Determining Highway Needs and Setting Road Project Priorities in Indiana Counties - An Executive Summary

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DETERMINING HIGHWAY NEEDS AND SETTING ROAD PROJECT PRIORITIES IN INDIANA COUNTIES

-- AN EXECUTIVE SUMMARY --

JON D. FRICKER AND JOSEPH L. SHAFFER

JUNE 1986

H-86-4

PURDUE UNIVERSITY - SCHOOL OF CIVIL ENGINEERING
In cooperation with
INDIANA DEPARTMENT OF HIGHWAYS
INDIANA ASSOCIATION OF COUNTY COMMISSIONERS
INDIANA ASSOCIATION OF CITIES AND TOWNS
FEDERAL HIGHWAY ADMINISTRATION
DETERMINING HIGHWAY NEEDS

AND SETTING ROAD PROJECT PRIORITIES

IN INDIANA COUNTIES

-- An Executive Summary --

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Highway Extension and Research Project
for Indiana Counties and Cities (HERPICC)
Purdue University
School of Civil Engineering
West Lafayette, IN 47907

June 1986
Highway Needs and Priorities

FOREWORD

The HERPICC project described in this Executive Summary began in response to a request from the LaPorte County Highway Task Force. That request was for the development of a method of setting priorities on county highway segments that was rational and understandable. HERPICC undertook this project with the feeling that many counties in Indiana had a similar need. This Executive Summary is intended to acquaint county officials with the issues involved and the techniques available, should a county wish to implement such procedures in-house or contract with a consultant.

The HERPICC researchers are grateful to the members of the LaPorte County Highway Task Force, chaired by Dr. Keith Powell, for their guidance and responsiveness during the project. Special appreciation is due to Mr. Gene Shurte, LaPorte County Road Supervisor, and his staff. Thanks to their technical and practical advice, data collection efforts, and overall cooperation, this project has resulted in specific results for LaPorte County and general lessons applicable to any county in Indiana.

The authors also thank Tippecanoe County Commissioner Sue Scholer for her careful review of this summary and her very helpful suggestions.
BACKGROUND AND INTRODUCTION

It is a rare county that has a highway budget large enough to make all the necessary road repairs and maintain its road system at adequate standards. Most counties must decide which of the many needy roads are most deserving of attention, subject to the limited road funds available. Sometimes, these decisions are made in a "black box" fashion,

```
? ?????????????????
?
 Question --------> Black Box --------> Response
?
? ?????????????????
```

in which the question is "Which roads should be repaired?", but the way in which the response is arrived at is known only to a few individuals. Whether the "black box" takes the form of a "smoke-filled room" or some consultant's mysterious computerized model, the response does not respect the right of county officials and the public to have a full understanding of the priority-setting process.

In most Indiana counties, the black box approach doesn't exist. Road project priorities are recommended by competent, experienced county highway officials. But whenever a large number of projects are competing for limited resources, and when subjective judgments are involved, a clearly-defined system for making such decisions has several advantages:

1. It enables highway officials to translate a large amount of data on a variety of factors into a recommended ranking of projects.

2. It helps the decision-makers to clearly define and review the explicit basis for their decisions.
3. It assures a high degree of consistency over time and in different locations, when making decisions that may involve strong personal opinions.

4. It provides an opportunity for conflicting viewpoints to find a compromise, by redefining the problem in terms of specific components and principles.

5. It opens up the process to public review, which may invite unprecedented criticism, increased public confidence, or both.

This executive summary contains the principal findings of a HERPICC project that led to a 156-page Masters thesis with the title, "A Methodology for Determining and Prioritizing County Highway Needs," prepared by Joseph Shaffer. (The figures and tables used in this summary retain the numbers used in Shaffer's thesis.) Among the project's principal findings are three priority-setting techniques that were designed to be acceptable alternatives to a "black box." Each method allows incorporation of all important road characteristics in a way that can be understood by any interested official or concerned citizen. Each method could even be carried out using a hand calculator, but to save time and avoid errors, computer programs are employed to do the calculations.

