirely to current design criteria in some instances if the cost is great and corresponding improvement in safety is questionable. As a result, requests for variance from current design guides were made to the Local Systems Office, that were reviewed and variances often granted, but without the use of any specific guidelines for the decisions. This has occurred not only on projects involving 3R but also for projects involving reconstructions. [Projects falling into the rehabilitation and restoration categories are reviewed against current design minimum AASHTO guides, whereas resurfacing projects are reviewed against separate guidelines (*2*)].

IOWA DESIGN EXCEPTION PROCESS

In 1985 and 1986, an engineer in the Local Systems Office of the Iowa Department of Transportation formulated a rational method for reviewing county requests for variances from current design criteria. This method, referred to as the Iowa Design Exception Process (IDEP), provides for the use of a simplistic benefit-cost analysis of county road improvements. It is used as a rational method of granting or denying an exception to the current design guides. The majority of these exceptions are on 3R projects with geometric features that require significant and expensive upgrading to meet current design guides.

The IDEP guidelines developed were in response to the FHWA Technical Advisory T–5040.21, addressing the issue of "Geometric Design Criteria for NonFreeway RRR Projects" and to the desire for a cost-effective approach to these 3R projects using the subject road's accident history.

Technical Advisory T–5040.21 addressed such issues as practicality and need for specific improvements—especially pavement condition, traffic volumes and characteristics, traffic safety and safety needs, and economic considerations.

The IDEP document went through the normal internal and external review and approval process and was forwarded to FHWA Office of Engineering and Operations in Washington, D.C., from the FHWA Region 7 office. IDEP was described in an FHWA memo as being "well thought out and encompasses a reasonable approach towards assuring safety enhancement on 3R projects" by FHWA and "an example of what can be done to assure proper mitigation of design exceptions." IDEP is currently in use as a means of evaluating requests for exceptions to current design guides for reconstruction projects as well as 3R projects. (Most of the use is for 3R projects.) The review and justification procedure is described briefly in the next section.

Justification Procedure

A decision as to whether to plan improvements for a given road is based on a number of factors, including pavement condition, accident experience, potential impacts on the surrounding land and development, and economic benefit to the existing highway system. Few of the FM roads in Iowa experience traffic flows that would cause the Level-of-Service (LOS) to fall below LOS B, though traffic might be the basis for choosing reconstruction over 3R. Whatever the reason or reasons for the decision to make a given improvement, the county may find that a proposed improvement may not meet one or more of the current design guides. This would not be an exceptional case, because current design guides have been upgraded in several areas from the 1954 version. Most difficult to upgrade would be sight distance, road width (including shoulders), ditch cross section, and bridge widths.

However, some improvements requiring upgrading to meet current design criteria can be economically justified on the basis of expected benefits accrued from an accident severity reduction compared to the costs of the improvement. But other improvements that include provisions to upgrade to current design guides may not be considered cost-effective. What was needed was a rational, objective procedure that could logically be used to justify an exception. Instructional Memorandum (IM) 3.216 (*3*) to County Engineers has provided the mechanism for the justification of exceptions.

Therefore, since 1986, should a county find itself in a position in which a proposed improvement does not meet one of the current design guides, the following procedure is used, as outlined in IM 3.216 (*3*).

1. The first step is to acquire accident data for the road. Accident data are available through the Iowa DOT, using the Accident Location and Analysis System (ALAS). ALAS can retrieve fatal, injury, and property-damage-only accident data for all road systems in the state. Data are then analyzed to determine locations for all accidents and related contributing circumstances. Of special interest would be any roadway environment contributing circumstances, but other accidents should be analyzed to determine whether improvements in roadway environment (flatter slopes, additional signs) could have lessened the severity of the accident.

2. The second step is to prepare an estimate of the cost to bring the deficiency or deficiencies up to current guidelines.

Estimates can be based on average conditions and are not expected to be precise.

3. Third, calculate the benefit-to-cost ratio, using the accident data, cost estimates, and the prescribed benefit-cost determination process outlined in IM 3.216.

