SCHOOL OF
CIVIL ENGINEERING

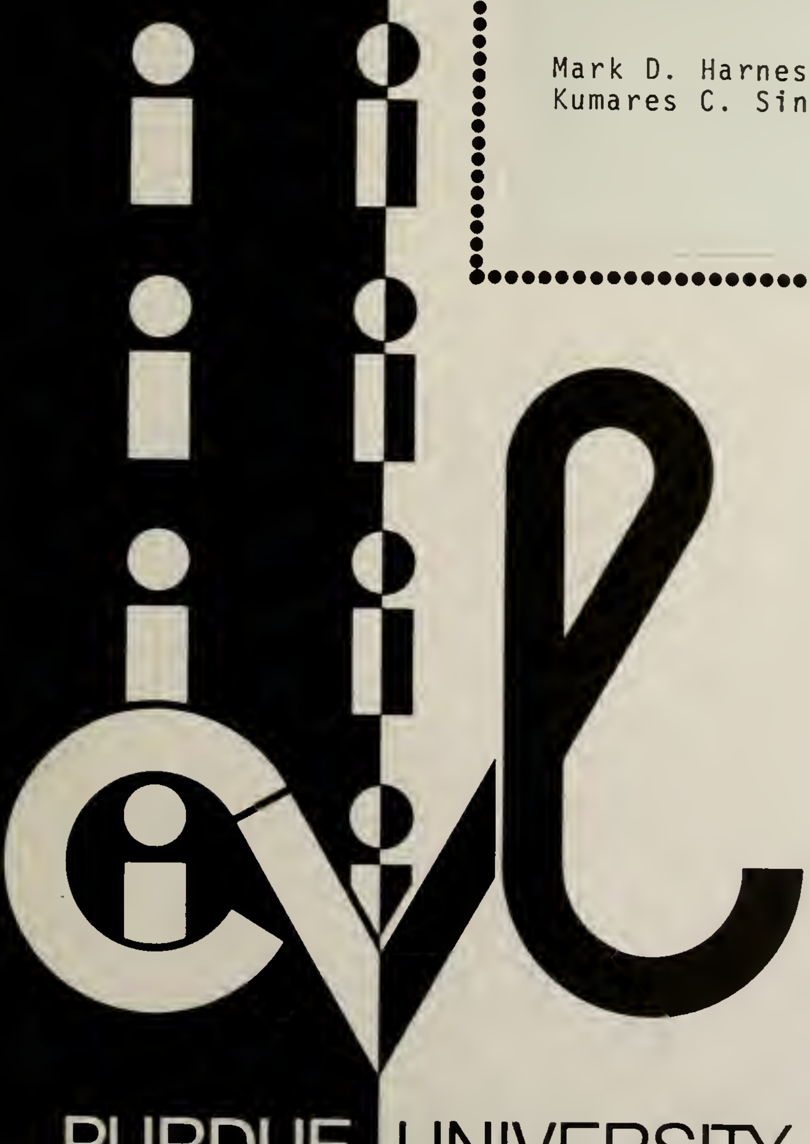
INDIANA
DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

JHRP-83-9

PRIORITY SETTING OF HIGHWAY IMPROVEMENT PROJECTS

Mark D. Harness
Kumares C. Sinha



PURDUE UNIVERSITY

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FINAL REPORT

PRIORITY SETTING OF HIGHWAY IMPROVEMENT PROJECTS

July 6, 1983

To: H.L. Michael, Director
Joint Highway Research Project

From: K.C. Sinha, Research Engineer
Joint Highway Research Project

Project: C-36-73I
File: 3-4-9

The attached final report is on JHRP Study on highway project evaluation and priority setting and it is titled, "Priority Setting of Highway Improvement Projects." The research was conducted by Mark D. Harness, Graduate Resarch Assistant under the direction of Professor K.C. Sinha.

The report includes discussion on the development of a priority setting technique that can be used in connection with capital improvement programming. The application of the technique has been illustrated by a sample problem involving a group of bridge replacement projects.

The findings of the study have been presented to the Planning Division of the Indiana Department of Highways. The report is submitted to the Board as fulfillment of the objectives of the research.

Respectfully submitted,

K.C. Sinha
Research Engineer

KCS/bjm

cc: A.G. Altschaeffl
J.M. Bell
W.F. Chen
W.L. Dolch
R.L. Eskew
J.D. Fricker
G.D. Gibson
W.H. Goetz
G.K. Hallock
J.F. McLaughlin
R.D. Miles
P.L. Owens
B.K. Partridge
G.T. Satterly
C.F. Scholer
R.M. Shanteau
K.C. Sinha
C.A. Venable
L.E. Wood
S.R. Yoder

Final Report

PRIORITY SETTING OF HIGHWAY IMPROVEMENT PROJECTS

by

Mark D. Harness
Graduate Research Assistant

and

Kumares C. Sinha
Professor of Civil Engineering

Joint Highway Research Project

Project No.: C-36-73I
File No.: 3-4-9

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana Department of Highways

Purdue University
West Lafayette, Indiana
July 6, 1983

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ABSTRACT

This project describes the development of a priority setting technique that can be used in connection with capital improvement programming. First, previously developed and implemented techniques were reviewed. These included sufficiency rating techinques, engineering economic and cost-effectiveness methods, mathematical programming, and other various priority setting techniques. Several computer packages used in priority setting were also examined.

Next, the work categories of the Indiana Department of Highways (IDOH) were reviewed. Impact categories were developed and their respective priority evaluation measures were assessed to measure the importance of specific projects within each impact category. Then existing priority setting techniques were critiqued and the proposed technique of successive subsetting was described.

A sample problem consisting of a group of bridge replacement projects was considered using the proposed technique and the priorities were set. In addition, the technique was applied to set priorities within a group of road replacement projects. Finally, suggested rankings for impact categories within each IDOH work category were listed, and priority evaluation measures were developed for the most significant work categories.

CHAPTER 1

INTRODUCTION

This research project develops a technique that can aid in the evaluation and selection of highway improvement projects for implementation within a given work category.

The overall process of highway project selection and programming is presented in Figure 1.1. First, a need for improvement is realized for a group of roadway sections or structures. It may either be realized through field observation, citizen complaints, or from an organized study which evaluates the condition, service, and safety levels of all roadways. From this set of deficient sections or structures, alternative projects are proposed for improvement. After evaluation of the cost and other impacts involved for each project, the best improvement alternative is selected. Next, these improvements or projects are classified according to the highway's functional classification or type of work category which they fall under. Then each project is evaluated with respect to each other project in its job category. From this evaluation of project impacts, the "best" set to projects is selected for implementation under the given budget level.

Priority setting is the method of evaluating each project with respect to each other project within a work

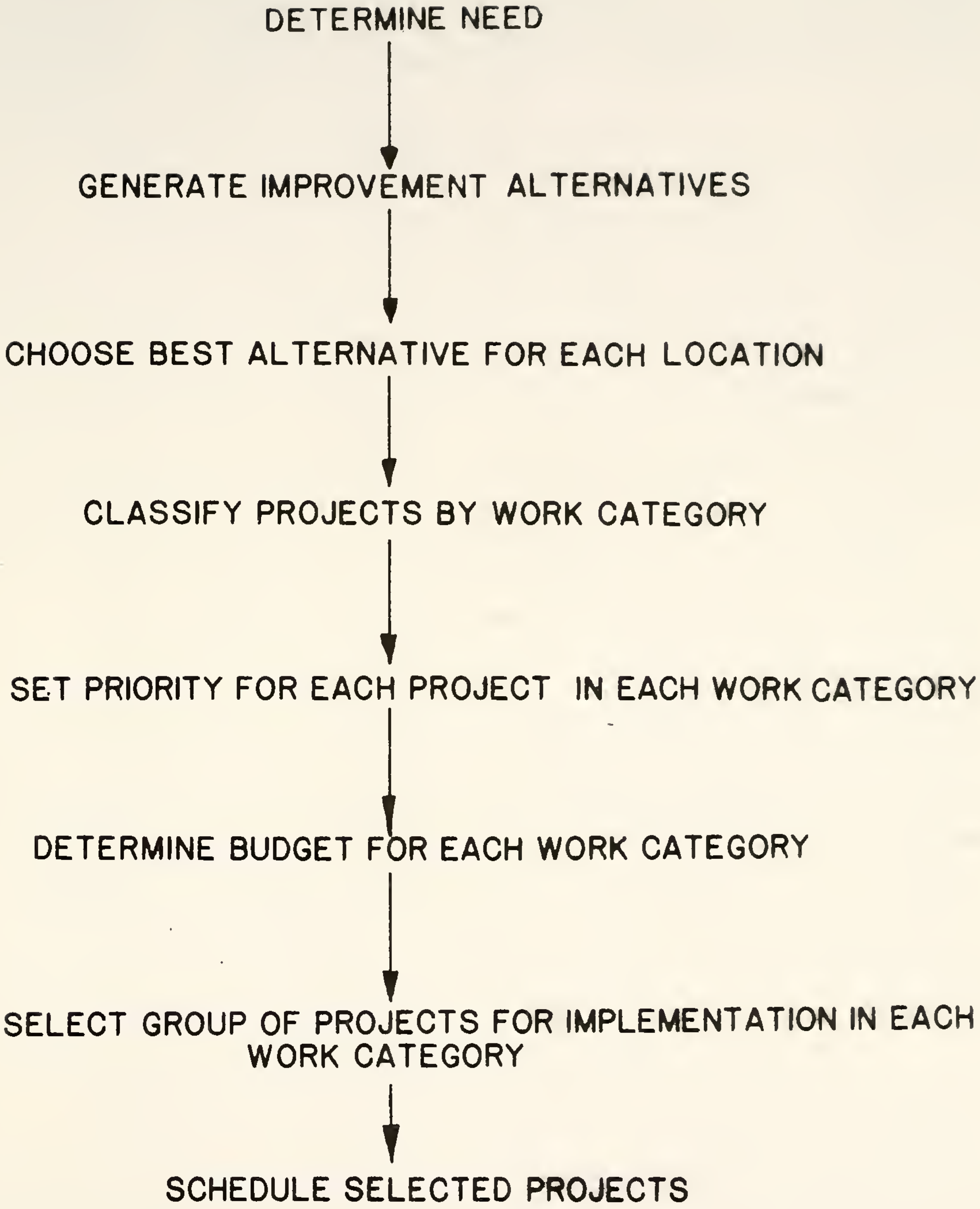


FIGURE 1.1

THE HIGHWAY PROGRAMING PROCESS

category. Programming is the matching of projects with available financial resources for implementation at a specific point in time (97).

Without a well defined technique for priority setting, the choice of projects for implementation may not always be optimal, nor can specific reasons always be given for selection choices. In the face of increasing highway construction costs and an increasing backlog of improvement projects, greater efficiency in selecting projects for implementation as well as provision for the defense of the set of projects selected for implementation must be established.

This research study assumes that projects have already been established for given needs. It also assumes that the best alternative within each project proposal for a particular location has already been chosen. Under these assumptions, a priority setting technique has been developed that can aid in the choice of the set of projects for implementation within a given work category. Having been sponsored by the Indiana Department of Highways (IDOH), this study has been developed for use within its Planning Division.

Special attention has been given to make this priority setting technique simple to use and understand by both highway department staff and the layman. In addition, it is flexible for use within different project categories, and it can result in an efficient and careful use of existing funds for providing highway improvements.

CHAPTER 2

PRIORITY SETTING BACKGROUND INFORMATION

This section discusses the priority setting techniques that have previously been developed and used in the context of state highway improvements programming Then specific techniques used by a number of state highway departments are also described.

A sufficiency or adequacy rating is traditionally an overall numerical procedure that produces a single value to represent the present condition, service, and safety levels of a roadway or structure as compared to a given standard (97). If the numerical value is described as the difference between the standard and the existing condition, it may be called a deficiency rating.

A priority rating is a procedure which combines all factors deemed important into a numerical value for use in evaluating or comparing different projects.

Sufficiency ratings evaluate sections of roadway or structures, while priority ratings compare projects.

Priority setting is the process of placing a group of projects in rank order of importance for implementation.

There are several approaches that can be used in evaluating projects that have a variety of impact types within each project. The most common approaches attempt to develop goals or objectives that can be measured and they set relative priorities for each of the goals or objectives.

These may then be commensurated to obtain a single "super number" which describes the importance or utility of a given project. The super number which the traditional sufficiency rating uses is the sum of the individual ratings for each impact factor.

SUFFICIENCY RATINGS

The first significant priority setting method was developed for the Arizona state highway system in 1946. It was developed to determine which highway sections should be reconstructed for a predetermined funding level. It consisted of determining twelve measurable, or at least subjectively estimable, factors that described the "sufficiency" of a highway section. Highway personnel would drive along a stretch of highway and estimate what they thought was the condition of the roadway for twelve elements. These factors were separated into three major categories of approximately equal weights; structural adequacy, safety, and service. These were then broken down into 3-5 elements each as is shown in Table 2.1.

A fraction of the total points was allocated for each road characteristic depending upon the ability of roadway sections to meet standard performance levels. Then the individual values were added up to get the "basic sufficiency rating". These ratings were adjusted by ADT to give

Table 2.1

Factor Weights for Arizona's Original Sufficiency Rating System

35		Structure
	17	observed condition
	5	maintenance economy
	13	remaining life
30		Safety
	8	road width
	7	surface width
	10	sight distance
	5	consistency of alignment
35		Service
	12	alignment
	8	passing opportunity
	5	surface width
	5	sway in cross section
	5	surface texture
100	Total	

Source: (70)

the final priority ratings. This was done either by dividing the basic rating by ADT or by subtracting the basic rating from 100 and multiplying by ADT.

Each section was then placed on a list in ascending sufficiency and ranked. The sections with the lowest ratings were chosen for improvement until the overall funding level was met (70).

Roadway Capacity in Sufficiency Ratings

In 1962 the Indiana State Highway Commission (now IDOH) used an expanded sufficiency rating system that included the factor of roadway capacity in the priority rating. As a result, this method could take into account the measure of congestion (v/c) as a factor in determining the priority for improvement as well as decreasing the relative priorities of both safety and service (52).

Economic, Environmental, and Traffic Safety Factors in Sufficiency Ratings

In 1971 the Arizona highway department decided to expand their original sufficiency rating system. They proposed three new factors in addition to the original three; Environment, Economic Development, and Traffic Safety (103). By 1981, the relative priorities had been adjusted to that which appears in Table 2.2.

Objective Measurements in Sufficiency Ratings

A recent proposal for sufficiency ratings for South Dakota includes 15 objective measurements and only four subjective measurements. These would then be combined into

Table 2.2

Factor Weights for Arizona's Sufficiency Rating System in 1971

50		Condition
	15	structure and remaining life
	25	ride
	10	percent cracking
30		Safety
	15	accident rate
	15	skid resistance
20		Service
	10	surface width
	10	passing sight distance
65		Economic
	40	direct economic benefits
	7.5	population
	15	environmental impact cost
	2.5	facility cost
25		Traffic Safety
	4	substandard items
	6	hazards
	3	operational inconvenience
	12	accident rate
10		Environment
		(all or nothing depending on expected delays due to EIS)
200 Total		

Source: (103)

five major factors: Condition(40%), Geometrics (20%), Traffic (16%), Maintenance (16%), and Safety (8%). Measurements in pavement strength, pavement smoothness, ADT, and pavement friction would all be mechanically measured in addition to objectively measured data for roadway width, shoulder width, surface width, gradient, curvature, sight distance, surface thickness, truck traffic, v/c, surface maintenance cost, and accident rate(90,26).

These non-subjective data provide unbiased descriptions for use in the framework of the sufficiency rating system which is much improved over the original subjective sufficiency rating process.

Priority Programming (PRIPRO)

A computerized procedure that determines highway improvement priorities based on the sufficiency rating method is called PRIPRO (Priority Programming). It can also determine priorities using cost-effectiveness analysis. The first method rates projects in order of importance using the traditional condition, safety, and service categories. A second method uses the same procedure in addition to a priority adjustment based on traffic volumes of roads (ADT). The third method uses cost-effectiveness which will be discussed later in this report. In addition, individual sufficiency ratings may be identified for each variable.

Some Problems with Sufficiency Ratings

Sufficiency rating systems do not take into account factors such as costs to make the improvements. "This method identifies problems in existing sections, but does not identify alternate improvements, optimal solutions, timing, or budgetary constraints" (97).

In addition, if there is a section that is good overall, but has one localized, very critical deficiency, the composite rating will not indicate a pressing need. In cases like these, it would be necessary to look at each element separately, rather than as an overall rating that takes into account many dissimilar factors.

ENGINEERING ECONOMICS

When values are expressed in terms of dollars, they may be evaluated using engineering economic analysis. By assuming an interest rate, the values of costs and benefits may be expressed at different points in time. Therefore, engineering economics may be used to determine when transportation improvements should be implemented.

Two methods for combining costs and benefits are most frequently used. The net present worth is the summation of all benefits minus the summation of all costs. The B/C ratio is the summation of all benefits divided by the summation of all costs (65,1,85).

B/C Ratio

In 1963 a study was done in San Diego to develop a priority setting formula to determine which street improvement programs should be done in urban areas. One formula that was tested used a priority index, which was the ratio of (Project Cost /Vehicle miles) to the Project Benefit Index. The Benefit Index was very similar to a sufficiency rating, which was the sum of points assigned in 10 benefit categories. This index was not used because it used too much weight for subjective measurements. However, the ratio of benefits to costs was a good step towards a useful formula (40).

In 1980, the California DOT used different priority setting methods for different job categories. Eight of their 15 categories used the traditional B/C analysis. These categories were maintenance, resurfacing, reconstruction, restoration, drainage, safety, traffic operations improvements and new construction (20).

One problem with the B/C ratio method is that it does not consider such important factors as social, environmental, and indirect economic impacts.

This method also had the problem that some projects could have had very large benefits, but also very large costs which the public did not want to bear. As a result other evaluation methods were developed which took into account absolute values of impacts rather than relatives.

COST-EFFECTIVENESS

Unlike engineering economics, the cost-effectiveness approach does not require both costs and benefits to be expressed in terms of dollars. Cost-effectiveness is the ratio of an effectiveness value in any convenient unit of measure to a cost in dollars. Therefore, effectiveness levels do not have to be commensurated into dollars. However, these cost-effectiveness measures must be determined separately for each type of impact of interest.

Highway Economic Evaluation Model (HEEM)

HEEM is a computer package developed and used by the Texas state highway department to evaluate highway improvement programs economically as well as to determine levels of mobility. Individual projects are evaluated according to effectiveness measures of changes in travel delay, accidents, user operating costs, and highway maintenance costs. These are divided by costs for construction and maintenance of the project to produce a B/C ratio or more precisely, effectiveness to cost ratio. It also determines the changes in mobility or average travel speed in a corridor for the system for each combination of projects proposed. Priorities are then set among projects according to their relative B/C ratios for programming (49,32).