It should be pointed out that these methods are intended to be a key ingredient in the county highway priority-setting process, but not a replacement for good management decisions. The rankings produced by these methods should be carefully reviewed for logic, accuracy of input data, and practicality of implementation. Correctly used, however, the methods constitute a valuable starting point and frame of reference for decisions that are better-
informed and easier to justify.

PRIORiTY-SETTiiiNG METHODS

Consider Table 3, which lists the eleven highway segments (A through K) in a hypothetical county. Which of the segments is most deserving of road repair funds? If road condition is your most important criterion, segments A and J are prime candidates. If the most heavily-traveled road deserves immediate attention, then segment C is the most deserving. Safety, with its associated liability insurance questions, may be of greatest concern. In this case, segments D, E, and H rise to the top of the projects list. If cost effectiveness (lowest $/mile to restore a road to a pre-specified standard condition) is the key factor, then perhaps segments G and B will receive the highest rankings. Of course, the best ranking method would combine some or all of these criteria (or factors) in a way that reflects the relative importance placed on them by the county officials. Three possible methods to achieve this are presented in this section.

The Index Ranking Method

The Index Method uses as a ranking method the proportion of distance that a given segment's factor value lies between the best and worst factor values. The total distance between the best and the worst factor values in the needs list is called the "range". A better value is one that would place a segment lower in the priority list than the segment currently under consideration. Therefore, a better segment would, for example, have lower traffic volumes on it, a higher pavement condition rating, a lower hazard index, or a higher cost per mile to upgrade with regard to the factor being evaluated. This Index Ranking Method is described in more detail in the Appendix.
Table 3
Data for Priority Setting

<table>
<thead>
<tr>
<th>Segment</th>
<th>PCR</th>
<th>ADT</th>
<th>HAZ</th>
<th>Length</th>
<th>$/MILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>366</td>
<td>0</td>
<td>2.3</td>
<td>79,000</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>448</td>
<td>0</td>
<td>2.5</td>
<td>18,000</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>5704</td>
<td>0</td>
<td>6.6</td>
<td>61,000</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>106</td>
<td>2</td>
<td>1.2</td>
<td>75,000</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>263</td>
<td>1</td>
<td>1.5</td>
<td>31,000</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>359</td>
<td>0</td>
<td>2.6</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>278</td>
<td>0</td>
<td>2.0</td>
<td>11,000</td>
</tr>
<tr>
<td>H</td>
<td>2</td>
<td>125</td>
<td>1</td>
<td>1.9</td>
<td>85,000</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>119</td>
<td>0</td>
<td>3.2</td>
<td>20,000</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>672</td>
<td>0</td>
<td>1.2</td>
<td>65,000</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>98</td>
<td>0</td>
<td>0.5</td>
<td>60,000</td>
</tr>
</tbody>
</table>

Segment: Road Segment Identifier  
PCR : Pavement Condition Rating (5 = best)  
ADT : Average Daily Traffic  
HAZ : Index of Safety Hazards (0 = safest)  
Length : Road Segment Length in Miles  
$/MILE : $/mile to Remove Segment Deficiency
The Percentile Ranking Method

For a single factor, a road segment can be ranked as being in worse condition (or more needy) than a certain percentage of the segments being considered in the information set. Each segment "competes" with the other segments on the needs list to see how much justification there is for allocating road funds to it. The segment's percentile ranking represents that proportion of the other segments in the needs list that fail to be as deserving of road funds as measured by the value of the factor under consideration. As in the index method, a "better" value is one that would place a segment lower in the priority list than the segment currently under consideration. This Percentile Ranking Method is described in more detail in the Appendix.

The Successive Subsetting Ranking Method

Since much of the road segment information is collected on a subjective basis, problems with accuracy of particular values or consistency between the opinions of individual investigators can occur. Weights assigned to the index and percentile methods are subjective in nature, and might imply a greater precision than is possible with the existing information. A feature of the successive subsetting method is that the sensitivity is controlled by the order in which factors are chosen for subsetting. There is no need for the determination of weights that might be difficult for a number of decision-makers to agree upon.