The prescribed benefit-cost determination process uses cost figures based on the estimated cost of the improvement and total accident benefit. Total accident benefit, the benefit term in the ratio, is a composite figure, based on the road's accident history since inception of ALAS (1979). (A sample worksheet is shown in Figure 2.) Briefly, the benefit is computed as follows:

1. Total loss from accidents is computed for the project, based on Iowa-developed costs of fatalities and injuries and actual values for the property damages associated with the accidents for a specific number of years.
2. Cost per accident is computed, using the total loss computed previously and dividing by the number of accidents.
3. The accident rate is computed and expressed as the number of accidents per hundred million vehicle-miles (HMVM) for roadway section and accidents per million entering vehicles (MEV) for spot locations, based on road accident history.
4. Total accident loss is then computed as the product of cost per accident, accident rate, and estimated traffic volume over the estimated service life (ESL) of the proposed improvement.
5. The total accident benefit represents an estimate of the savings expected—an estimate of the reduction in accidents or accident severity, because a given design feature is brought up to current design guidelines. Estimated accident or accident severity reduction factors for the various types of improvements and estimated service life values are provided as part of IM 3.216 (*3*).

Most of the percent reduction factors used in computing the total accident benefit are either taken from *Accident Reduction Levels Which May Be Attainable From Various Safety Improvements*, published by the federal Office of Highway Safety in 1982 or Iowa's own update. Iowa's update is based on Iowa's experience along with the University of Kentucky's Research Report UKTRP-85-6, *Development of Accident Reduction Factors*, and used to keep reduction percentages current. Changes are reviewed by engineers from the Office of Local Systems, FHWA division office, and the Bureau of Transportation Safety (BTS).

The benefit-cost ratio is then computed, using the total accident benefit (computed as described) and the estimated cost of the improvement. This figure is used in reviewing the application for a design exception.

If the benefit-cost ratio is high (>1.00), then obviously the improvement, designed to meet current design guides, is feasible. Conversely, if the ratio is low (<1.00), then it is not cost-effective. However, this is not the usual form for using this economic evaluation technique. Under normal circumstances, a discount rate is used as part of the evaluation. But although the time line for costs can be predicted, it would be impractical at the local level to try to estimate the time line for accidents. Therefore, no discounting is taken into account. (Perhaps using the term "benefits per dollar of outlay" would be better for IDEP, because this method of comparison does not use discounting.)

Therefore, review of the application uses three different ranges of values for the benefit-cost ratio:

1. If the ratio exceeds 1.20, then the improvement is probably cost-effective and should be completed in conformance with current design guides.
2. If the ratio is less than 0.80, then the improvement is probably not cost-effective if current design guides are followed. Therefore, approval of the exception is likely providing steps are taken to mitigate the situation—to provide some means to make the location safer, short of attempting to meet current design guides. An example would be the use of some positive guidance techniques, in the form of signs or pavement markings (such as edgelines, advisory speed plates, and chevrons).
3. Should the ratio fall between 0.80 and 1.20, then a more in-depth review is in order. A more detailed study of the accident data might reveal that most had occurred at spot locations along the project, suggesting that these spots be upgraded, while the rest of the project not be required to meet current design guides. IM 3.216 (*3*) provides some guidance on this review, which would be used to provide additional input to determine whether the improvement would be considered to be cost-effective.

The range of 0.80 to 1.20 was established after consultation between engineers from the Office of Local Systems, FHWA division office, and the BTS. There was a desire for a more careful review when the benefit-cost ratio was within 20 percent of the break-even point (ratio = 1.00). Therefore, additional consideration is given to (a) accident rate compared to statewide average, (b) type of accidents versus type of improvement, (c) severity of accidents, (d) cost of improvement versus project costs without improvement, (e) environmental and social effects of improvement, and (f) other alternatives to the improvement.

The County Engineer provides the data on forms developed by the Office of Local Systems for this purpose plus a cover letter requesting the exception. The letter would include the county justification (reasons) and any steps proposed to mitigate the exceptions covered by the request.

Upon receipt of a request, Office of Local Systems will review data provided and either approve or disapprove the exception. For projects not involving any federal funds, written approval from the Office of Local Systems is sufficient. But for projects that involve federal funds, requests that have been approved are forwarded to FHWA, along with Iowa DOT's recommendation.