As mentioned earlier, PRIPRO also has an option that can determine highway improvement priorities dependent upon cost-effectiveness measures. It first ranks sections according to their present sufficiency ratings. Next it measures the change in the section sufficiency ratings due to the improvement as well as numerical ratings for social, environmental, economic, user costs, improvement life, and projected ADT. These are then compared to project costs to determine relative cost-effectiveness values. Finally the improvements are ranked according to their cost- effectiveness values (49).

Another engineering economics technique that does not require the estimation of an interest rate in advance is the internal rate-of-return method. This method assumes that the summation of the present worth of benefits equals the summation of the present worth of costs and finds the corresponding interest rate or rates.

INCREMENTAL OR MARGINAL ANALYSIS

Incremental analysis looks at the change in benefits divided by the change in costs for an improvement. One study using a method very similar to this was done in 1971 for Pittsburgh urban street improvement programs. A formula was used for incremental benefits that was also weighted to give a higher priority to more important facilities. The priority index was computed as follows:

$$\text{Priority Index} = (R_i - R_e) * W / C \qquad \text{(Eqn. 2.1)}$$

R_i = Improved Condition Rating

R_e = Existing Condition Rating

W = Importance Weight

C = Incremental Cost

After each improvement was given a Priority Index number, they were ranked in order of Priority Index (95).

This approach is good for mutually exclusive projects which only have one incremental cost involved per project. However, this technique can lead to suboptimal improvement benefits if used for projects having more than one investment level. One way to get around this problem is explained by Juster and Pecknold (54).

Highway Investment Analysis Package (HIAP)

HIAP is a computer package developed by the Federal Highway Administration (FHWA) to evaluate highway improvements using incremental analysis. It does not automatically come up with an optimal package of improvements which should be implemented. Instead, it relies on the user successively inputting groups of projects to be evaluated. For each new project or group of projects entered, a new evaluation number is generated. The evaluation number is similar to the B/C ratio. It is the ratio of an evaluation measure (EM) to cost. The EM may be measured in either road user and governmental costs, change in fatal accident rate, change in injury accident rate, or change in total accident rate. Each new project is added until the overall programming period budget is met (49).

This program is best used when evaluating a number of major transportation improvements. When comparing minor projects to major projects, the benefits for minor projects tend to be minimal. This package is also large and complex, creating a need for large time investments in order to get it running.

WEIGHTED FACTORS

Another common technique used in producing priority indexes involves multiplying a breadth of impact value by a severity of impact variable and sometimes dividing this number by a cost value. Overall impacts of a project may be described as the sum of individual factor importance weights times individual factor impact levels. This method produces a commensurate value for different impacts depending on assigned weights. Sufficiency ratings are actually one form of this rating method without cost factors included.

California DOT's Weighted Factor Method

In 1980, the California DOT used types of cost-effectiveness measures in six of their 15 highway improvement categories; safety roadside rest area construction, safety roadside rest area restoration, highway planting, vista points and roadside enhancement, noise attenuation, and new bicycle facilities (20).

An example is the cost-effectiveness index for safety roadside rest areas:

$$\text{c-e index} = \text{AADT rating} * [(wt_1 * \text{alternate stops rating}) + (wt_2 * \text{climate rating}) + (wt_3 * \text{deficiency reduction rating})] \,/\, \text{Project cost} \qquad \text{(Eqn. 2.2)}$$

$$wt_1 + wt_2 + wt_3 = 100 \qquad \text{(Eqn. 2.3)}$$

Georgia DOT's Weighted Factor Method

In 1973 the Georgia DOT developed a priority analysis model. This method was set up similarly to a sufficiency rating system, except the weights for each factor or evaluating parameter were set according to decision makers' consensus. The model was originally calibrated according to the Delphi Technique. The evaluating parameters were: need for improvement, physical deficiency, operational deficiency, safety deficiency, continuity of travel, B/C ratio, indirect economic aspects, social aspects, and environmental aspects. Each evaluating parameter was made up of several component parameters. The individual component weights were different for each type of improvement. An evaluating parameter rating was determined by:

Category Rating= Sum(component rating * component weight) / Sum (component weights) (Eqn. 2.4)

Using the category weights given by the decision makers, the overall ratings were established.

Overall Priority Rating = Sum(category rating * category weight) / Sum (category weights) (Eqn. 2.5)

After three years of data gathering and use, most of the improvement categories were dropped from use by this method (32).

Minnesota DOT's Combination of Weighted Factors

The functional category of resurfacing and reconditioning for the Minnesota DOT uses a weighted sum of three different priority measures for their priority index. The priority measures and weights are as follow ; condition rating (70%), cost-effectiveness (20%), and functional class (10%) . The composite index for reconstruction and major new construction work categories is comprised of sufficiency rating (35%), cost-effectiveness (20%), goods movement (20%), peak-month traffic (5%), and functional class (20%). These ratings and others were used in developing Minnesota's 1982-1987 highway improvement program (49).

A priority index suggested by a study done for the California DOT was as follows (20):

$$\text{Priority Index} = (\text{delay index rating})^{.5} + \text{safety index rating} + \text{community impact index rating} \qquad \text{(Eqn. 2.6)}$$

Transportation Resource Allocation System (TRANS)

TRANS is a computerized model which determines relative priorities of transportation improvements on the basis of weighted factors. It sums the products of individual objective weights times effectiveness measures to find the priority of an individual project and attempts to maximize the benefits for a given budget level. The effectiveness measures are for user benefits, economic development, and environmental factors. Shortcomings of this procedure are that programming is not allowed for greater than one period, and specific weights must be determined for each objective to get a composite rating for each project

Baerwald's Priority Rating Technique

In 1956 Baerwald suggested an improvement over the traditional sufficiency rating system. He let the roadway service, structure, and safety ratings be called a road rating that measured the physical condition of the highway section. In addition, he included elements of traffic volume, traffic composition, adjacent land use and community service as a community service rating. The priority rating was then expressed as:

$$\text{Priority Rating} = K * (\text{Service Rating})^{p} * \log(100 / \text{Road Rating}) \qquad \text{(Eqn. 2.7)}$$

The values of K and p were experimentally found to be 2.5 and 1.25, respectively, for Allen County, IN in 1956.

While the original sufficiency rating method raised or lowered the basic rating depending upon the traffic volume after the physical value had been estimated, Baerwald's method combined the physical rating plus the road usage factor into a single value simultaneously. This method included more information in determining the priority rating, however, the complex mathematical procedure may be confusing to the typical decision maker (2).

MATHEMATICAL OPTIMIZATION TECHNIQUES

Linear programming, integer programming, dynamic programming , and goal programming are all mathematical techniques which may be used to optimize an objective or set of objectives within certain quantifiable constraints. The complexity of these methods usually requires the use of sophisticated computer packages. Again, the problem appears in that relative priorities must be established between objectives to obtain a single best alternative or set of projects which should be implemented. It is also possible to obtain a set of trade-off curves between each pair of objectives using these programming techniques. However, this becomes increasingly complex and difficult when comparing a large number of impact types.

Linear Programming

Linear programming is a mathematical method which optimizes a certain value within a group of linear constraints. In this process, a group of equations are expressed which represent constraints, such as funding and manpower levels and a formula for the computation of benefits. The algorithm then determines the set of improvements which give the maximum level of benefits that can be obtained. An alternate method could find the package of improvements which would minimize cost or optimize any other quantity that can be expressed as a linear function (87).

One such technique was developed for the Chicago Area Transportation Study by Northwestern University in 1962. This model minimized the user and construction costs for a variety of highway improvements (44).

In addition, methods have been developed which will look at trade-offs between optimization of more than one variable. These programs then provide solutions which are intermediate between solutions for any one objective (74).

Priority Programming System (PPS)

PPS is a computer package that was developed by the Ontario Ministry of Transportation and Communications. This package uses linear programming to determine the best timing for a large number of major transportation improvements over a period of time using engineering economic analysis (84). It can also determine the overall consequences of changing project timing, costs, and value assumptions (which were used in commensuration) (49).

First it calculates user benefits due to transportation improvements based on the change in travel time, operating costs, and accident rates. It then calculates the present value of all benefits and costs for each possible year in which the improvement could be implemented. Then the linear programming algorithm selects and schedules the set of improvements that will maximize the total benefits to highway users within the given budget constraints.

Benefits may either be defined as change in travel time, change in vehicle operating cost, change in accident rate, the summation of change in travel time, change in vehicle operating cost, and change in accident rate, or by the traditional B/C ratio.

In 1978 this package was tested using 26 highway improvement projects in Maryland. Due to the complexity of this package, much time and money was needed to implement the computer package. It also requires an extensive data base, some of which requires periodic updating. The complexity of the assumptions required to make this program run make the results difficult for decision makers to fully comprehend (4, 5).

Integer Programming

Integer programming is really just an extension of linear programming in which certain constraints are limited to integer values. While this method will usually result in less overall benefits realized in the optimization problem, it will also result in more realistic variable values. For example, it may not be feasible to do a fraction of a project in a given budgeting period. One example application of an integer programming technique as applied to transportation improvements was developed by Mahoney to determine optimal pavement management strategies (61).

Goal Programming

Goal programming is another linear programming technique that optimizes a number of objectives by minimizing deviations from targets in each category (88). Goal programming may also be used to generate trade-off curves between different objectives. This technique is especially good when measurements of different goals having different weights of importance cannot be expressed in similar terms or units. Therefore, this method would be usable with cost-effectiveness measures rather than measures in dollars only (66).

A study of Indiana highway improvement programs was done using this technique at Purdue University in 1981. It was able to describe trade-offs between various program objectives, highway classes, and activity types as well as to analyze the effects of policy decisions by administrators (62).

Dynamic Programming

Dynamic programming is similar to linear programming in that an objective function and constraints are developed which are complex enough to require the use of a computer. However, with dynamic programming, the constraints do not have to be linear. The constraints must be separable and involve the use of one or more recursive relationships to make it dynamic. As a result, this method is useful when considering relationships which change over time.

Several procedures have been developed in the area of highway improvements programming to produce optimal staging of projects. However these applications have been used subsequently to priority setting to determine the best staging of the most important improvements (21,39,53,76).

OTHER POSSIBLE TECHNIQUES

Fuzzy Sets

Fuzzy sets is a technique that may be used to evaluate parameters that cannot be evaluated precisely or are not easily quantifiable. This method uses membership of factor levels which may be established through a poll of educated persons in the subject of interest (16,106). The specific techniques used in evaluating fuzzy sets are very similar to those used in typical statistics. Since many of the impact measurements used in project priority setting are subjective, the fuzzy sets approach may have application in combining the impact information for use in decision making.

Delphi Technique

The Delphi technique is used to generate subjective data through group consensus. A team of interviewers poll a group of knowledgeable persons through which they design sets of questionnaires to obtain a central opinion of the persons questioned. This method has the disadvantage of being subjective and also dependent upon the input of the questionnaire formers (22). This technique was used in developing the category weights according to decision makers as described in Georgia DOT's Weighted Factor Method on p. 16.

Game Analysis

Another possible evaluation method is "game analysis". In this method a set of carefully designed rules are developed within which participants assume various roles within the operational structure. For example, the structure may be designed to simulate the operations of a transportation segment of a region. This method is also very subjective and is useful mainly in generating alternative scenarios which alternative policy decisions may produce (22)

PRIORITY SETTING TECHNIQUES EMPLOYED BY STATE

Vermont, Iowa, Maryland, and Kentucky

As of 1978 these states still used the sufficiency rating system. The Vermont Agency of Transportation evaluated highway projects according to sufficiency rating, economic development potential, adequacy of engineering and capacity standards, continuity, proximity to major highways, accident rate, and equity. The priority setting by the planning division is relatively subjective within these objectives (49).

South Dakota and Arizona

South Dakota uses a sufficiency rating system that uses more objective data (See Objective Measurements in Sufficiency Ratings, p. 7). Arizona has a new sufficiency rating system that includes economic, environmental, and traffic safety priorities (see Economic, Environmental, and Traffic Safety Factors in Sufficiency Ratings, p.7).

California

The California DOT uses cost-effectiveness indexes within various improvement categories to generate priorities as discussed in California DOT's Weighted Factor Method on p. 15.

Texas

In Texas individual districts develop their own highway improvement projects. These are then sent to the state office where they are evaluated using HEEM. This program determines if the scope of each project would be more cost-effective at a different level. These proposed projects then have their priorities set over the whole state to provide the most cost- effective set of projects for programming (49).

Georgia

The Georgia DOT uses a weighted sum of impact measures to define its project priorities as may be seen in Georgia DOT's Weighted Factor Method on p. 16.

Minnesota

The Minnesota DOT uses a weighted sum of priority indexes to develop its project priorities. This has been shown in Minnesota DOT's Combination of Weighted Factors on p. 17.

Idaho

The Idaho state highway department has recently updated their highway improvement programming system. From traditional roadway sufficiency data, they use a computer package, HWYNEEDS, to propose possible road improvements. With these data, in addition to their own Pavement Management System improvement recommendations, they use HIAP to choose the best programs to implement for their given budget levels (26).

Illinois

Illinois' programming approach has two major categories: 1-- capital and operating projects and 2-- projects that represent critical needs. Priorities for capital and operating projects were developed subjectively by state and local officials within a set of written objectives. Priorities for critical projects were established by public opinion in addition to highway officials' opinions (99).

Washington

The Washington state highway improvement programming method has three major categories; non-interstate improvements to existing standards, interstate improvements, and non-interstate major improvements to improved standards. Meetings are held that voice MPOs', local officials', interest groups', Washington DOT administration's, and advisory committee's views to establish which projects should be included in the new two year transportation program. Then priorities are subjectively determined within each category (49).

Florida

In Florida funds are distributed to each district by formulas depending upon population, road mileage, estimated motor fuel sales, and road "needs". It is then up to district officials to determine the priorities for projects within each of 25 program categories (32, 49).

Wisconsin

WisDOT has four major program categories; state trunk highway and RRR programs, major projects, bridges, and interstate programs. Each category uses different criteria to develop priorities. In addition, the state uses three possible funding levels in which to develop groups of projects to be funded. In the RRR category district offices are able to subjectively determine their own priorities using a list of criteria supplied by the state and PSI ratings. The state office determines bridge improvement priorities from bridge sufficiency rating formulas in addition to various other criteria. Interstate priorities are developed using cost estimates. Finally major projects are evaluated using HIAP and deficiency rating data. The relative priorities are then subjectively chosen taking HIAP data, deficiency rating data, and non-quantifiable information into account. The set of projects within each funding level is then sent to the state legislature where they are then approved for implementation at their desired funding levels (49, 99).

SUMMARY

There are several concepts which have been used to determine transportation improvement priorities. The earliest method was the sufficiency rating system. This technique subjectively analyzed the physical condition of the roadway and used these values in addition to traffic volume to produce a priority rating value.

Since sufficiency ratings only included impacts of highway improvements on road users, later methods were expanded to include measurements of costs, traffic volume, and capacity. Even later, these impacts were expanded to include social, economic, and environmental impacts related to highway improvements. Over time, the original subjective measurements have been improved to include more objective condition measurements.

Priority indexes vary widely, but most compare the levels of benefits of an improvement to the costs associated with it. The most widely used has been the B/C ratio. This method requires all benefits and costs to be commensurated into the same units.

When costs and benefits are commensurated into monetary terms, they can be evaluated using engineering economic analysis to find either the B/C ratio, net present worth, or the internal rate-of-return. While B/C ratios only measure relative impacts, present worth values can indicate absolute values at a given point in time. However, it requires the value of all impacts to be expressed in dollar values. As a result, noncommensurable impacts may not be evaluated. However, a series of B/C ratios in the form of cost-effectiveness values may be evaluated for noncommensurable impacts. HEEM analyzes improvement impacts in this manner.

Marginal analysis is similar to B/C indexes, except it looks at changes in benefits divided by changes in costs.

It has advantages and disadvantages similar to the B/C ratio. HIAP uses this approach.

One impact index commonly used is a severity of impact value multiplied by a breadth of impact value divided by a cost value. Another index uses the sum of impact values times impact importance factors for different impacts to arrive at an overall priority level TRANS uses this approach.

Mathematical programming techniques provide useful tools in optimizing "objective" values within a set of constraints. However, these procedures require computational sophistication that may not be desirable in many highway agencies. PPS is one such package that uses linear programming.

CHAPTER 3

INDIANA DEPARTMENT OF HIGHWAYS PROJECT CLASSIFICATION

The Highway Improvement Program (HIP) of the IDOH has three major improvement categories; capital, operational, and maintenance. These are subdivided into new facilities, improved facilities, and facility preservation. However, the distribution of work categories within these subareas is not exact. Whether a job category is preservation or improvement depends upon whether the design of the project meets the original standards or improved standards. An improvement to a structure to original standards is generally preservation, rather than an improvement. The distinction between new facilities and improvements is less precisely defined. A project which is in itself a new facility may be an improvement to a larger existing facility. One example would be the construction of a rest area on a highway. The distribution of work categories within these overall groupings is shown in Table 3.1.

Capital improvements may be either new, improvement, or preservation. Operational improvements may either be improvement or preservation. Maintenance is always preservation.

Table 3.1

Classification of IDOH Work Categories

	New	Improvement	Preservation
Capital	Road Construction Bridge Construction Interchanges Grade Separations New Completion of Interstate Rest Area Construction Weigh Station Construction Road Grading Road Paving Park Roads Construction Cooperative Recreational Highway Projects Building and Grounds Projects	Added Travel Lanes Rest Area Modifications Weigh Station Modifications Rest Area Construction Weigh Station Construction	Road Replacement Bridge Replacement
Operational		Rest Area Modifications Weigh Station Modifications Road Reconstruction Access Control Intersection Improvements Interstate Safety Improvements Non-Interstate Safety Improvements Sight Distance Corrections RR Grade Crossing Im provements Signalization (New or Modified) Signing (New or Modified) Lighting (New or Modified) Drainage Problem Corrections Small Structure Replacements Landscaping Fencing Junk Yard Control Park Roads Construction Cooperative Recreational Highway Projects Building and Grounds Projects	Interstate Resurfacing Non-Interstate Resurfacing Bridge Rehabilitation Erosion and Slide Control Road Reconstruction RR Grade Crossing Improvements Small Structure Replacements
Maintenance			Roadway and Shoulder Maintenance Roadside Maintenance Drainage Maintenance Bridge Maintenance Traffic Control Winter Emergency Public Service Support Activities Special Maintenance Field Supervision and Training

CLASSIFICATION BY FEDERAL-AID SYSTEM

While IDOH work categories are determined by the nature and extensiveness of work performed, they are also affected by the type of Federal funding available for each improvement. As a result, work categories may be functionally the same, but have different funding types.

For Federal funding purposes, all roads are separated by functional classification into roughly three categories; local roads, collectors, and arterials. Local roads have low operating speeds and basically serve adjacent land uses. Arterials are mainly used for long distance travel at high speeds between different regions. Collectors collect local traffic and connect them to arterials. They have travel speeds intermediate between arterials and local roads. The majority of miles of roads in the United States are local roads, while the majority of vehicle-miles travelled is on arterials. Consequently, Federal aid is targeted at high volume roads such as arterials and major collectors.