The successive subsetting method assumes that projects can be only roughly lumped into subsets according to a given factor. The members of each factor subset should have approximately the same value for the factor under consideration. Each one of these smaller sets can then be further subdivided
using subsequent evaluation criteria. The subsets can then be divided as many times as there are information categories, or subsets within a category.

Using the successive subsetting method, a large number of road segments can be ranked in a small number of steps, by using information that need not be precise. Only a limited amount of information has to be collected, with a saving in acquisition cost.

For the successive subsetting method to be effective, decision-makers must clearly understand their priorities. Since the first subsetting step has the greatest effect on the final ranking, the first priority must be chosen carefully. This Successive Subsetting Method is described in more detail in the Appendix.

A STEP-BY-STEP OVERVIEW

Now that the three ranking methods have been introduced, and advice on selecting values of the factors weights $w_j$ has been offered, the suggested sequence of steps that make up the overall Needs-Priority process is listed here.

1. Identify the factors to be used to describe the highway segments. Examples are measurements of safety, pavement condition, traffic volume, cost to repair. Select as many as necessary to fully distinguish one road segment from another, but remember that the costs of acquiring, maintaining, and manipulating the data increase with each new factor added.

2. Create a complete list of the highway segments in your jurisdiction. Each segment should be homogeneous, that is, having similar characteristics along its length. If pavement condition or traffic volumes within a segment change significantly, that segment should be broken up into two or more homogeneous segments.

3. Determine factor values for each segment. If these values are not immediately available and new data collection is not practical within available time or budget, some estimates can be used temporarily. One example is to use "synthetic traffic volumes" on segments that do not have valid or current volume counts. To do this, assign each road in the
jurisdiction to one of three volume levels — high, medium, or low — using your best judgment. Find the average of the actual traffic volumes for those roads in each level that have valid counts. Assign the high level average to each road segment thought to have a high volume, but is lacking a current actual count. Do this for all roads in each level that lack a current count.

4. Put road segments that are in good condition (e.g., PCR > 4 and HAZ = 0) into a routine maintenance list. This reduces the number of segments that enter into the priority setting calculations for road repair work as "needy" segments.

5. Determine the relative importance of the factors chosen in step 1 by assigning weights to each factor. Be careful not to chose weights that are too high in value. (See "Advice on Weights" section below.)

6. Apply one or more of the available ranking methods (Index, Percentile, Subsetting, and any that you may develop) to the "needy" segments.

7. Check the results for road segments that appear to have an illogically high or low ranking. This can be evidence of errors in data entry. If any such errors are found, correct them and repeat the previous step.

8. Estimate how many of the top-ranked projects could be undertaken, given the available budget. If any of these segments have synthetic traffic volume values (see step 3) or other temporary approximate factor values, obtain actual volume counts and more precise values for the other factors. This focuses the often-costly or time-consuming data collection efforts on those segments that are the most likely candidates for road repair. The data collection to replace the temporary values determines whether the segments really are deserving of their high ranking. Then repeat step 5. If all the top-ranked projects have valid actual factor values, proceed to the next step.

9. If cost-effectiveness is desired as an additional criterion, develop improved cost estimates for each road project ranked highly after step 7. Lower-ranking road segments could receive rough estimates of $/mile values (perhaps based on a function of PCR, HAZ, and ADT) as a temporary factor value, much like the synthetic traffic volumes in step 3. Return to step 5, unless the priority list (at least as far down as the budget limits) contains only segments with valid actual factor values. In this case, proceed to step 9.