Project Experience

The first full year of IDEP was 1987, with a number of requests for exceptions in 1987, 1988, and 1989. Although there was some resistance to the process initially from the county engineers, it is now well accepted. It has been used both for reconstruction and 3R projects, but the majority of the requests have been for 3R projects.

County______________

BENEFIT/COST DETERMINATION
(Rural Roadway Section)

Project No.______________________________ Date______________________

Location________________________________ Prepared by________________

Length_____________________________miles Current ADT________________

ACCIDENT DATA: From ___________ to _________, Total # ________________years
(date) (date)

Fatal Accidents _____ # Fatalities _____ x $435,000 = $ __________

Injury Accidents _____ # Injuries _____ x $ 15,000 = $ __________

Property Damage Acc. _____ Actual Prop. Dam. (Total) = $ __________
(Use $900/Acc. if none given)

(1) Total # Acc. _____ (2) Total Loss = $ __________

(3) Cost/Acc. = $\frac{(2)}{(1)}$ = Total Loss/Total # Acc. = $ ____________/accident

(4) Acc. Rate = $\frac{\text{Total \# Acc.} \times 100{,}000{,}000}{\text{ADT} \times \text{Length} \times \text{years} \times 365}$ = ____________ Acc./HMVM

IMPROVEMENT BEING CONSIDERED:

Description of Improvement:

(5) Estimated Cost $_________ (Thousand)

Estimated Service Life (E.S.L.) ____years

Estimated Percent Reduction in accident/severity _______________percent

B/C ANALYSIS:

(6) Estimated Traffic Volume =

ADT x $\frac{1 + (1.02)^{\text{E.S.L.}}}{2}$ x E.S.L. x Length x 0.00000365 = ________ HMVM

(7) Total Accident Loss = (3) x (4) x (6) =

Cost/ Acc. x Acc. Rate x Est. Traf. Vol. = ______________ (thousand)

(8) Total Acc. Benefit = (7) x % reduction =

Tot. Acc. Loss x Est. % Acc. Reduction = ________________ (thousand)

Benefit/Cost Ratio = $\frac{(8)}{(5)}$ = $\frac{\text{Tot. Acc. Benefit}}{\text{Est. Cost Imp.}}$ = _________________

FIGURE 2 Sample worksheet for IDEP.

In order to better understand how IDEP has been used, all projects during the period 1987 through 1989 were analyzed for a sample of 12 of the 99 counties in the state. Variation in topography in the state is well represented in the sample, and some urban counties were selected, along with predominately rural counties.

There were a total of 134 FM or federal aid projects from the 12 counties during the 3 years, or about 4 projects per county per year. A total of 82 (61 percent) of the projects were classified as either new or reconstruction, whereas the remaining 52 (39 percent) fit the guidelines of IM 3.214 (*2*) for 3R projects. Of the 82 new projects, a total of 61 were bridge replacement projects only and not needing IDEP review. Of the remaining 21 projects that involved grading or paving, design exceptions for vertical curves were granted for 6 projects.

An examination of the 52 3R projects revealed that about 30 percent, or a total of 16, were granted design exceptions. The 16 design exceptions granted break down as follows:

Exception Category	*Frequency*
Vertical curves	9
Horizontal curves	1
Foreslopes	2
Shoulder widths	1
Bridge widths or guardrail variance	3

Case Study

One of the 12 counties was selected for a more complete study of its design exception experience. During the 3 years studied, five projects received approval for exceptions to existing design guides. Bids were received on three projects in 1987, one in 1988, and one in 1989. Some details about the projects are as follows:

Project	*Type*	*Length (mi)*	*ADT (vpd)*	*Deficiency*	*B/C Ratio*
1	resurfacing	2.0	410	vertical curve	0.66
2	resurfacing	3.0	160	vertical curves, foreslopes	0.39
3	resurfacing	2.0	1,480	foreslopes	0.19
4	resurfacing	2.9	301	vertical curves	0.60
5	resurfacing	6.0	610	vertical curves, shoulders, and foreslopes	0.68

A comparison of the exceptions granted for the sample of 12 counties and the county selected for the case study shows strong similarities, with vertical curves being the predominate reason for the request for variance. All of the exceptions were granted for resurfacing projects, which is not surprising, in view of the pavement ages throughout the state, as shown in Figure 1. Traffic volumes on the roads varied considerably, suggesting that it would be inappropriate to surmise that exceptions would only be granted on the lightly traveled roads. Benefit-cost ratios for the projects were all sufficiently below the ratio of 0.8 set by IM 3.216 (*3*) for "improvements probably not cost-effective at this time."