The Federal-Aid System is the result of a collection of legislation by the Federal government which helps finance road improvement costs through Federal road user taxes. There are three major types of programs within the Federal-Aid System; System Programs, National Purpose Programs, and Special Programs. The System Programs comprise the majority of funding. These are the Interstate, Primary, Secondary, and Urban Programs (see Table 3.2). Rural arterials and their extensions through urban areas make up the Primary

Table 3.2

Distribution of Indiana Highways by Federal-Aid Classification

System Funding Program	Highway Mileage in 1981 (Percent of Total Mileage)						
	Rural			Urban			All Functional Road Types
	Arterials	Collectors	Local	Arterials	Collectors	Local	
Primary	4292(4.68)			735(.80)			
Interstate	855(.93)			260(.28)			
Urban				2991(3.26)	1651(1.80)		
Secondary		8976(9.79)					
Total Federal-Aid	5147(5.61)	8976(9.79)	0(0.00)	3986(4.34)	1651(1.80)	0(0.00)	19760(21.54)
Total Non-Federal Aid	97(.11)	11002(12.00)	48760(53.19)	13(.01)	140(.15)	11904(12.98)	71916(78.44)
Total Indiana Highway System							91676(99.98)

Source: (51)

System. Major rural collectors compose the Secondary System. Urban collectors and urban arterials not in the Primary System compose the Urban System. The Interstate System consists of a special network of arterials within the Primary System.

From Table 3.2 it can be seen that 6% of Indiana's highway system is in rural arterials, and most of the rural arterial mileage is in the Federal-Aid System. About 22% of the state system is in rural collectors of which half are federally funded. Finally, 53% of Indiana's roadways is in local rural roads of which none are federally funded.

About 4% of the highway system in Indiana consists of urban arterials of which almost all are Federally funded. Urban collectors comprise 2% of the highways of which most are Federally funded. Again 13% of the roadways are urban local roads of which none receive Federal assistance. Although 21.5% of the roads in Indiana are Federally funded, approximately 86% of the vehicle-miles travelled are on the Federal-Aid highways (51).

The distinction must be made between highways in the State of Indiana and highways on the IDOH state system. The former consists of all roads in Indiana, while the latter is the set of highways maintained by the IDOH.

Presently all of the mileage in the Primary System (5027 mi) and the Interstate System (1115 mi) are on the IDOH state system. Fifty percent (4466 mi) of the Federal-Aid Secondary System are IDOH highways. Eleven percent (523 mi) of the Urban Federal-Aid System are on the IDOH state system. Finally, approximately 0.2% of non-Federal-Aid highways in Indiana (108 mi) are on the IDOH system.

Projects within the Interstate System generally receive 90% Federal funds with 10% state matching funds. However, the Federal funds may only be used for specific sections of new Interstate construction. Interstate 4R (Reconstruction, Rehabilitation, Restoration, and Resurfacing) improvements may receive 90/10 matching funds. Primary, Secondary, and Urban funds all receive 75/25 matching of funds. Over the United States approximately 18% of Federal Aid funds were spent in the Primary Program, 6% in the Secondary Program, and 8% in the Urban Program in 1979. Within each program, funds may either be spent for new construction of roads or 4R. Recent legislation requires that at least 40% of the funding be spent on 4R.

Two of the programs within the National Purpose Program are of major interest to state highway improvement programming. These are the Bridge Replacement and Rehabilitation Program and the Highway Safety Program. Funds are available for bridges whether they are on Federal-Aid systems or not. They may receive 80/20 matching funds. The Highway Safety Program is comprised of two major programs; Hazard Elimination and Rail-Highway Crossings. These both receive matching funds of 90/10.

Programs within the Special Purpose Program provide funds for special highway related projects in specific locations (24).

WORK CATEGORY CLASSIFICATIONS

A variety of terminology exists for highway improvement projects. The following is a list which describes more specifically the nature of each work category in the IDOH.

New Capital Projects

Road Construction--purchase of ROW, earthwork and paving of a new road, relocated road, or a bypass.

Bridge Construction -- construction of a new bridge within a road construction project or grade separation project.

Interchanges -- construction of a new interchange to improve an existing roadway.

Grade Separations--the separation of an existing highway from an at-grade road or railroad crossing.

New Completion of Interstate--road construction, interchanges, and grade separations built to interstate standards to complete the interstate system.

Rest Area Construction--the construction of a new rest area along an existing roadway including ramps, parking, buildings, sewage treatment, landscaping, lighting, and signing.

Weigh Station Construction--the construction of a new weigh station along an existing roadway including all incidentals.

Other activities in this category may include road grading, road paving, park roads construction, cooperative recreational highway projects, and building and grounds projects.

Capital Improvements

Added Travel Lanes--the construction of additional lanes onto existing highways.

Rest Area Modifications--construction which upgrades existing rest areas including ramps, parking, buildings, sewage treatment, landscaping, lighting, and signing.

Weigh Station Modifications -- construction which upgrades existing weigh stations.

Rest area construction and weigh station construction may also be thought of as capital improvements to a roadway, rather than new construction.

Capital Preservation Projects

Road Replacement--the replacement of sub-base, base, pavement, shoulders, small structures, and guard rail on approximately the original roadway alignment.

Bridge Replacement--the replacement of a bridge structure and necessary approaches in the original location.

Operational Improvements

Road Rehabilitation or Road Reconstruction -- improvements on the same alignment of an existing road to improve the surface, shoulders and drainage. It may include added turning lanes, shoulder replacement, slope/ditch reworking, guard rail construction, fence construction, signing, signalization, and lighting.

Access Control--the addition of access control to an existing road to improve the roadway It may include the addition of fencing.

Intersection Improvements--the improvement of an existing intersection. It may include added turning lanes, channelization, signal modernization, signing improvements, shoulder improvements, traffic markings, grading, paving, or drainage improvements.

Non-Interstate Safety Improvements--safety improvements along a relatively long section of highway. These may include modernization of signs, guard rail installation, culvert headwall removal, gore treatments, impact attenuators, and glare treatment.

Interstate Safety Improvements--safety improvements such as new or modernized signing or lighting on an interstate highway.

Sight Distance Corrections--the correction of a sight distance visibility restriction, such as the grading of a hill on a road section.

Railroad Grade Crossing Improvements--improvements to approach roadway, crossing, or protection devices at a railroad crossing.

Signalization (New or Modified)--the installation of new or modernization of existing traffic signals.

Signing (New or Modified)--the installation of new or modernization of existing ground-mounted or overhead signs on non-interstate highways. This may include lighting of signs.

Lighting (New or Modified)--the installation of new or modernization of existing lights to illuminate non-interstate roadway.

Drainage Problem Corrections--the remedy of drainage problems by changing channels, rip-rap, inlets, and pipes.

Small Structure Replacements--the replacement of pipes or drainage structures less than 20 feet in length to improve a roadway.

Landscaping--planting of trees, shrubs, and vines. It may also include minor seeding and sodding.

Other activities may include fencing and junk yard control. Park roads construction, cooperative recreational highway projects, and building and grounds projects may be thought of as operational improvements rather than new construction. Weigh station modifications and rest area modifications may be thought of as operational improvements rather than capital improvements.

Operational Preservation Projects

Non-Interstate and Interstate Resurfacing--these may include patching, smoothing, reshaping, and wedging and leveling of an existing surface before the placement of a new surface in addition to the placement of an asphalt surface. Reshaping of the road shoulders may also be included.

Bridge Rehabilitation or Bridge Reconstruction--either the reconstruction, widening, or replacement of a component part or repair of damaged or worn parts of an existing bridge.

Erosion and Slide Control--slide control involves ROW acquisition and embankment correction. Erosion control involves seeding, sodding, mulching, or drainage changes necessary after the completion of a highway project.

Road reconstruction may be considered to be preservation rather than improvements depending upon the degree and type of improvements. Small structure replacements and railroad grade crossing improvements may be considered preservation rather than improvement.

Maintenance (Preservation) Activities

Roadway and Shoulder Maintenance--these may include patching, seal coating, wedging and leveling, crack repair, blading, and clipping roads and shoulders.

Roadside Maintenance--mowing, clipping, herbicide treatment, tree trimming or removal, and ROW fence repair.

Drainage Maintenance--ditch reshaping and cleaning, minor drainage structure replacement or cleaning, and small pipe replacement.

Bridge Maintenance--cleaning, painting, deck patching, deck sealing, and repair of bridges costing less than $100,000.

Traffic Control--sign maintenance and replacement, traffic signal maintenance and replacement , lighting maintenance and replacement, guard rail maintenance and replacement, and painting center lines, edge lines, letters, or symbols on pavement.

Winter Emergency--stockpiling sand and salt in addition to snow and ice removal.

Public Service--roadside park, rest area, and weigh station maintenance in addition to roadway cleaning and litter pick-up.

Support Activities--repair and maintenance of equipment, traffic shop operations, building and grounds maintenance, and detour signing.

Special Maintenance--minor spot improvements to road surface, shoulders, roadside, drainage, bridges, traffic, buildings, and grounds.

Other activities include field supervision and training.

PAST AND PROPOSED EXPENDITURES BY WORK CATEGORY FOR IDOH

Table 3.3 shows the amount of money spent by IDOH for highway improvement projects for the years 1980 to 1982, not including maintenance activities. The majority of funds have been spent in bridge reconstruction, rural secondary resurfacing, bridge replacement, interstate 3R (restoration, rehabilitation, and repaving), and road reconstruction. In 1980 these categories represented 51.2% of the highway improvements budget, excluding maintenance. They represented 79.9% of the budget in 1981, and 82.6% in 1982.

Table 3.3

IDOH Highway Improvement Funding by Work Category for 1980 to 1982

	1980			1981			1982		
Work Category	No.	$10^3\ \$$	%	No.	$10^3\ \$$	%	No.	$10^3\ \$$	%
Road Relocation	2	6,453	4.2	1	4,719	3.5	0		
Road Construction	1	2,355	1.5	1	1,274	.9	0		
Bridge Construction	6	10,253	6.6	1	1,110	.8	1	1,006	1.1
Bridge Replacement	17	9,460	6.1	36	28,126	20.7	35	19,042	21.3
Rural Secondary Resurfacing	65	32,164	20.8	86	28,866	21.2	49	17,105	19.1
Bridge Reconstruction	266	28,742	18.6	190	33,437	24.6	65	11,711	13.1
Road Replacement	3	8,159	5.3	0			2	1,271	1.4
Grade Separation	0			0			0		
Interstate RRR	7	15,014	9.7	12	16,909	12.3	12	20,888	23.3
Interstate & Non-Interstate Safety Revisions	7	6,430	4.2	13	5,460	4.0	2	475	.5
Railroad Crossing Improvements	1	40	.0	1	467	.3	0		
Railroad Protection Improvements	14	1,521	1.0	14	2,085	1.5	6	690	.8
Added Travel Lanes	0			1	2,704	2.0	1	3,257	3.6
Erosion Control	9	1,079	.7	0			2	16	.0
Slide Correction	2	3,372	2.2	1	893	.7	0		
Interchange Construction	0			0			1	2,839	3.2
Signalization Improvement	32	4,026	2.6	23	1,121	.8	34	862	1.0
Non-Interstate RRR	0			8	2,370	1.7	5	755	.8
Road Reconstruction	10	12,365	8.0	3	1,442	1.1	6	5,232	5.8
Access Control	0			0			1	652	.7
Intersection Improvement	15	2,345	1.5	8	1,090	.8	6	811	.9
Sight Distance Correction	0			4	919	.7	2	533	.6

Table 3.3 (continued)

	1980			1981			1982		
Work Category	No.	10^3 \$	%	No.	10^3\$	%	No.	10^3 \$	%
Rest Area Modifications	0			2	86	.1	1	561	.6
Small Structure Replacement	3	388	.3	1	50	.0	6	380	.4
Rest Area Construction	0			1	778	.6	0		
Weigh Station Construction	0			0			0		
Sign Improvements	6	8,063	5.2	7	1,799	1.3	5	1,319	1.5
Drainage Improvements	0			0			2	166	.2
Lighting Improvements	9	1,854	1.2	4	336	.2	1	28	.0
Junk Yard Control	2	30	.0	0			0		
Landscaping	0			0			0		
Weigh Station Modifications	1	154	.1	0			0		
Total	478	154,267	99.8	441	136,041	100.2	283	89,599	99.9

Source: IDOH Division of Planning

As of 1982 these categories represented 48.1% of the 1983 proposed budget and 55.6% of the proposed 1984 budget (50) (see Table 3.4). These budgets were the ones proposed before the new Federal gas tax legislation was passed. The exact amounts subsequent to 1983 were not yet available at the time this report was written.

If maintenance activities are included in the proposed budget, they would represent about 25% of the total budget (see Table 3.5).

The previous shortage of highway funds has resulted in greater priority being placed on capital preservation rather than on new or vastly improved facilities. The newer 1984-1985 budget shows greater priority being placed on the categories of road construction and bridge construction than in previous budgets. A tremendous backlog of road construction projects have also been approved, however they have not been budgeted for the 1983-1984 biennium. A backlog of projects also exists for the bridge replacement, road replacement, added travel lanes, and new interstate completion categories. These five categories amounted to 87% of the unbudgeted funds as of 1983. A large number of bridge replacement projects will most likely be programmed due to the increase in funds from the recent highway funding legislation.

There is a large degree of uniformity between yearly funding both within most job categories and between yearly

Table 3.4

IDOH Proposed Highway Improvement Funding by Work Category for
1983, 1984, and the Future

	1983			1984			Future		
Work Category	No.	10^3 $	%	No.	10^3 $	%	No.	10^3 $	%
Road and Bridge Construction	17	53,973	25.3	17	39,875	21.1	132	636,554	53.2
Bridge Replacement	58	41,373	19.4	69	40,321	21.3	301	187,703	15.7
Non-Interstate Resurfacing	62	30,859	14.5	67	30,315	16.1	41	17,375	1.5
Bridge Rehabilitation	134	29,516	13.9	96	30,399	16.1	198	40,455	3.4
Interstate Resurfacing	4	20,585	10.0	5	27,385	14.5	0		
Road Replacement	1	6,988	3.3	0			11	63,828	5.3
Grade Separation	1	6,003	2.8	0			1	1,220	.1
Interstate Safety Improvements	7	2,455	1.2	3	2,039	1.1	9	12,934	1.1
Non-Interstate Safety Improvements	3	2,650	1.2	3	2,650	1.4	0		
Railroad Grade Crossing Improvements	18	2,515	1.2	18	2,493	1.3	0		
Added Travel Lanes	1	4,500	2.1	0			18	67,304	5.6
Erosion & Slide Control	1	2,250	1.1	3	1,203	.6	13	8,360	.7
Interchange Construction	1	2,857	1.3	0			2	1,815	.2
Signalization Improvements	2	1,340	.6	2	1,500	.8	1	700	.0
Road Modernization (Road Recon. & Access Control)	2	734	.3	5	3,915	2.1	28	42,994	3.6
Intersection Improvements	8	980	.5	10	1,187	.6	54	15,396	1.3
Sight Distance Corrections	3	1,108	.5	6	977	.5	13	4,228	.4

Table 3.4 (continued)

	1983			1984			Future		
Work Category	No.	10^3 $	%	No.	10^3 $	%	No.	10^3 $	%
Rest Area Modifications	2	951	.4	1	1,050	.6	5	4,010	.3
Small Structure Replacement	7	924	.4	1	1,130	.6	6	858	.0
Rest Area Construction	0			1	1,020	.5	7	6,215	.5
Weigh Station Construction	0			1	900	.5	1	2,000	.2
Signing Improvements	1	200	.1	1	200	.1	1	800	.0
Drainage Problem Correction	1	90	.0	2	310	.2	1	50	.0
Lighting Improvements	1	50	.0	0					
Junk Yard Control	1	11	.0	0					
New Completion of Interstate	0			0			22	82,796	6.9
Landscaping	0			0					
Weigh Station Modernization	0			0					
Total	336	212,912	100.1	311	188,869	100.0	865	1,197,595	100.0

Source: (50)

Table 3.5

IDOH Proposed Maintenance Program by Activity Type for 1983 and 1984

	1983		1984	
Work Category	10^3 $	% of Total HIP Funds	10^3 $	% of Total HIP Funds
Roadway & Shoulder Maintenance	14,600	5.3	15,500	6.0
Traffic Control	13,700	4.9	14,500	5.6
Winter Emergency	11,000	4.0	11,600	4.5
Field Maintenance, Supervision, & Training	6,900	2.5	7,300	2.8
Roadside Maintenance	5,000	1.8	5,300	2.1
Maintenance Support Activities	4,000	1.4	4,200	1.6
Bridge Maintenance	3,100	1.1	3,300	1.3
Drainage Maintenance	2,600	.9	2,800	1.1
Public Service	1,900	.7	2,000	.8
Special Maintenance	1,700	.6	1,800	.7
All Maintenance	64,500	23.3	68,300	26.6
Other Highway Improvement Program Categories	212,912	76.7	188,869	73.4
Total HIP Funds	277,412	100.0	257,169	100.0

Source: (50)

totals This is because job category budgets have been approved in advance by the state legislature.

CHAPTER 4

HIGHWAY IMPROVEMENT IMPACT CATEGORIES AND THEIR PRIORITY EVALUATION MEASURES

When priorities are determined for individual projects within a work category or functional classification, significant types of impacts must be determined. After this, methods for measuring the extent of these impacts must be developed to describe the importance of each project. An impact category is defined as the general impact type which has a specific importance level within a work category. A priority evaluation measure is the value which represents the importance of a project with respect to a given impact type.

IMPACT SECTORS

The implementation of a highway improvement project can have a variety of impacts on many entities related to it. These entities may be roughly divided into three sectors; users, non-users, and providers. Users are entities which may either be persons, businesses, or institutions whose transportation activities are directly affected by provision of a highway system. Non-users are entities which may either be persons, businesses, institutions, or governmental agencies which are not directly affected by the provision of the highway system, but they may be directly or indirectly affected by the presence of a roadway or its users. Finally, there is the provider. This is the entity which constructs and maintains highway facilities for the public at large. The provider may represent any combination of Federal, state, or local levels of government. For the purpose of this report, the provider is the state highway department.

IMPACT CATEGORIES

The major types of impacts upon users, non-users, and the provider have been combined into thirteen impact categories. Within each impact category, possible priority evaluation measures for these impacts have been listed (see Table 4.1).

Highway Department Costs

The first impact category listed is highway department costs. This impact category is associated with the provider of the highways; the highway department. Measures of the highway department costs include the construction cost, maintenance cost, administrative cost, and the cost of borrowing money. These costs are usually estimated in construction estimates and project cost estimates. Administrative costs include supervisory, design, and estimating wages of personnel. In addition, the highway department may incur occasional litigation costs. This type of cost cannot be measured but is highly correlated with the relative safety of a facility. If the level of safety is high, the risk of legal costs is low.