10. Use the ranking(s) as the starting point for developing the road repair work plan for the next planning period. Efficient use of personnel and equipment and equity between the various regions of the county are examples of considerations that may justify minor modifications to the ranking(s).
Summary of Priority Ranks

The results of the three small examples (Tables 4 and 5, and Figure 11 in the Appendix) are instructive. There is a certain amount of agreement between the three methods — segments C, J, and E always rank near the top — but there are also noticeable differences. For example, segment D is ranked 2nd, 4th, and 8th out of eleven by the three methods in the example. The choice of ranking method can be based on whichever one(s) the decision-makers feel comfortable with, but some rules of thumb are:

a. If your factor values are accurate and up-to-date, the Index Method offers the best combination of precision and simultaneous consideration of the factors.

b. If the factors you are using are approximate or subjective, but you want to retain the simultaneous consideration feature, the Percentile Method is a good choice.

c. If you have approximate or subjective factor values, and simultaneous consideration of multiple factors is not important to you, the Successive Subsetting Method is appropriate. In fact, preliminary results indicate that this method most closely duplicates the rankings made intuitively by individuals. It involves a sequential (rather than a simultaneous) consideration of the factors, from most important to least important.

However, the best strategy would be to use all the methods you find acceptable and look for results that reinforce each other, since no method is inherently better than the others.
Advice on Weights

Equations 2, 4, and 5 above have involved the use of the weight $w_j$. A common tendency is to select such a large $w_j$ value for the most important factor, that the least important factors have no influence and could have been excluded, except to break ties. If this happens, the ability to incorporate all chosen factors into the ranking has been lost. Experience to date indicates that the ratio of the highest to lowest $w_j$ values should not exceed the values shown in the table below.

<table>
<thead>
<tr>
<th>Index Method</th>
<th>Percentile Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCR</td>
<td>2</td>
</tr>
<tr>
<td>ADT</td>
<td>3</td>
</tr>
<tr>
<td>HAZ</td>
<td>2</td>
</tr>
</tbody>
</table>

A good procedure is to set the lowest $\ w_j = 1$, the highest $w_j$ value within the bounds shown in the table above, and any remaining $w_j$ to values between the high and low. Non-integer values (e.g., 1.5, 1.67, etc.) are acceptable.
APPENDIX — HOW THE METHODS WORK

The Index Ranking Method

The ADT index value for segment C, using equation (1) in Figure 9, will be:

$$I_{ADT}^C = \frac{5704 - 98}{5606} \times 100 = 100$$

Segment K will receive an index value of 0 since no segment has a less needy traffic factor value than it does. Because of segment C's very large ADT, the rest of the segments will receive low index values, as illustrated in Table 4.

Once all the factors are evaluated individually, a composite index value can be calculated. Each factor index value can be weighted before calculating the total. For this example, each factor weight is set at 1. Using equation (2), the composite index for road segment C is:

$$\frac{75\times1\ (PCR) + 100\times1\ (ADT) + 0\times1\ (HAZ) + 28\times1\ ($/MILE)}{1 + 1 + 1 + 1} = 50.8$$

The complete ranked list of segments can be seen in Table 4.

The Percentile Ranking Method

For a single factor:

$$P = \frac{B}{B + W} \times 100 \quad (3)$$

Where:

$$P = \text{Percentile rank of the segment}$$

$$B = \text{Number of segments with better values}$$
\( f_w \) — Most needy segment

\( f_b \) — Least needy segment

\[ i \]

\[ 0 \]

\[ x \] — Segment under consideration

\[ (100) \]

\[ (0) \]

\[ \text{Range} \]

\[ w. \]

\[ \text{Least needy segment} \]

\[ \text{Most needy segment} \]

\[ \text{Segment under consideration} \]

\[ (1) \]

\[ (2) \]

\[ I_j = \frac{x}{R} \times 100 \]

\[ IC = \sum_{j=1}^{n} \frac{I_j \times w_j}{\sum_{j=1}^{n} w_j} \]

Where

\( f \) : Worst value of factor for segments in needs list

\( f_w \) : Best value of factor for segments in needs list

\( x \) : Difference between \( f_b \) and the factor value

\( R \) : Difference between \( f_b \) and \( f_w \), the "Range"

\( I_j \) : The segment's index value, based on its value for factor \( j \)

\( n \) : Number of factors in the evaluation; \( j = 1, \ldots, n \)