Steps taken to mitigate the vertical curve exceptions included painting of edge lines and marking and resigning the no-passing zones for the current height-of-eye requirements. Painted edgelines were also used where shoulder width failed to meet current design guides.

A close examination of the completed applications for variance showed an interesting facet. The county engineer had obviously carefully examined available information about accidents on each project. In several instances, it was noted that given accidents did not apply to the design condition covered by the application. They included accidents at a narrow bridge site that has subsequently been replaced with a wider bridge, intersection accidents having nothing to do with the variance requested, and accidents involving animals in the roadway. In each instance, the logical step was taken to remove the accidents from consideration and, in each case, the removal aided in making the case for approval of the requested exception.

Acceptance of IDEP

When IDEP was first introduced in 1986, there was some resistance on the part of some county engineers. It would involve more forms to complete and more work for the engineer and would not be a better system than the one currently in use.

However, engineers from the Office of Local Systems approached the problem of acceptance of IDEP in positive ways. They conducted familiarization sessions with groups of county engineers to familiarize them with the process and how to complete an application. In some instances, they assisted the county engineer in completing an application.

The county engineers found that it was easier to justify a request for variance than anticipated. Reviews were easier and approvals seemed easier to get, because guidelines were clearly stated. County engineers found that they became more aware of high-accident locations on roads in their jurisdiction. Communications improved between some engineers and local law enforcement agencies, as the agencies were made aware of the need for good and timely accident information. (Sometimes the engineer would not be aware of an accident until ALAS records were requested and received.)

In its 4 years of use, IDEP has gained acceptance from most of the county engineers. In one instance, an engineer who was originally firmly against it is now one of its strongest supporters.

CONCLUSION

It is apparent from examination of projects in the 12 counties sampled that IDEP is working. Exceptions are not granted or requested in a majority of projects, because most of the projects meet current design criteria or the improvements upgraded to meet current design guides can be shown to be cost-effective. The high approval rate of requests for variance suggests that county engineers are not submitting requests when the improvements are demonstrated to be cost-effective.

High-accident locations are being identified and corrected, whereas less critical locations receive treatment to make them safer, such as better signs and additional pavement marking.

As might be expected, the exception most often encountered is vertical alignment. The change from 4.5-ft height-of-eye to 3.5 ft would require considerable changes in gradient in many locations, with concomitant high costs, yet safe stopping sight distance does not appear to be a significant accident factor on secondary roads.

It is, perhaps, too early to gauge its effect on tort liability claims and judgments against local jurisdictions, but to date there have been none filed involving projects covered by IDEP variances granted. It may take a few more years of use of IDEP to really judge its effectiveness in protecting county administrators from tort liability claims based on failing to meet current design guides, but at least initial tort liability experience (or lack thereof) has been good.

Iowa has had enough experience with IDEP to recommend the concepts demonstrated by IDEP to other jurisdictions seeking ways to make decisions on exceptions less subjective. It seems to be a more defensible approach than that used previously. In addition, the engineer-applicant is better informed regarding the basis for the request for variance. It also provides the decision makers with some good comparative numbers on which to base a decision, which makes the job easier to do.

REFERENCES

1. *A Policy on Geometric Design of Highways and Streets.* AASHTO, Washington, D.C., 1984.
2. Instructional Memorandum 3.214. Office of Local Systems, Iowa Department of Transportation, Ames, Oct. 15, 1985.
3. Instructional Memorandum 3.216. Office of Local Systems, Iowa Department of Transportation, Ames, Feb. 1, 1986.