Table 4.1

List of All Priority Evaluation Measures by Impact Category

HIGHWAY DEPARTMENT COSTS

Construction Cost
Administration Cost
Litigation Costs
Maintenance Cost
Cost of Borrowing

ROAD USER COSTS

Vehicle Operating Costs
Accident Costs
Travel Time Cost
Out-of-Pocket Costs

CONDITION

Smoothness
Pavement Strength
Superstructure Condition
Appurtenance Condition
Skid Resistance
Substructure Condition
Deck Condition

SERVICE

Traffic Volume
Delay
Operating Speed
Railroad Crossing Protection Devices
Service Area
Volume/Capacity Ratio
Road Alignment and Cross-Section

SAFETY

Fatal Accident Rate
Total Accident Rate
Number of Hazardous Obstructions
Road Alignment and Cross-Section
Traffic Control Devices
Smoothness
Delay
Sight Distance
Injury Accident Rate
Railroad Crossing Protection Factor
Night Accident Rate
Volume/Capacity Ratio
Adjacent Land Use
Skid Resistance
Train Volume

Table 4.1 (continued)

ENVIRONMENTAL

Water Quality
Noise Level
Litter Volume
Rate of Energy Use
Air Quality
Lighting Level
Vibration Level
Esthetic Appearance

SOCIAL

Adjacent Land Use
Number of Businesses Displaced
Number of Institutions Displaced
Number of Families Displaced
Number of Historic Buildings Removed
Number of Recreational Areas Displaced

NON-USER ECONOMIC

Construction Wages
Property Values
Tax Rate
Sales Level
Building Construction Profits
Land Development
Tax Base
Employment Level
Relocation Costs

COMFORT

Smoothness
Volume/Capacity Ratio
Esthetic Appearance
Delay

CONTINUITY

Roadway Spacing and Locational Distribution

CONVENIENCE

Accessibility
Volume/Capacity Ratio
Delay
Continuity
Operating Speed

Table 4.1 (continued)

EQUITY

Region of Project
Service Area of Facility
Revenue Generated by Area

LOCATION

Highway Classification
Area Population
Type of Area (rural or urban)

Road User Costs

The next impact category listed is road user costs. Costs to road users are involved in the necessity of time spent travelling to a place, costs associated with the operation or use of a vehicle, and the additional cost involved in vehicular accidents.

Vehicle costs may be estimated from fuel costs and vehicle maintenance costs which vary as a function of road condition. These have been estimated for a variety of road geometries, surfaces, and traffic conditions (1). Travel time costs may be estimated either directly from personal surveys of road users or indirectly from socio-economic census data.

If any tolls or fares are imposed on a facility such as a toll road or parking lot, this would increase the daily operating cost for a road user. One cost which is very difficult to measure is the change in distance or time which existing travellers have to go if they change the routes they would have normally taken. Ultimately, this could be measured from trip assignment models (98,104). Estimates of expected accident costs have been evaluated and tabulated in the literature (1).

Condition

A main type of highway impact on the users and the provider is the physical condition of the road pavement. The condition of the pavement's surface affects the speed, safety, and comfort of persons using the roadway, while the strength of the pavement gives an indication of how long it will last. This will affect when the highway department will need to improve the pavement.

There are two measures which describe the condition of the pavement's surface profile; smoothness and skid resistance. The smoothness describes how much vertical movement is involved in a vehicle's ride. There are numerous specific ways in which this movement can be measured. In general a machine, either in a vehicle or pulled behind a vehicle, is used to measure the frequency and/or distance that a set of wheels moving along the pavement move up or down in relationship to one another. The PCA roadmeter measures the number of movements of the back axle of an automobile (107). Skid resistance describes the coefficient of friction between a tire and wet pavement during acceleration or turning. This measurement is not an indicator of driving comfort, but of safety. A very smooth road may be very slick. One technique used in determining this value involves towing a trailer behind a truck. Water is then sprayed in front of the trailer's tires and the relative slickness of the pavement is then measured when the tires of the trailer are locked up. This procedure finds the coefficient of wet sliding friction between the skidding tires and the pavement.

Pavement strength is usually measured by applying a weight to a section of pavement and seeing how far it will deflect. Indiana uses a Dynaflect which can be towed behind a truck which measures this value.

A bridge is dependent upon the conditions of the substructure, superstructure, and the deck. The condition of the deck is determined in the same way as regular road pavement. The condition of the substructure and the superstructure generally can only be estimated by visual inspection. The physical condition may be approximated from the age of the structure and the design vehicle used in design of the bridge. Another factor affecting the physical condition may also be the number and type of loads applied to the bridge over its life. This may be determined by using the traffic volume counts and vehicle classification data.

The condition of roadway appurtenances may only be visually evaluated with respect to their level of physical deterioration or ability to perform their appropriate function.

Service

The service level of a roadway measures the speed, safety, and comfort which a given section provides to users. This may be determined by the traffic volume, congestion level, operating speed, travel delay, and road alignment.

Traffic volume indicates the number of persons being served on a segment. Service area indicates the geographic area over which persons are served. Operating speed represents the degree of utility provided to each driver in the form of time expenditure. Delay is the extra time spent stopping or slowing down. This is also a measure of utility and travel time expenditure. Congestion level is usually measured as a ratio of traffic volume to roadway capacity. This also shows the relative level of driver comfort and safety.

The road alignment can only be described in the number and severity of vertical and horizontal curves, vertical grades, and lengths of tangent sections. This gives an indication of the level of safety and driver comfort.

Pavement width, lane width, shoulder type, shoulder width, horizontal clearance, and vertical clearance also measure road geometry. They are also used in determining the road capacity mentioned earlier (45,96).

The level of service provided at grade crossings is dependent basically upon the crossing smoothness, the type of warning device provided, and the amount of delay encountered by motorists.

Safety

The level of safety provided to road users is described by every impact which reduces the probability of an accident between vehicles or between a vehicle and a physical object. Factors which affect accident potential on a roadway are road cross-section, vertical and horizontal alignment, traffic control devices, and the presence of hazardous obstructions. It is very difficult to estimate the safety of a roadway since accidents tend to be low probability, high cost occurrences. The level of safety on a section is best measured by the accident rate. This may be broken down into three levels of severity, fatal, injury, and property damage. Accidents can further be evaluated by type, location, and severity. Location and type of accident give indications as to the causes. The night accident rate gives an indication of the effect of lighting on safety levels.

In addition, roadway alignment, cross-section, traffic congestion, adjacent land use, traffic control devices, and the presence of hazardous obstructions give insight into the expected accident rate on a section. Sections having good smoothness, high skid resistance, low congestion levels, long sight distances, and low delay should have good safety ratings.

The estimated safety of a bridge is dependent upon its physical design. Factors which may measure this relationship are approach roadway width, the degree to which the road narrows, the deck width, the vertical clearance, and the alignment of the approach roadway.

The accident rate is obviously a measure of the safety of vehicles operating on the bridge. Also, if a bridge is in poor physical condition, the probability of collapse while a vehicle is on it can also be a measure of its safety (78,31).

Most importantly highway/railroad grade crossings create a safety hazard, especially for motorists. A road user may either run into a train, into grade crossing apparatus, or into another object due to a rough crossing.

Roadway smoothness indicators, which are the same for road pavement smoothness, may be used to approximate the crossing roughness. Factors which affect the probability of a car/train accident are train volume, highway volume, type of warning device provided for the crossing, and the roadway geometry, especially sight distance. The most general measure of safety at a crossing is the accident rate.

Environmental

In general, environmental impacts may be defined as the degree to which the physical environment is changed from its natural state Environmental impacts affect both users and non-users. Users are only affected by the roadways they use, while non-users are affected by both the highway facility and the presence of users on it. Environmental impacts include changes in water quality, air quality, noise levels, lighting levels, litter, vibration, energy consumption, and aesthetics. Water quality may be evaluated according to the level of particulates and organic matter present. Future levels may only be roughly estimated depending on the type and extent of construction. Air quality is measured according to the type and volume of particulates emitted into it. Future levels may be determined if the future traffic volume, facility geometry, and traffic composition are known. Vibration and noise levels are measured by the intensity and frequency of construction equipment and for generated traffic. These are measured from the same roadway characteristics as air quality. The vibration and noise levels have also been estimated for given future traffic levels. Illumination levels may be determined from the type and location of luminaires proposed for installation. Simple physics may be used to determine light intensity levels at various distances. Levels of litter may only be estimated depending upon the level of law enforcement present, the type of facility, and the degree of maintenance activities present. Finally, since no two persons are alike, aesthetics are completely subjective. Therefore different structures may be evaluated by local residents to determine their preferences. This may be done by a poll or by a person who is familiar with the group of persons' tastes. Energy use depends on the traffic volume, traffic composition, operating speeds, and construction methods.

Social

Social impacts of highways affect users and non-users. While the presence of a road allows users to make contacts with persons in other locations, it also may inhibit a specific social event between non-users which would have occurred had the facility been absent. Most social impacts are either due to the change in mobility of the population or are due to negative impacts caused by highway facility construction or improvements. While highway improvements only disrupt community activities for a while, road construction affects social patterns in the long run.

It is very difficult to measure to what degree communities are disrupted for smaller changes other than by measuring the length of time which construction will take. Large projects which involve taking of property for right-of-way may be quantified by the number of families relocated, businesses displaced, historic buildings removed, religious and institutional structures removed, or recreational area taken However, it is difficult to estimate the change in property values and subsequent distribution of socio-economic strata due to highway changes in the long run. The adjacent land use of roadways being improved gives an indication of the type of social activities being affected.

Non-User Economic

Economic impacts on non-users are less obvious. They usually occur over a longer period of time and are influenced by a larger number of external factors than are most highway improvement impacts. Major impacts are in changes in property values, sales volumes for businesses, tax rates, tax base, employment, prices of goods and services, building construction profits, uncompensated relocation costs, and public utility location costs. Wages to construction or maintenance workers can be estimated from construction or project estimates. Impacts on nearby land development due to land taken for right-of-way, houses taken, and businesses taken may be measured by land area taken and market values of land and structures. In addition, tax base decreases can be determined from existing tax records.

Other more difficult measurements are of the number of jobs created or destroyed, the change in future land development mixes and values, the change in business generated for existing and future businesses, the changes in rental rates, and the changes in demand for building construction. These may be estimated from regional plans and labor estimation. However, the accuracy of these estimates may not be high.

Comfort

Driver comfort is a composite of many of the previously mentioned factors. It measures the ease with which a user can access and operate on a roadway system. It is usually associated with the number of decisions and driving restrictions or hindrances.

Driver comfort is highly correlated with service, safety, and condition. A safe roadway will require a minimum of rash decisions and outside interferences. A road with a high service level will be very uncongested and require a minimum of conflict with other drivers. A road with a smooth surface will give the most seating comfort to the passengers In addition, good aesthetics will help the driver to be relaxed and calm. Consequently, comfort has already been considered in other impact categories.

Continuity

Good continuity provides the lowest road user travel costs and the lowest costs to the highway department for construction of auxiliary roads. Continuity basically measures how well roadways in different areas and of various types fit together. High volume roadways should be widely spaced and continuous, and local streets should be densely located but with less continuity. Networks having good continuity usually have the lowest road user costs and require the least amount of road mileage. Continuity may be meaured by looking at individual paths of drivers to see how far they have to drive, not in the direction of their destination, to get to their destination.

Convenience

Convenience relates to the ease with which a user can access the road network and how easy it is for him to travel from origin to destination. Again, convenience is made up of a variety of previously measured impacts. If a road system has good continuity, it will have good convenience. If the system has low levels of congestion, it will be more convenient. If there are higher operating speeds and less delay, the system will be more convenient. If road user economic costs are low, it will probably be more convenient, because each inconvenience usually has a time or economic cost related to it.

With respect to road access, the number and spacing of access points will measure the convenience of a roadway.

Equity

Equity is the uniform distribution of benefits between different socio-economic groups or different geographical areas. One type of equity provides equal service to all groups, while the other type provides service according to how much each user has paid. In the context of state improvement projects, the state can either implement projects in regions according to the amount of revenue received from each or provide the same level of service to all regions. Consequently, equity may either be determined from traffic volume counts, vehicle-miles travelled, or from district populations.

Location

The location of a highway improvement also has a significance as to which group of projects should be implemented. The highway classification will either be primary, secondary, or local. This is usually a function of traffic volume and service area. The type of area (rural or urban) may also affect the type of projects selected. Area population gives an indication of how many non-users may be affected by a facility.

SUMMARY

From this list of impact categories and priority evaluation measures, one can take an individual work category, determine the type of impacts important within the category, and then determine how these impacts can be measured in a highway improvement priority setting context.

CHAPTER 5

THE PROPOSED PRIORITY SETTING TECHNIQUE

CRITIQUE OF AVAILABLE TECHNIQUES

In the context of the present study, several priority setting techniques were examined. A brief critique of these techniques is presented below.

Sufficiency rating techniques use very subjective data to evaluate existing levels of condition, service, and safety for roadways. These "needs" in addition to a traffic volume adjustment are used to rank each section in order of need. Improvement projects are then developed to meet these needs.

Although a priority setting technique could be developed based on this approach, a range of priority evaluation measures may require greater accuracy than is presently available in highway departments. In addition, exact numerical weights for priority evaluation measures are necessary, which again imply a greater degree of accuracy than is actually possible from existing data.

Weighted factor techniques also determine a single number for each project by arithmetically combining the measures of impacts. This approach does not allow explicit consideration of all possible impacts and it requires assignment of impact weights in advance.

B/C ratios and marginal analysis may be used to provide a priority index for each project. However, only those impacts that can be expressed in terms of dollars can be considered.

Although cost-effectiveness methods do not require that each impact be expressed in terms of dollars, once again, every impact must be expressed relative to the project cost. As a result, a series of cost-effectiveness values must then be evaluated for each project, which must then be commensurated to provide a final priority for each project.

Mathematical programming techniques such as linear programming, integer programming, goal programming, and dynamic programming all use sophisticated mathematical formulas and computer programs to evaluate project priorities. While these methods are useful, they require a large investment in time and money in getting the programs running and debugged. Moreover, the imprecise type of input data available does not justify the use of a precise mathematical approach.

Consequently, it can be seen that although there are a great number of priority setting methods available, none are exactly suited for use in the environment of the IDOH at the present time. A new method is necessary that can objectively and systematically combine input data that have a low degree of accuracy.

CHARACTERISTICS REQUIRED OF A NEW PRIORITY SETTING TECHNIQUE

In developing a new priority setting technique, certain characteristics must be met. Priorities should be evaluated for projects within their appropriate work categories or functional classifications (97). Projects in different work categories have different levels of importance for the same impact categories.

The technique should be designed to be simple and easy to understand. The technique should also be quick, practical, and flexible to use. It should be useful if more impact types are added, if some are left out, or if impact measures are changed. The technique should also be easily adaptable to highway departments at different levels of government or for different levels within a department (99, 12, 5, 97).

Levels of uncertainty or risk should be taken into account (97, 54, 49, 99). Graphical as well as numerical methods should be used to describe project characteristics (5). The interaction of conflicting priorities within projects should be addressed (54, 49). The final set of projects implemented should be distributed equitably throughout the region of jurisdiction (97, 54, 49). Finally, the position of each project in the "pipeline" should be taken into account (49).

THE SUCCESSIVE SUBSETTING TECHNIQUE

The major problem in using a priority setting technique is that available data are mostly subjective and have a low degree of accuracy. Consequently, the proposed technique assumes that impacts of highway improvements cannot be measured precisely, and if they can be, their limits of accuracy are quite large. It assumes that all projects in each impact category can only be roughly lumped into a small number of groups. The members of each group will then have approximately the same impact value or priority evaluation measure.

However, the key to this technique is that each smaller group or subset may also be divided into additional smaller groups using different evaluation criteria. A representation of the successive subsetting operations is in Figure 5 1. As a result, although the first separation of projects may only produce, for example, five groups, the second round of subsetting may produce 25 groups (or five groups of five). This procedure may be used for as many times as there are impact categories. Consequently, a group of projects separated into three subgroups five times will produce 243 subsets. Five groups divided five times will produce 3125 subsets.

Therefore, using this technique a large number of projects may be ranked in a small number of steps using data that need not be highly accurate. In addition, only several impact measurements are necessary for each project proposed. This means a small amount of data is required.

REQUIREMENTS OF THE SUCCESSIVE SUBSETTING TECHNIQUE

Instead of determining the numerical priorities for each type of impact, the relative importance for different

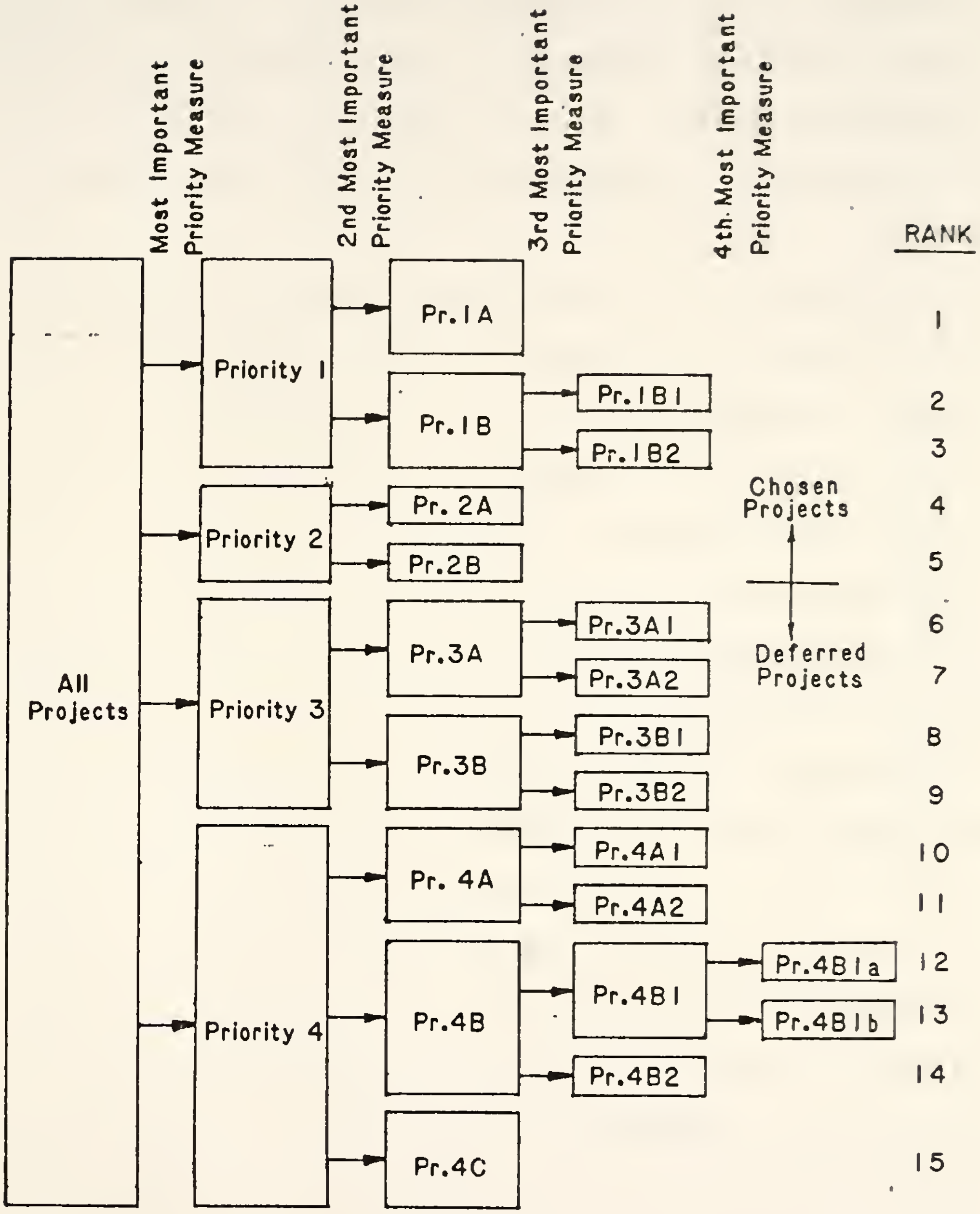


FIGURE 5.1
A FLOW CHART OF THE SUCCESSIVE SUBSETTING TECHNIQUE

types of impacts need to be ranked. Then for each budgeting or work category, the projects must be split into several subgroups according to the most important priority measure. Then each subgroup must again be separated into more subsets using the second most important priority evaluation measure. This continues until all projects belong in a separate subset.