\( IC \) : Composite factor index of the segment under consideration, including all factors

\( w_j \) : Weight for jth factor

**Figure 9**

The Index Ranking Method
### Table 4

Index Ranking Results

<table>
<thead>
<tr>
<th>SEG #</th>
<th>PCR Index</th>
<th>ADT Index</th>
<th>HAZ Index</th>
<th>$/MILE Index</th>
<th>*Composite Index</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>7.4</td>
<td>0</td>
<td>7</td>
<td>28.6</td>
<td>9th</td>
</tr>
<tr>
<td>B</td>
<td>50</td>
<td>6.2</td>
<td>0</td>
<td>79</td>
<td>33.8</td>
<td>4th</td>
</tr>
<tr>
<td>C</td>
<td>75</td>
<td>100</td>
<td>0</td>
<td>28</td>
<td>50.8</td>
<td>1st</td>
</tr>
<tr>
<td>D</td>
<td>75</td>
<td>0.1</td>
<td>100</td>
<td>12</td>
<td>46.8</td>
<td>2nd</td>
</tr>
<tr>
<td>E</td>
<td>50</td>
<td>2.9</td>
<td>50</td>
<td>64</td>
<td>41.7</td>
<td>3rd</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>4.7</td>
<td>0</td>
<td>100</td>
<td>26.2</td>
<td>10th</td>
</tr>
<tr>
<td>G</td>
<td>25</td>
<td>3.2</td>
<td>0</td>
<td>87</td>
<td>28.8</td>
<td>8th</td>
</tr>
<tr>
<td>H</td>
<td>75</td>
<td>0.5</td>
<td>50</td>
<td>0</td>
<td>31.4</td>
<td>7th</td>
</tr>
<tr>
<td>I</td>
<td>50</td>
<td>0.4</td>
<td>0</td>
<td>76</td>
<td>31.6</td>
<td>6th</td>
</tr>
<tr>
<td>J</td>
<td>100</td>
<td>10.2</td>
<td>0</td>
<td>24</td>
<td>33.6</td>
<td>5th</td>
</tr>
<tr>
<td>K</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>26</td>
<td>11th</td>
</tr>
</tbody>
</table>

* All factor weights set to 1
W = Number of segments with worse values

As in the index method, a "better" value is one that would place a segment lower in the priority list than the segment currently under consideration. For simplicity, those segments having the same factor value as the segment being ranked are excluded from the counts of B and W. In the rare, but possible, case in which all segments have the same factor value, P is set to 50 arbitrarily.

This percentile ranking is done separately for each factor, then combined into a weighted sum $\pi$ for each segment. The weighted sum $\pi$ is then divided by the sum of the weights, $\Sigma w_j$, to produce the composite percentile, PC.

$$
\pi = \Sigma w_j \times P_j
$$

$w_j =$ Weight of jth factor

$$
PC = \frac{\pi}{\Sigma w_j}
$$

Using equation (3), segments B, E and I will receive the following percentile:

$$
P_B = P_E = P_I = \frac{2}{2 + 6} \times 100 = 25
$$

Once again, segments with the same factor value are excluded from the counts of B and W. Segment F, with a PCR of 5, will receive a percentile of 0, as no segments have a better factor value than it does. The same procedure is then followed for the remaining factors.

For this example, each factor will be considered equally important. Thus the weights $w_j$ assigned to each factor are set to 1. For segment C, using equations (3), (4), and (5) to determine PC, the composite percentile:
Highway Needs and Priorities

\[ p_{PCR} = \frac{5}{5 + 2} \times 100 = 71 \]

\[ p_{ADT} = \frac{11}{11 + 0} \times 100 = 100 \]

\[ p_{HAZ} = \frac{0}{0 + 3} \times 100 = 0 \]

\[ p_{$/MILE} = \frac{4}{4 + 6} \times 100 = 40 \]

\[ \pi_c = (1 \times 71) + (1 \times 100) + (1 \times 0) + (1 \times 40) = 211 \]

\[ p_c = \frac{211}{1 + 1 + 1 + 1} = 52.8 \]

Segment C's composite percentile is 52.8. The composite percentile is then computed for each remaining segment. A list of project ranks is then compiled and printed. See Table 5 for the results.

The Successive Subsetting Ranking Method

In Figure 11, four ADT subsets are distinguishable. The first subset contains only segment C, with an ADT of 5704 that is much larger than the second greatest ADT value. The second subset contains only segment J, with an ADT of 672. Five segments, A, B, E, F, and G, fall into another subset of similar ADT values, from 448 to 263 vehicles per day. The final subset, segments D, H, I, and K, consists of segments with low ADT's, from 125 to 98.

The next factor to be considered is the Pavement Serviceability Rating factor, or "PCR". Segments C and J remain at the top of the list, because they are the only segments in their respective subsets. The third initial subset can be divided into four new subsets. Segment A, with the lowest PCR value, 1,
Table 5

Percentile Ranking Results

<table>
<thead>
<tr>
<th>SEG. #</th>
<th>PCR %tile</th>
<th>ADT %tile</th>
<th>HAZ %tile</th>
<th>$/MILE %tile</th>
<th>*Composite %tile</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>70</td>
<td>0</td>
<td>10</td>
<td>45</td>
<td>7th</td>
</tr>
<tr>
<td>B</td>
<td>25</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>46.3</td>
<td>6th</td>
</tr>
<tr>
<td>C</td>
<td>71</td>
<td>100</td>
<td>0</td>
<td>40</td>
<td>52.8</td>
<td>3rd</td>
</tr>
<tr>
<td>D</td>
<td>71</td>
<td>10</td>
<td>100</td>
<td>20</td>
<td>50.3</td>
<td>4th</td>
</tr>
<tr>
<td>E</td>
<td>25</td>
<td>40</td>
<td>89</td>
<td>60</td>
<td>53.5</td>
<td>2nd</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>60</td>
<td>0</td>
<td>100</td>
<td>40</td>
<td>8th</td>
</tr>
<tr>
<td>G</td>
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<td>50</td>
<td>0</td>
<td>90</td>
<td>37.5</td>
<td>9th</td>
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<tr>
<td>H</td>
<td>71</td>
<td>30</td>
<td>89</td>
<td>0</td>
<td>47.5</td>
<td>5th</td>
</tr>
<tr>
<td>I</td>
<td>25</td>
<td>20</td>
<td>0</td>
<td>70</td>
<td>28.8</td>
<td>11th</td>
</tr>
<tr>
<td>J</td>
<td>71</td>
<td>90</td>
<td>0</td>
<td>30</td>
<td>55</td>
<td>1st</td>
</tr>
<tr>
<td>K</td>
<td>71</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>30.3</td>
<td>10th</td>
</tr>
</tbody>
</table>

* All factor weights set to 1
Figure 11
Successive Subsetting Subset Formation
will form an individual subset, because no other segments in the initial subset have as needy a PCR value. The second new PCR subset, contains segments B and E, with PSR values of 3. The PCR of segments B and E makes them less needy than segment A, so they are ranked below A. Segments G and F, with PCR values of 4 and 5, respectively, form the final two least needy subsets from the third initial subset. Segment I forms a new subset ranked below the fourth original subset, because segment I has a less needy PCR value than segments D, H, and K.

The hazard rating, "HAZ", further divides the 6 subsets. Three segments, D, E, and H, have hazard ratings greater than zero, and form new individual subsets. Segment K forms an individual subset, ranked below the subset containing segment H.

The final factor to be used for subsetting is the cost per mile, "$/MILE", to correct the segments' deficiencies. Because the segments are already in individual subsets, the "$/MILE" factor is not needed for further subsetting. If "$/MILE" was used, a segment with a lower cost per mile would be ranked above a segment with a higher cost per mile.

All road segments are now ranked in individual subsets, according to the order of priorities: "ADT", "PCR", "HAZ", and "$/MILE". The most needy road segments can now be selected for funding.