For a single subsetting step, the decision maker must have an understanding of the degree of accuracy of the priority evaluation measures to be used. However, rather than using precise statistical methods to determine which values are statistically different, the user can visually observe the distribution of the values and make approximations between different values. Then, by repeating this step using other priority evaluation measures for each of the smaller subgroups, each category may be roughly subdivided a number of times to produce a finely separated distribution of all projects by rank.

Before the impact categories may be ranked, the decision maker must clearly understand the relative importance between each impact category and their respective priority evaluation measures. The first subsetting step has the greatest influence as to what priority a given project will have. For in the second subsetting step, in the absence of the use of any trade-off curves, the second most important priority evaluation measure will only affect the ranking of projects within the original subgroups. For example, a project located in the second most important subgroup in the first subsetting step cannot move up to the most important subgroup.

If the relative importance of impact categories are clearly distinguished, that is, if each priority evaluation measure clearly has a greater significance than the next most important measure, then the priority evaluation measures may be ranked and applied successively to produce individual subsets for all the projects.

However, if some priority evaluation measures have similar importance levels, either within or between different impact categories, then trade-off curves must be developed to combine these measures. A figure displaying how two priority evaluation measures may be combined to subgroup projects is shown in Figure 5.2. The relative importance between the two priority evaluation measures are reflected in the slope of the lines separating the subgroups.

If more than two priority evaluation measures have about the same level of significance, they may be combined as in Figure 5.3. Here the resulting subgroupings for the first two measures are traded off against a third measure. The result of this subgrouping step may then be traded off with further priority evaluation measures.

However, when two or more measures are traded off, they combine to produce only one subgrouping step. Consequently,

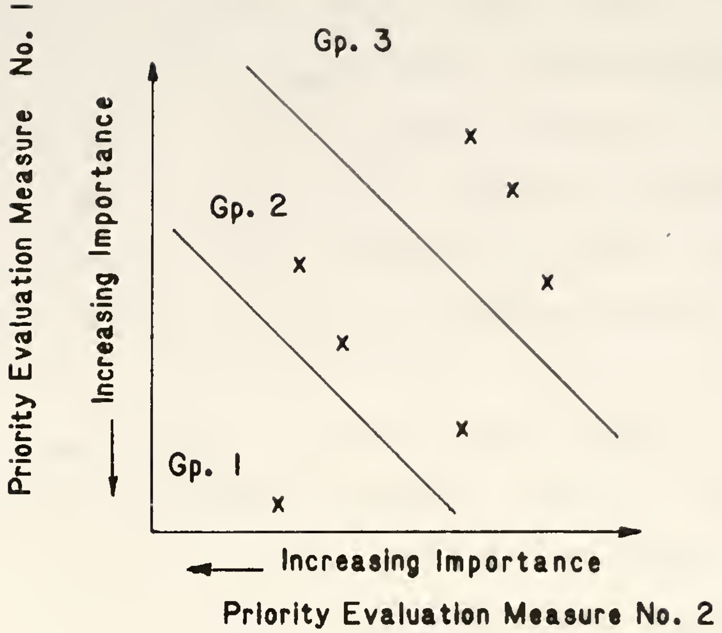


FIGURE 5.2

SINGLE SUBGROUPING OF PROJECTS USING TWO PRIORITY EVALUATION MEASURES

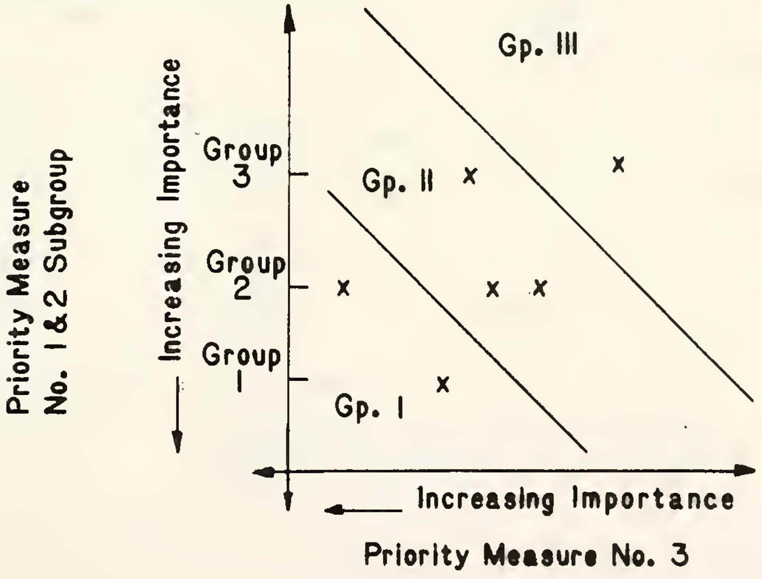


FIGURE 5.3

SINGLE SUBGROUPING OF PROJECTS USING THREE PRIORITY EVALUATION MEASURES if a large number of projects must have their priorities determined, this may be a disadvantage in that more subsetting steps are desired. It is possible, however, to offset this small number of subsetting steps by increasing the number of groups made in each subsetting step. However, again the limits of accuracy of the data must not be overestimated.

One advantage of this priority setting method is that sets that have no subsets with more than one project do not have to be further subdivided. Only those groups having projects with very similar priority evaluation measure values must be subdivided using the increasingly less significant impact categories.

In addition, if the overall budget level is known, subsetting of projects need only be applied in the groups where the cutoff point lies between programmed and deferred projects. A group does not need to be subdivided if all of the projects in it will be selected. However, for the purposes of this study, all of the projects will be ranked in case future changes in budget level will be made.

SENSITIVITY OF THE TECHNIQUE

This priority setting technique has been developed to use inaccurate data to produce a finely classified distribution of projects by rank. This has been done by successively applying rough separations of projects into groups.

However, some sensitivity must exist for the technique to be able to distinguish the order of projects with some accuracy.

This sensitivity comes in the determination of the relative priorities of evaluation measures. While values for individual measures may be quite inaccurate, changes in the order of application of different priority evaluation measures will produce a different final ranking of projects.

For example, if one of two projects has a poorer condition rating, and the other has a poorer safety rating, the final ranking between the two projects will depend upon which evaluation measure was given the highest priority. If the condition rating was applied first, then the project with the poorer condition rating would be given the higher final rank.

However, the final ranks of projects will only be greatly different for those projects having greater importance in one impact category, such as safety, and less importance in another impact category, such as service. If a project has great need in all categories, then it will receive an important rank, no matter what relative significance the individual priority evaluation measures are given. Likewise, a project having low importance in all categories will receive a low overall rank.

Therefore, the sensitivity of this technique will only affect those projects having high importance in some impact categories and low importance in other impact categories.

SUMMARY OF STEPS

The general steps involved in the application of the proposed technique are listed below:

1 List priority measures in order of decreasing significance, combining those having nearly equal importance.

2 Plot projects by their most important priority evaluation measure or measures.

3 Separate projects into subgroups.

4 For each subgroup, repeat steps 2 and 3 using the next most important priority evaluation measures until each project is in its own subgroup.

5 Rank projects in decreasing order of priority.

6 Select projects for implementation in order of rank until the budget for the given period has been met.

CHAPTER 6

AN APPLICATION OF THE PROPOSED TECHNIQUE USING THE BRIDGE REPLACEMENT WORK CATEGORY

This section describes the application of the successive subsetting technique to the bridge replacement work category in general and then uses a set of 22 proposed bridge replacement projects to show an actual application of this technique.

In developing the specific successive subsetting technique for a given work category, one must understand what priority evaluation measures describe each impact category of importance, the relative importance of each impact category, and the available data for projects within the work category.

Bridge replacement projects may be evaluated using four major impact categories; the cost to the highway department to replace the bridge, the physical condition of the present bridge, the traffic volume using the bridge, and the safety of persons driving over the bridge (see Table 6.1).

PHYSICAL CONDITION

The most important factor in bridge replacements is the physical condition of the existing bridge. This measures the ability of a bridge to avoid a catastrophic failure.

Table 6.1

Relative Importance of Bridge Replacement Priority Evaluation Measures

Rank	Impact Category	Priority Evaluation Measure
1	Physical Condition	Minimum of Superstructure Condition and Substructure Condition
2	Physical Condition	Remaining Life
3	Traffic Safety	Deck Width
4	Traffic Safety	Road Narrowing on Bridge
5	Service and Highway Department Cost	ADT ÷ State Share of Construction Cost
6	Traffic Safety	Approach Alignment
7	Traffic Safety	Deck Pavement Condition
8	Location	Road Classification

Since IDOH bridge data are gathered according to Federal guidelines (31), priority evaluation measures available for this impact category are the subjective measures of substructure condition, superstructure condition, and the remaining life (see Table 6.1). Theoretically, a bridge's life will end when either the substructure or the superstructure becomes so poor that the bridge must be closed to prevent a collapse while someone is using the structure. Therefore, ideally the remaining life value will be proportional to the minimum of the substructure and superstructure condition values. However, this is not always true, due to the subjective nature of the measurement of these values.

So instead of using only remaining life as the sole measure of physical condition, both the minimum of the two condition ratings and the remaining life may be used. These may be combined by plotting the minimum of the superstructure and the substructure ratings against the remaining life value (see Figure 6.1).

Since two priority evaluation measures have been used to evaluate the same impact category, projects having inaccurate data may be identified. If a point lies above or below the spread of points on the graph, then either the remaining life, superstructure, or substructure condition values are in error. For example, if a point lies above the spread of points, then either the remaining life rating is too low, or the minimum or the superstructure and substructure condition ratings is too high. It would be very

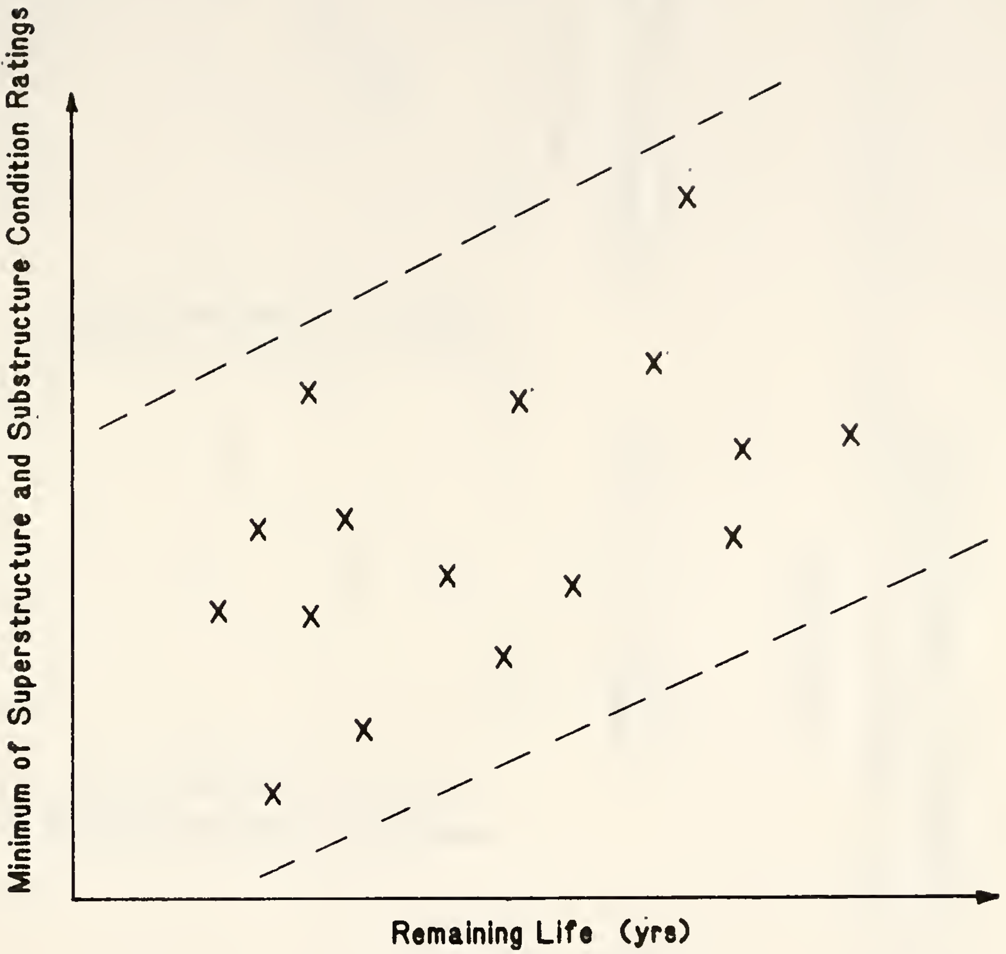
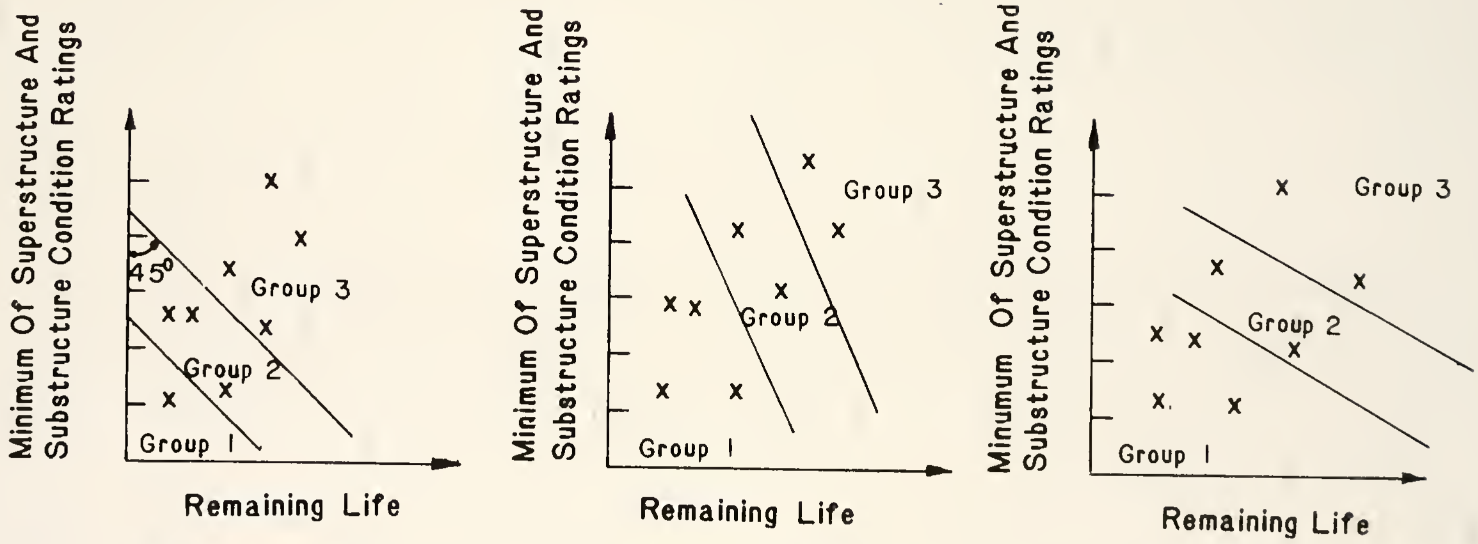


FIGURE 6.1

AN EXAMPLE OF A SINGLE SUBGROUPING OF PROJECTS USING SUPERSTRUCTURE CONDITION, SUBSTRUCTURE CONDITION, AND REMAINING LIFE PRIORITY EVALUATION MEASURES



Remaining Life Is As Reliable As Condition

Remaining Life Is More Reliable Than Condition

Remaining Life Is Less Reliable Than Condition

FIGURE 6.2

THREE EXAMPLES OF TRADING OFF TWO PRIORITY EVALUATION MEASURES WITH DIFFERENT DEGREES OF IMPORTANCE helpful to recheck the input data for these specific projects to resolve the discrepancy between the two measurements.

Now it is necessary to determine the relative accuracy between the condition ratings and the remaining life. With this in mind the projects can be grouped into several subsets by separating them into groups with lines whose slopes reflect the relative reliabilities (see Figure 6.2). For example, if a 45 degree line represents measurements that are equally accurate, then a 60 degree line from the horizontal would indicate that remaining life is more reliable than the minimum of the condition ratings. Now the set of projects having the lowest remaining life and the lowest superstructure or substructure ratings will be in the most important group for implementation.

TRAFFIC SAFETY

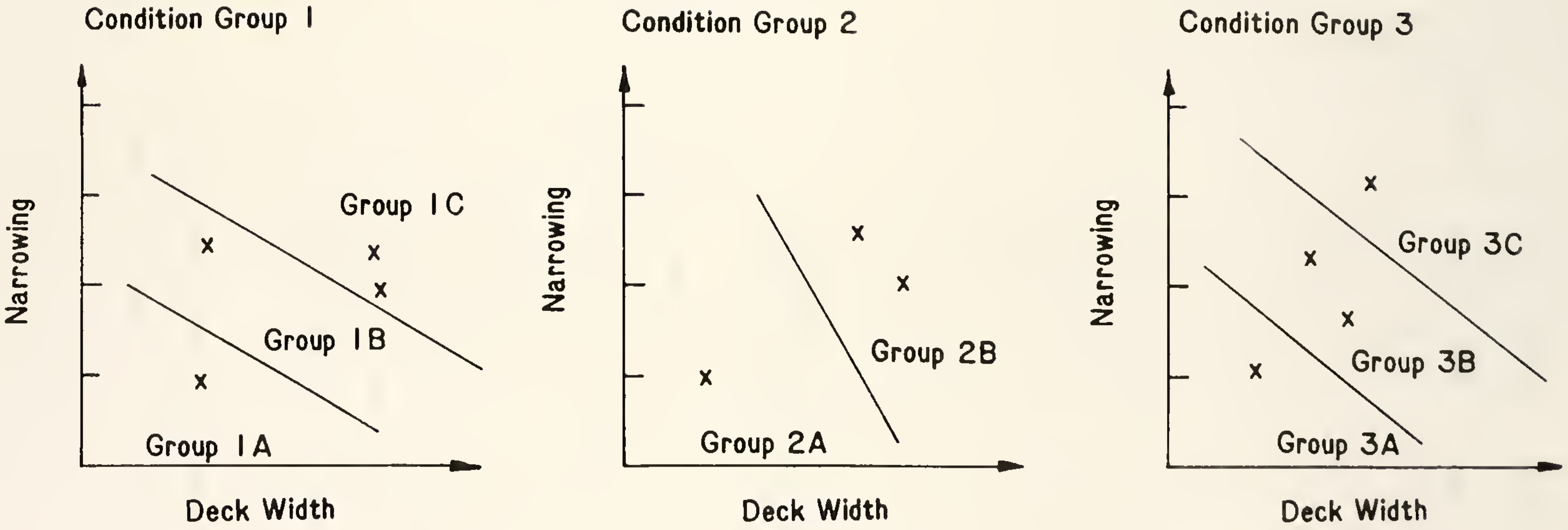
The second most important aspect in determining bridge replacement priorities is traffic safety The best measurement of this is the accident rate on the bridge. However, since this was not available, values of approach alignment condition, deck width, road narrowing on the bridge, and deck pavement condition from the bridge sufficiency rating data were used (see Table 6.1). Road narrowing was defined as the bridge deck pavement width minus the roadway pavement width

Assuming deck width is the most important priority evaluation measure , and road narrowing is the next most significant, each subgroup from the physical condition subsetting step may be subdivided into several subsets (see Figure 6.3)

For the most important condition group (Condition Group 1), Group 1A represents the set of projects in this group having the most critical traffic safety situation. Group 1C represents the least important traffic safety subgroup in the most important physical condition group. Group 3A represents the most important traffic safety subgroup in the least important physical condition group. Likewise, Group 3C represents the least important traffic safety subgroup in the least important physical condition group. Depending upon the relative importance of deck width and road narrowing, the slope of the lines separating subgroups may be determined as in Figure 6.2.

SERVICE AND HIGHWAY DEPARTMENT COST

The next most important impact group for bridge replacements is the cost to replace the bridge. The level of service provided by the bridge is also important (see Table 6.1). Since these two groups have approximately the same level of importance, they may be combined into a single subsetting step. The highway department cost may be measured by either the total ROW and capital cost of the bridge or the share of this cost that the state highway department must pay. The latter method will give higher priority to bridges having greater amounts of Federal funding. The



Condition Group I

Condition Group 2

Condition Group 3

FIGURE 6.3

THREE EXAMPLES OF SUBGROUPING PROJECT CLASSES BY ROAD NARROWING AND DECK WIDTH PRIORITY EVALUATION MEASURES level of service provided by the bridge may be easily measured by the ADT on the roadway which the bridge serves.

Rather than using a trade-off curve to combine the service and cost measures, a logical measure combining these two measures would be the service to cost ratio, as shown below.

Service/Cost Ratio = ADT/Construction Cost (Eqn. 6.1)

This value shows the relative number of vehicles that would be served per dollar of construction cost. A larger value would represent a more cost-effective project. Now these values may be used to subdivide the subgroups which result from the previous traffic safety subsetting step.

SUBSEQUENT IMPACT CATEGORIES

At this point, subsets still having greater than one project per group may be ranked according to less important factors such as approach alignment, deck condition, deck pavement condition, road classification, and so on (see Table 6.1). Again the first three of these priority evaluation measures are found in the Federal bridge sufficiency ratings (31). It may be seen that priority evaluation measures from previously applied impact categories may also be used.

Now each project must be ranked against each other project. This may be done by listing the total set of projects in descending order of importance. For example, if only the first three impact categories were used, the most important project would be in the most important condition group, the most important safety subgroup, and the most important service/cost subgroup

Finally, after each project has been ranked, projects may be chosen for implementation during the budget period until the total budget level has been met. If the next project on the list would cause the total budget to be exceeded, it may be either tentatively overbudgeted, extra funds may be unspent, or the next most important project which stays within the overall budget may be chosen.

ASSUMPTIONS USED IN THE BRIDGE REPLACEMENT PRIORITY RATING PROCEDURE

To give equal priorities to two lane and four lane bridges within the deck width classification step, four lane bridges may be converted to two lane by either dividing by two or adding only the outside two lanes. Adding only the two outside lanes of a four lane highway should approximate the lateral clearance of a two lane highway.

For priority setting of bridge replacement projects, it is assumed that all proposed projects will eventually be implemented. The only question is that of when they will be implemented. In this light, social and environmental impacts do not need to be reconsidered, since it can be assumed that they will be minimized in the design stage of the project. If a project is to be abandoned due to significant social and environmental impacts, it will never have reached the priority setting process.

BACKGROUND INFORMATION FOR THE SAMPLE PROBLEM

Now that a specific successive subsetting procedure has been determined for the bridge replacement work category, priorities may be determined within a group of bridge replacement projects. This section describes a sample application of the technique to a group of actual bridge replacement projects.

First, 22 of the 430 bridge replacement projects proposed in the 1983-84 IDOH Highway Improvement Program were selected (50). Projects were selected for state highways 1 through 9. From this group of projects data were gathered from Federal-Aid forms that were used to apply for Federal funding.

Next, bridge inventory ratings for each of the 22 bridges were collected. These were rated in accordance with the FWHA Bridge Inventory and Appraisal Manual (31). The key for the subjective condition ratings as required by this manual is shown in Table 6.2.

Finally, 19 of the bridges proposed for replacement were visited and the data were examined for completeness, consistency, and accuracy. The final bridge replacement priority evaluation measure matrix is the result of this field investigation (see Table 6.3). The values in this table represent the author's opinion as to the actual

Table 6.2

Key for Subjective Condition Ratings

Numerical Rating	Bridge Condition
9	new
8	good
7	good with minor maintenance needed
6	fair with major maintenance needed
5	fair with minor rehabilitation needed
4	marginal with major rehabilitation needed
3	poor with rehabilitation or repair needed
2	critical with need to close and rehabilitation or repair needed
1	critical, is closed and may not be repairable
0	critical, is closed and beyond repair

Source: (31)

Table 6.3

Priority Evaluation Measures by Project No. for
Sample Bridge Replacement Problem

Project No.	844	852	5	1	878	2859	2860	2861
Construction Cost, State Share $[10^3\ \$]$	57	95	131	30	122	67	67	67
Narrowing [ft], Deck Width-Road Width	4	8	10	5	16	12	12	11
Deck Width [ft]	25	28	46	30	34	34	32	33
Deck Pavement Condition	7	8	7	7	6	8	8	8
Remaining Life [yr]	5	10	10	10	5	15	10	15
Substructure Condition	4	7	5	4	4	7	5	8
Superstructure Condition	4	6	4	8	4	7	5	7
ADT	1200	1900	1100	1100	1200	3000	3500	6600
Approach Alignment Condition	8	8	7	7	8	7	7	6
ADT/State Share of Construction Cost	21	20	8	37	10	45	52	99

Table 6.3 (continued)

Project No.	2862	15	143	167	91	1549	59	56
Construction Cost, State Share [10^3 $]	110	136	253	221	101	19	302	237
Narrowing [ft], Deck Width-Road Width	0	0	4	5	6	6	0	10
Deck Width [ft]	24	22	$\frac{44}{2}$	28	34	28	30	32
Deck Pavement Condition	5	5	4	5	5	5	7	6
Remaining Life [yr]	15	5	15	15	10	5	10	5
Substructure Condition	4	3	6	7	7	3	3	4
Superstructure Condition	5	3	5	6	4	3	3	5
ADT	1700	6300	13300	1700	7500	3100	6300	9400
Approach Alignment Condition	3	2	5	6	7	7	4	7
ADT/State Share of Construction Cost	15	44	53	8	69	163	21	40

Table 6.3 (continued)

Project No.	166	2867	888	8	889	147
Construction Cost, State Share [10^3 $]	166	39	73	45	122	57
Narrowing [ft], Deck Width-Road Width	0	8	18	-3	12	6
Deck Width [ft]	24	32	40	29	32	28
Deck Pavement Condition	8	6	4	6	7	4
Remaining Life [yr]	5	15	5	5	20	10
Substructure Condition	3	4	4	3	7	4
Superstructure Condition	4	4	4	3	8	8
ADT	3200	6300	4300	1000	900	4600
Approach Alignment Condition	5	2	8	7	7	3
ADT/State Share of Construction Cost	18	162	59	22	7	81

subjective ratings for each project. The location of the proposed projects are shown in Figure 6.4. The order of impact categories is shown on Table 6.1.

APPLICATION OF THE PROCEDURE TO ACTUAL PROJECTS

The projects were subdivided into 8 groups according to physical condition (see Figure 6.5). In this case, both the minimum condition rating and the remaining life are measures of the same impact type; physical condition. It can be seen that a remaining life of 5 years is approximately equivalent to a minimum superstructure or substructure condition rating of 3. Likewise, 20 years of remaining life corresponds to a minimum condition of 7. Therefore, projects that lie perpendicular to the values of the linear relationship should be placed in the same subgroup. This should best reconcile the discrepancy for projects having remaining life and minimum condition values which do not fall on the line. Therefore, projects having condition ratings of three and a remaining life of five years were placed in the most important category (Group A). The next most important group consisted of the projects having conditions of four and lives of five years and the project having a condition of three and a life of ten years. The five projects in this category (Group B) were deemed to be in approximately the same physical condition. The remaining 13 projects were combined into six groups in the same manner. Of these eight groups, Groups F and H needed no further subdivision.

Figure 6.4
Locations of Sample Bridge Replacement Projects

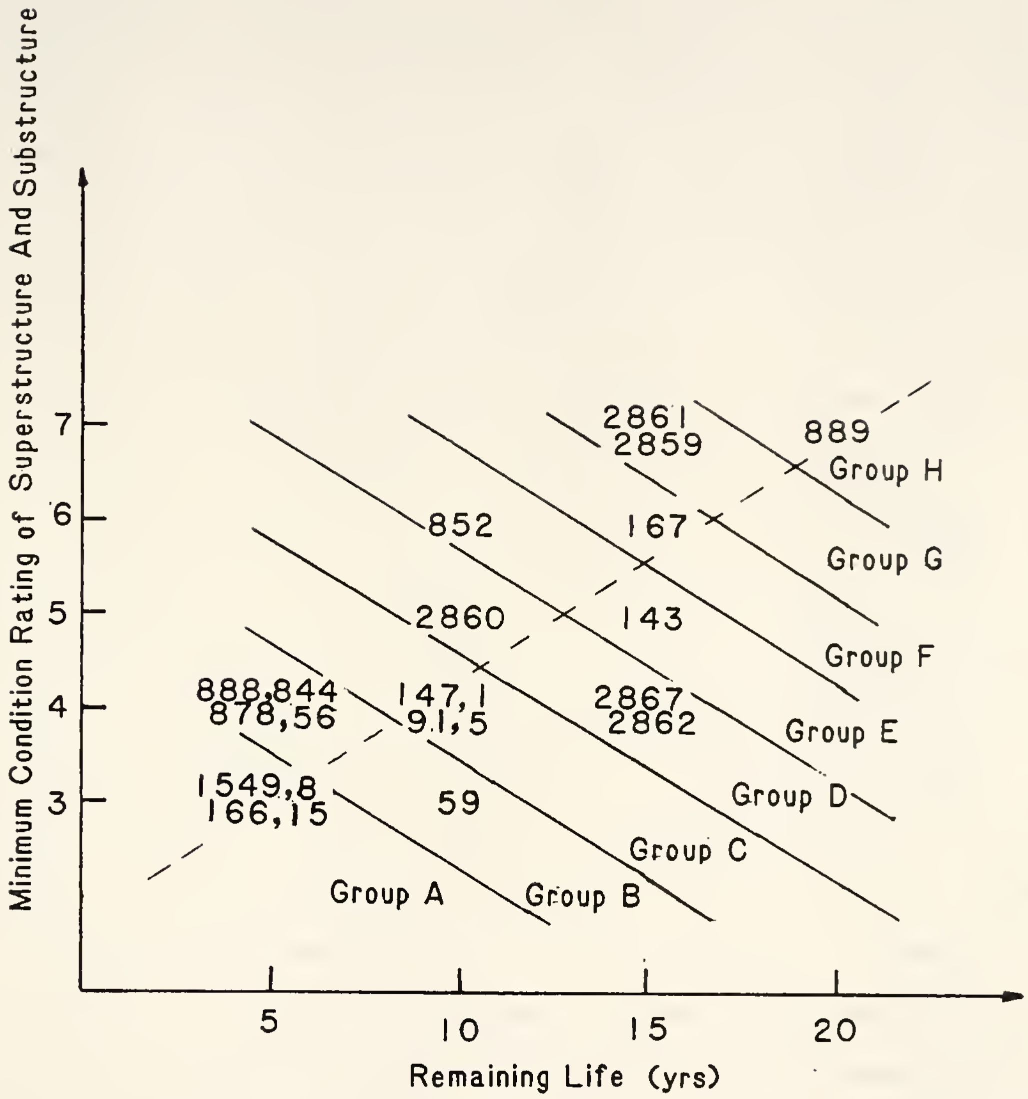


FIGURE 6.5

FIRST SUBGROUPING STEP FOR SAMPLE BRIDGE REPLACEMENT PROBLEM

The remaining six groups were subdivided according to safety in Figure 6.6. In this subsetting step, deck width and road narrowing represent two different types of safety hazards, but deck width was determined to have greater influence on the priority than road narrowing on the bridge. An example of this is that while Project No. 8 had a pavement width five feet narrower on the bridge than on the approach and Project No. 1549 was five feet wider on the bridge, both projects were placed in the same safety subgroup since both had deck widths of about 35 feet.

In drawing the lines separating the subgroups, the decision maker must decide in each case how much need in the narrowing evaluation measure is required before a project may be advanced to a group having greater need according to the deck width evaluation measure. In all six classes (see Figure 6.6) it may be seen that the slope of the lines separating the subgroups could have been vertical without changing the membership of each subgroup. However, for example, if Project No. 56 had the same deck width, but a very low road narrowing value, the line separating the groups could have been drawn further to the right to include this project in Group B.a.

From these subgroups, only six groups needed further subdividing. These were subdivided according to the service/cost ratio in Table 6.4. Here Groups A.c, B.a, B.b, C.a, D.b, and G.a had their remaining projects ranked. Since each of these groups had only two projects in them,

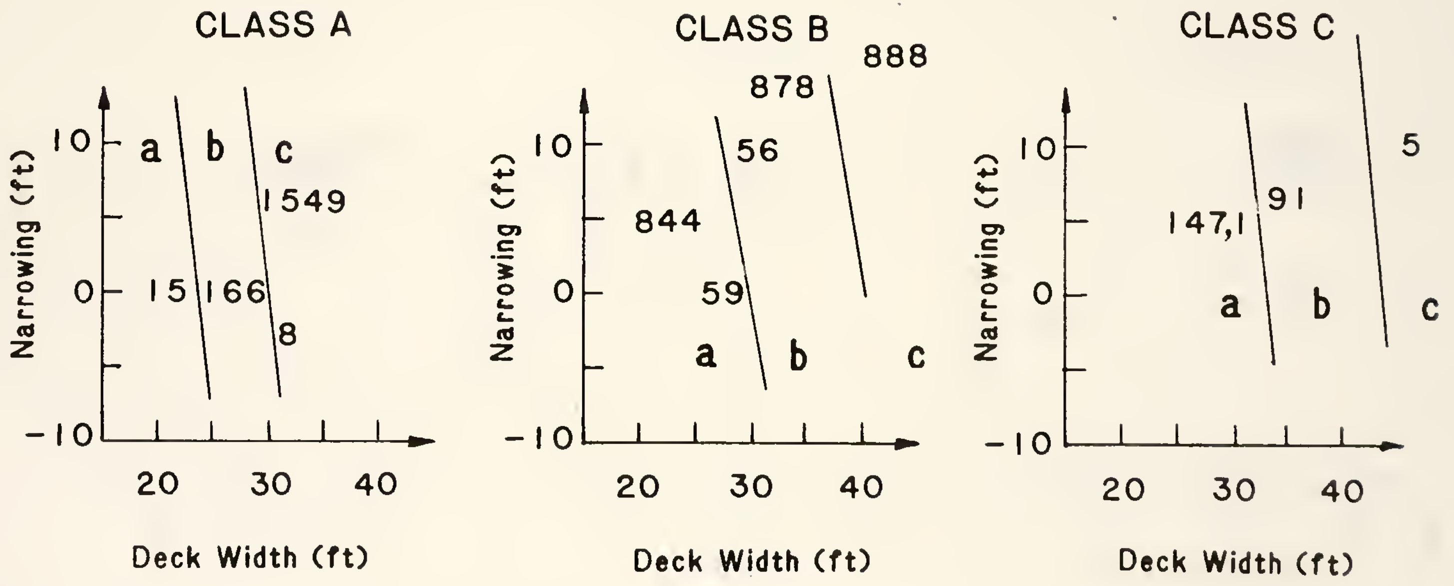


FIGURE 6.6
SUBGROUPING BY SAFETY PRIORITY EVALUATION MEASURES WITHIN EACH CONDITION CATEGORY FOR SAMPLE BRIDGE REPLACEMENT PROBLEM

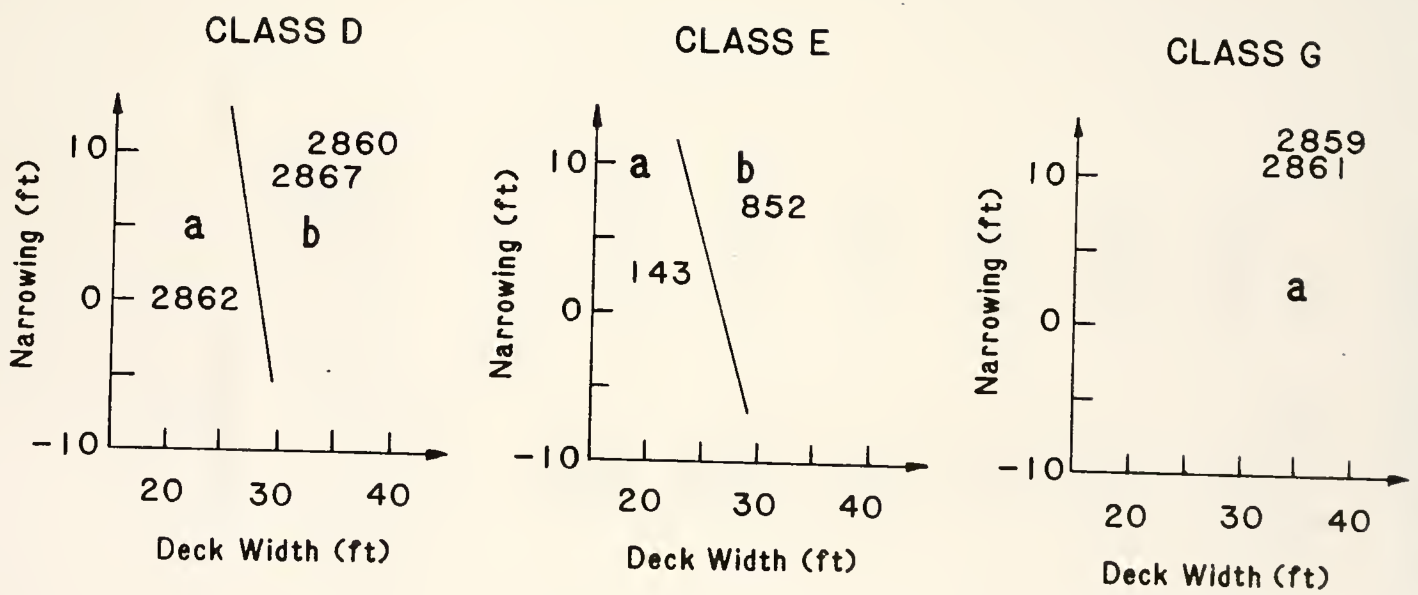


FIGURE 6.6 (continued)

Table 6.4

Subgrouping by Service/Cost Ratio for Remaining Safety Categories for Sample Bridge Replacement Problem

	Project No.	Service ÷ Cost	Rank
Class A.c.	1549	163	i.
	8	22	ii.
Class B.a.	844	21	i.
	59	21	i.
Class B.b.	878	10	ii.
	56	40	i.
Class C.a.	147	81	i.
	1	37	ii.
Class D.b.	2860	52	ii.
	2867	162	i.
Class G.a	2861	99	i.
	2859	45	ii.

Table 6.5

Subgrouping by Approach Alignment for Remaining Category for Sample Bridge Replacement Problem

Class B.a.i.

Project No.	Approach Alignment	Rank
844	8	2
59	4	1

the project with the greater service/cost ratio was given the higher priority. However, in Group B.a, both projects had the same service/cost ratio. Therefore, only one subgroup (Group B.a.i) needed further subdividing. This is shown in Table 6.5, where it is divided according to approach alignment (another safety measure).

The schematic diagram of this subsetting procedure is shown on Figure 6.7. Finally the projects were ranked and the appropriate projects chosen for implementation on Table 6.6. The total budget allocated for bridge replacement projects in the 1983-1984 Highway Improvement Program (50) was approximately $80,000,000.The two year budget for application in this sample problem was reduced proportionally by multiplying by the number of projects considered, 22, and by dividing by the total number of projects in the bridge replacement category, 430. This value was then adjusted to account for state share of construction cost rather than total construction cost by multiplying by the fraction of the construction cost the state must pay, 1/4. These adjustments produced a budget for this sample problem of $1,025,000.

RESULTS OF THE SAMPLE PROBLEM

The technique used for the bridge replacement problem has resulted in a ranking of the 22 candidate projects of which 7 projects were chosen for implementation within a two

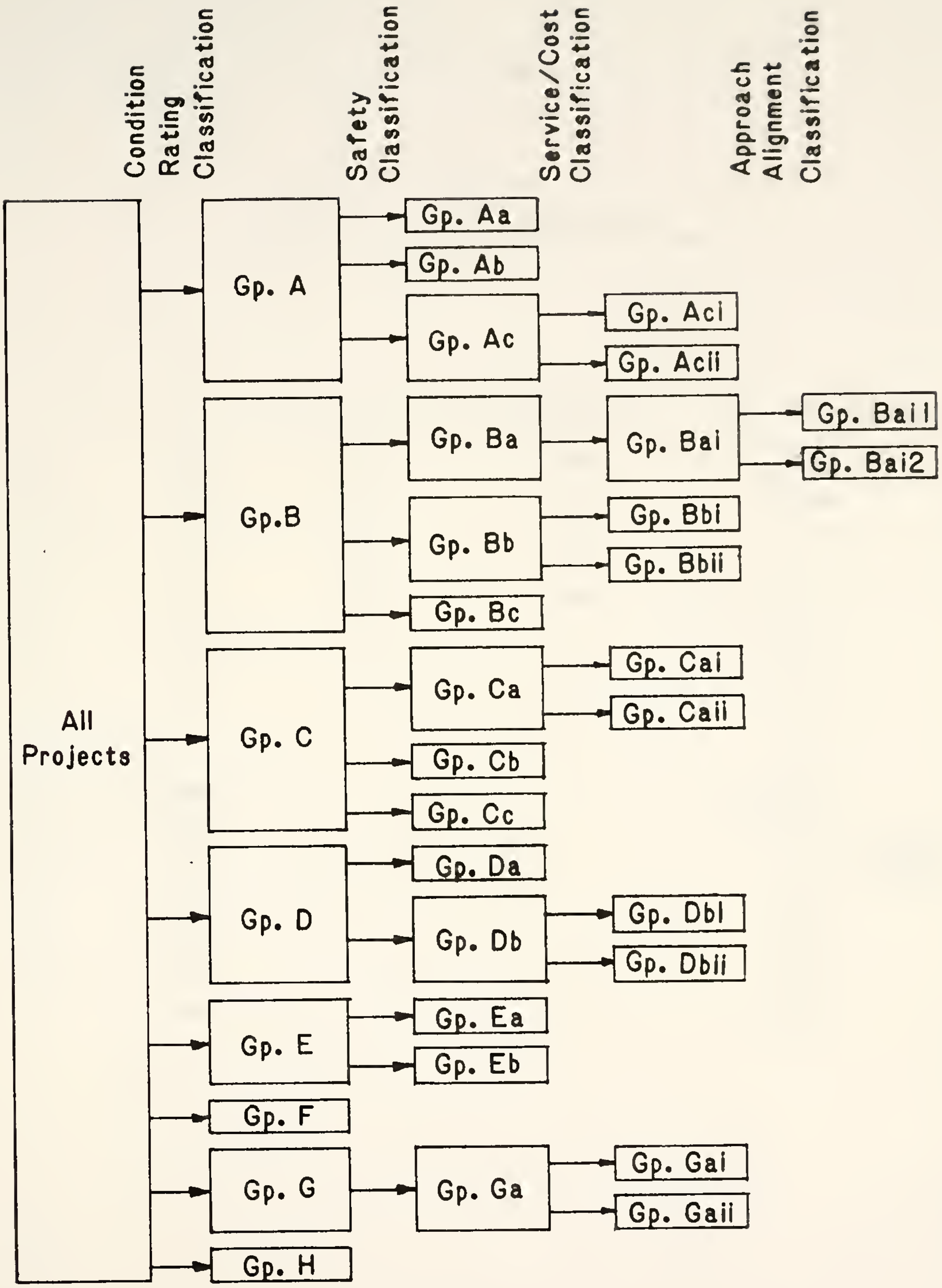


FIGURE 6.7

A FLOW CHART SHOWING SUBGROUPING OF PROJECTS FOR SAMPLE BRIDGE REPLACEMENT PROBLEM

Table 6.6

Final Rankings and Project Choices for Implementation for Sample Bridge Replacement Problem

Rank	Project No.	Project Cost $[10^3 \$]$	Available Budget $[10^3 \$]$		Overall Condition Estimate	
A.a.	15	136	1025		(not done)	
A.b.	166	166	889		very poor	
A.c.i.	1549	19	723		poor	
A.c.ii.	8	45	704		poor	
B.a.i.1	59	302	659		poor	
B.a.i.	844	57	357		poor	
B.b.i.	56	237	300	↑ chosen	poor	
B.b.ii.	878	122	63	↓ deferred	poor	
B.c.	888				poor	
C.a.i.	147				fair	
C.a.ii.	1				fair	
C.b.	91				fair	
C.c.	5				fair	
D.a.	2862				(not done)	
D.b.i.	2867				(not done)	
D.b.ii.	2860				poor	← Subjective rating error
E.a.	143				fair	
E.b.	852				fair	
F.	167				good	
G.a.i.	2861				good	
G.a.ii.	2859				good	
H.	889				very good	

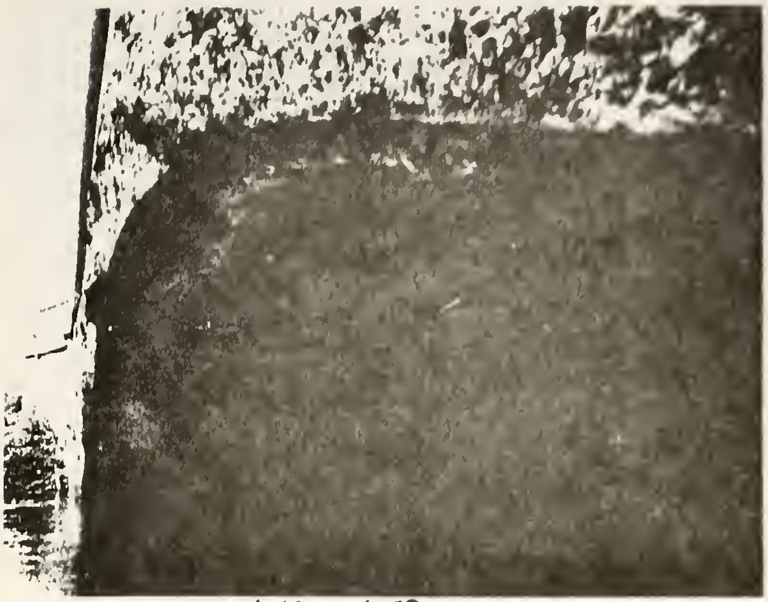
year budgeting period. Due to the nature of the subsetting technique, these 7 projects were in the worst physical condition of the projects considered.

This can be validated by comparing the rank of each project with the overall condition rating for each project (see Table 6.6). The overall condition rating was a subjective rating developed in this study during the field survey to describe the total need for replacement of a bridge. It can be seen that, except for one project, the bridges were ranked in order of poorest overall condition to the best. The project ranked 16th received a poor rating and was ranked in the middle of the fair projects. This bridge was the third one visited of the 19, so the evaluator did not have a good base of knowledge for comparing the condition of the bridges yet. The superstructure rating should probably have been a 3 or 4 instead of a 5. This would have placed this project with the other projects having poor overall conditions.

The visual comparison of several of the actual bridge replacement projects with the individual condition ratings may be seen from the following photographs.

Figure 6.8 shows a view of the underside of Project No. 59. The excessive deterioration led to a superstructure rating of 3. Project No. 59 had a final rank of 5.

Figure 6.9 shows the pier of Project No. 1, which received a substructure rating of 4. Its overall rank was 11.



4.10 #59

Figure 6.8

An Example of Excessive Superstructure Deterioration

6.3 #1

Figure 6.9

An Example of Severe Substructure Erosion

Figure 6.10 shows the underside of Project No. 5. Here tiny stalactites were formed from the process of water seeping through the deck and superstructure. The superstructure received a rating of 4 while the overall rank was 13.

Figure 6.11 shows excessive deterioration of the deck of Project No. 167. Since the substructure and superstructure of this bridge was in relatively good condition, the overall project received a rank of 19.

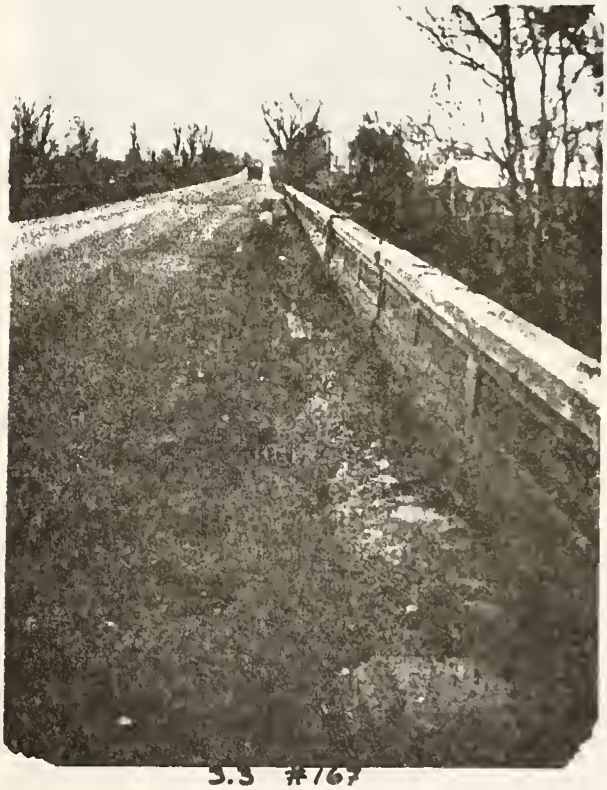
Figure 6.12 shows a deteriorated superstructure leaving exposed reinforcing bars for Project No. 2860. This project received a low overall rank of 16 and an overall subjective rating of poor As previously shown, this project should have been placed in a more important category.

For the two year budgeting period, the bridges in the worst physical condition subgroup and three of the five bridges in the second worst condition subgroup were selected. All three of the projects in the second worst condition subgroup had low safety ratings. By looking at the position of these bridges on Figure 6.5 of the sample problem, it can be seen that all 7 projects chosen had a minimum superstructure or substructure condition of 4 or

4.4 #5

Figure 6.10

An Example of Tiny Stalactites Formed on Underside of Superstructure



5.5 #167

Figure 6.11

An Example of Excessive Deck Deterioration

1.9 #2860

Figure 6.12

Example of Exposed Reinforcing Bars in a Deteriorated Superstructure less and a remaining life of 10 years or less. In addition, all seven projects had a road narrowing value of 10 ft or less, and six had a deck width of 30 ft or less.

From Figure 6.13 the distribution of the priority evaluation measures may be seen for all the proposed projects.

Obviously, the categories with the greatest degree of need being given priority are in substructure condition, superstructure condition, and remaining life. The distribution of chosen projects is also concentrated on the right side in the deck width and road narrowing categories. The categories of state share of construction cost, deck pavement condition, approach alignment condition, and ADT are relatively uniform for the chosen projects. This is due to the relatively lower degree of importance placed on these priority evaluation measures.

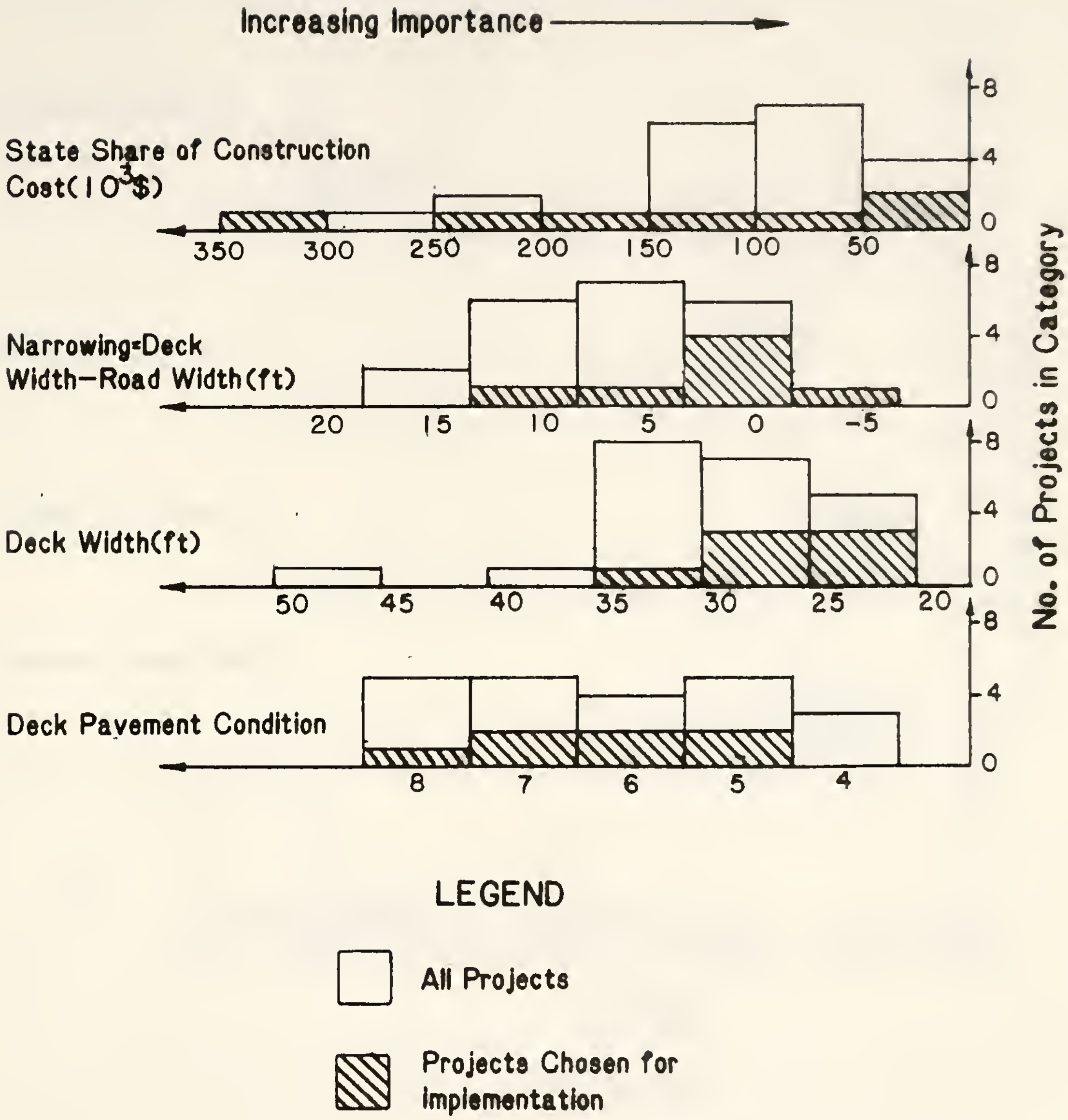


Figure 6.13

The Distribution of Priority Evaluation Measures for All Sample Bridge Replacement Projects and for Those Chosen for Implementation

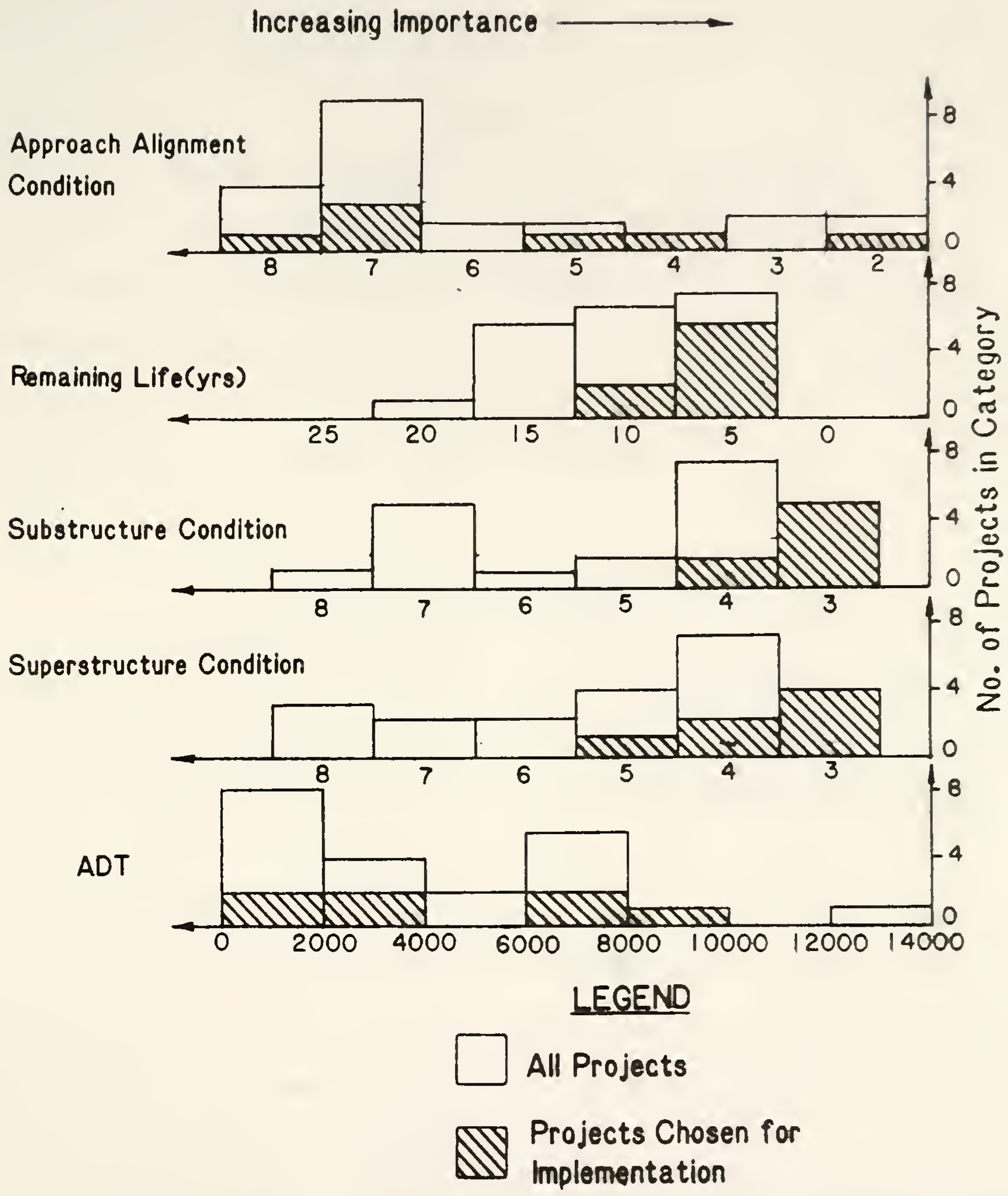


Figure 6.13 (continued)

CHAPTER 7

AN APPLICATION OF THE PROPOSED TECHNIQUE USING THE ROAD REPLACEMENT WORK CATEGORY

This chapter describes the application of the successive subsetting technique to the road replacement work category using a set of eight proposed rural road replacement projects in the 1983-1984 Highway Improvement Program (HIP) (50).

BACKGROUND INFORMATION

One assumption which must be made in order to rank these projects is that urban road replacement projects will be treated differently than rural road replacement projects. This is because different priorities are placed on the impact categories of rural and urban projects. Urban projects put more emphasis on capacity and parking, while rural projects put more importance on safety. Since only two of the projects in the road replacement category are urban, this sample problem has been simplified by looking only at the rural projects.

The data used in this sample problem were gathered from Federal-Aid forms held at the IDOH central office in addition to roadway condition data that were taken from the IDOH Research and Training Center records. These values appear in Table 7.1.

Table 7.1

Priority Evaluation Measures by Project Number for
Sample Road Replacement Problem

Project No.	12	1573	1583	1588	486	1641	1639	198
Total Construction Cost [10^3 $]	4840	2269	1210	6050	3580	11,132	11,139	6988
Roughness No.	4000	1446	1653	2000	3275	1098	1800	2000
ADT	3265	1300	800	3000	1210	6120	7526	2181
Length of Project [mi.]	6.1	3.0	1.3	3.0	4.8	8.0	8.0	3.7
Present Pavement Width [ft.]	20	18	18	22	20	24	24	22
Highway Classification	Prim.	Sec.	Sec.	Prim.	Sec.	Prim.	Prim.	Sec.

PRIORITY SETTING PROCEDURE

The impact categories and their priority evaluation measures have been ranked in Table 7.2. The most important factor in determining the priority of a road replacement project is the physical condition of the pavement. While pavement strength is the best measure of condition, these values were not available for use in this sample problem. Therefore, the next best measure of the existing pavement condition, pavement roughness, was used instead. The skid resistance values would also have been useful, however complete data were not available for the projects in question.

Traffic safety is the next most important impact category. Accident rate would have been the most desirable measure of this priority, however, since it was not readily available, pavement width was used as a proxy.

Although the road condition is more important than the level of safety, it may be preferable to place very unsafe projects in categories having projects in worse physical condition. Therefore, these two measures will be evaluated using trade-off curves. Since the number of projects considered in the sample problem is not great, the process of combining both priority evaluation measures into one subsetting step will not be a disadvantage.

The next most important impact categories are of service and highway department cost. Since both of these factors have approximately the same level of importance, they have been combined into a convenient unit of measure. The

Table 7.2

Relative Importance of Road Replacement Priority Evaluation Measures

Rank	Impact Category	Priority Evaluation Measure
1	Road Condition	Roughness Number
2	Safety	Road Width
3	Service and Highway Department Cost	ADT x Project Length/Total Construction Cost
4	Location	Highway Classification

service/cost ratio was defined as the length of the project times the ADT divided by the total construction cost. This single measure represents the vehicle miles of the project per dollar of construction cost. In this example the total construction cost has been used instead of the state's share of the construction cost as in the bridge replacement sample problem. This has been done to show the adaptability possible in the highway improvement programmer's context in choosing priority evaluation measures.

Finally, the least important impact category was the location of the project. This was described as the primary or secondary highway classification upon which the given road replacement project was located.

APPLICATION OF THE PROCEDURE TO ACTUAL PROJECTS

Now that the specific subsetting procedures have been developed for the road replacement work category, the set of eight projects can be evaluated.

The set of projects has been classified into five subgroups in Figure 7.1 using roughness and road width. In this step, the projects have been traded off between two different impact categories; physical condition and traffic safety The reason these two steps were combined into one subsetting step is so projects having slightly lower roughness numbers than those in a more important subgroup could be given a higher priority if their roads were very narrow.

This may be seen in the case where Project No.s 198, 1588, 1583, 1573, and 1639 all have about the same roughness

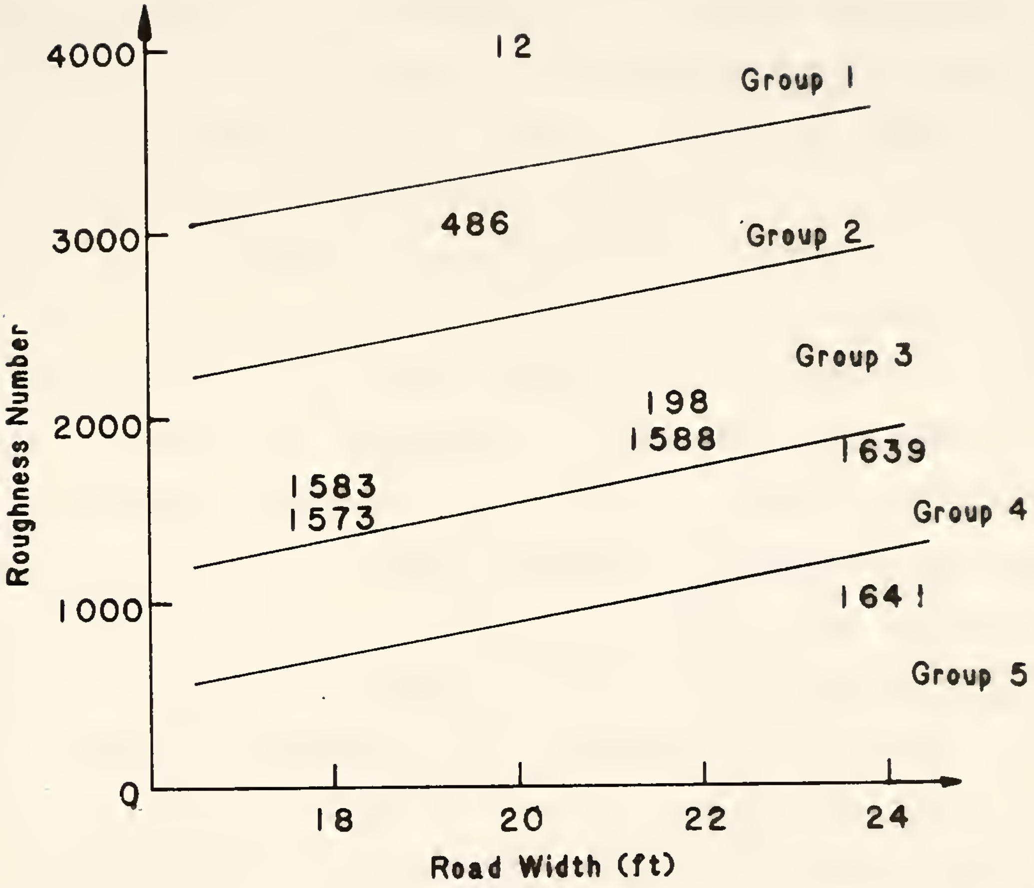


FIGURE 7.1
SUBGROUPING BY CONDITION AND SAFETY FOR SAMPLE ROAD REPLACEMENT PROBLEM

numbers. However, since Project No. 1639 has a high road width, it was placed in a less important subgroup by adjusting the slope of the lines separating these subgroups. Also, although Project No.s 1583 and 1573 have slightly smaller roughness numbers, they were placed in the more important subgroup, since they had very narrow road widths. Therefore, the slope of the lines separating these five projects into Group 3 and 4 show the relative importance between roughness and road width.

It was not necessary to give all the trade-off lines the same slope. But in this case, it was done to show that the same relative priorities between the two values is the same for high and low values of roughness and road width. Due to the small number of projects in the road replacement category, only one category remained with greater than one project in it. This remaining group (Group 3) was then subdivided into three subgroups by service/cost ratio in Figure 7.2. Group 3A contains the most important projects in this class.

Finally, one subgroup (Group 3A) had two projects remaining in it which were ranked according to highway classification in Table 7.3. The primary highway project was given the higher priority for the two projects having the same levels of condition, safety, and service/cost ratio.

All of the projects were then ranked in Table 7.4. The budget of $5,600,000 for the programming period was estimated for the purpose of this sample problem from the

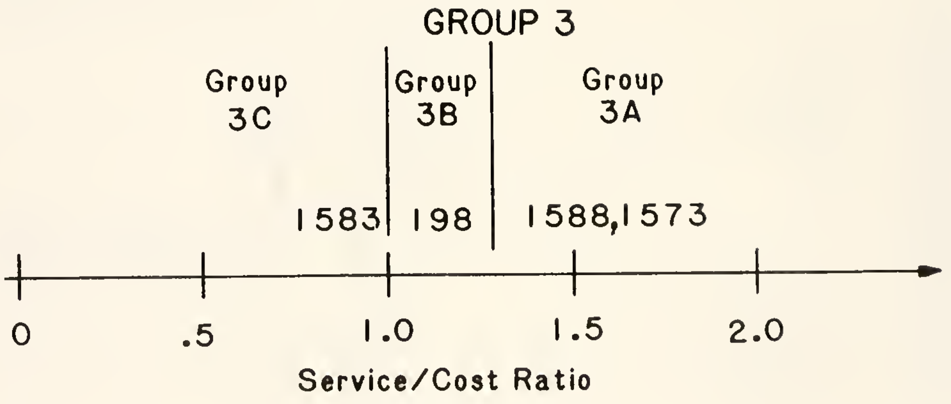


FIGURE 7.2
SUBGROUPING BY SERVICE/COST RATIO FOR REMAINING CATEGORY OF SAMPLE ROAD REPLACEMENT PROBLEM

Table 7.3

Subgrouping by Location for Remaining Category for Sample Road Replacement Problem

	Project No.	Location	Subgroup
Group 3A.	1588	Primary	Group 3Ai.
	1573	Secondary	Group 3Aii.

Table 7.4

Final Rankings and Project Choices for Implementation for Sample Road Replacement Problem

Rank	Project No.	Total Construction Cost $[10^3\ \$]$	Available Funds $[10^3\ \$]$
1	12	4840	5600 ↑ Budgeted
2	486	3580	760 ↓ Deferred
3	1588	6050	
4	1573	2269	
5	198	6988	
6	1583	1210	
7	1639	11,139	
8	1641	11,132	

two year budget for the road replacement category in the HIP. Since only eight of the ten projects were considered for implementation in this sample problem, the actual budget was multiplied by 0.8. For approximately this budget level, only the first project was chosen for implementation in the two year budgeting period. Since $760,000 was still available after the project was selected, either these funds could be transferred to another work category, or sufficient funds could be transferred to this work category to implement the second most important road replacement project.

CHAPTER 8

THE DEVELOPMENT OF IMPACT CATEGORIES AND PRIORITY EVALUATION MEASURES WITHIN EACH WORK CATEGORY

Having discussed the sample application of the successive subsetting technique for two work categories, it can be seen that specific procedures must be developed for each work category to use this technique. Impact categories must be ranked and their respective priority evaluation measures must be combined in each work category. In this chapter, recommended impact category rankings and priority evaluation measures are proposed for the five major work categories of the IDOH Highway Improvement Program (HIP). These categories, Bridge Replacement, Bridge Rehabilitation, Road Construction, Interstate Resurfacing, and Non-Interstate Resurfacing, represent approximately 65% of the HIP budget (50).

BRIDGE REPLACEMENT AND BRIDGE REHABILITATION

The bridge replacement and bridge rehabilitation categories are approximately the same with respect to relative priorities. Therefore, the actual order and combination of evaluation measures will be the same as in Chapter 5. It may be noted that the condition and safety categories may either be used to produce two subsetting steps or using trade-off curves to produce one subsetting step.

In addition, it would probably be better for the service/cost ratio to be measured by ADT divided by the total construction cost rather than divided by the state share of the construction cost. This would reduce confusion since most bridges receive the same level of matching funds.

ROAD CONSTRUCTION

The new road construction category should have service as the most important impact category (see Table B.1). This may be measured by estimated ADT on the roadway, the number of persons to be serviced by the new facility, and the change in levels of congestion and delay due to the new facility. The service category may be used either separately or in conjunction with the road user cost category. Road user costs may be determined from the estimated change in vehicle operating costs, the estimated change in travel time, and the estimated change in accident costs.

Next, the highway department cost should be considered. This may be measured from the initial construction cost and the change in annual maintenance cost incurred by the highway department due to the expansion of the highway system with the construction of the new facility.

Then the location may be used to further subdivide groups. This may be measured by the highway classification or the area type.

Table 8.1

Recommended Impact Category Rankings and Priority Evaluation Measures for Road Construction Work Category

Rank	Impact Category	Priority Evaluation Measure
1	Service	ADT Service Area Volume/Capacity Ratio Delay
2	Road User Cost	Change in Vehicle Operating Cost Change in Travel Time Cost Change in Accident Costs
3	Highway Department Cost	Construction Cost Change in Annual Maintenance Cost
4	Location	Highway Classification Area Type (rural or urban)
5	Convenience	Change in Continuity
6	Social	Number of Displacements
7	Environmental	Change in Air Quality Change in Noise Level Change in Wetlands
8	Non-User Costs	Change in Employment Level Relocation Costs

If further subgrouping is necessary, measures in the categories of convenience, social, environmental, and non-user costs may be considered. It is doubtful that subsetting of groups to this degree of detail will be necessary, though, considering the large cost and small number of road construction projects which are proposed in this work category. It is more likely that political and administrative factors will have a much greater effect than will precise subsetting techniques in this category.

INTERSTATE AND NON-INTERSTATE RESURFACING

The most significant factor in resurfacing is the condition of the existing pavement (see Table 8.2). This can be described by roughness number and pavement strength. In addition, the impact on safety will also be significant. This can best be described by the expected change in accident rate. Pavement friction number can also represent the present level of safety. The next most important impact categories are service and highway department cost. These categories may be combined to determine the service/cost ratio. This may be calculated as ADT times project length divided by the construction cost.

Finally, categories still needing subdividing may be grouped according to highway classification, such as primary or secondary

OTHER WORK CATEGORIES

The previous three sections have shown the relative importance of impact categories within work categories and

Table 8.2

Recommended Impact Category Rankings and Priority Evaluation Measures for Interstate and Non-Interstate Resurfacing Work Categories

Rank	Impact Category	Priority Evaluation Measure
1	Condition	Roughness Number Pavement Strength
2	Safety	Accident Rate Friction Number
3	Service and Highway Department Cost	ADT x Length of Project/Construction Cost
4	Location	Highway Classification

have suggested priority evaluation measures for the five major work categories. In the same way, impact categories and their priority evaluation measures may be developed for the remaining work categories. In Table 8.3, similar work categories have been grouped and recommended impact categories have been ranked within each group. Specific priority evaluation measures must then be developed to fit data availability and other specific factors of importance within each work category.

Table 8.3

Recommended Impact Category Rankings for Remaining Work Categories of IDOH

Road Relocation, New Interstate Construction, and Bridge Construction

Rank	Impact Category
1	Service
2	Road User Cost
3	Highway Department Cost
4	Location
5	Convenience
6	Social
7	Environmental
8	Non-User Economic

Added Travel Lanes and Interchanges

Rank	Impact Category
1	Service
2	Safety
3	Highway Department Cost
4	Road User Cost
5	Location
6	Social
7	Environmental

Grade Separations and Access Control

Rank	Impact Category
1	Safety
2	Service
3	Highway Department Cost
4	Road User Cost
5	Location
6	Social
7	Environmental

Table 8.3 (continued)

Rest Area Construction and Weigh Station Construction

Rank	Impact Category
1	Service
2	Highway Department Cost
3	Location
4	Social
5	Environmental

Rest Area Modifications and Weigh Station Modifications

Rank	Impact Category
1	Condition
2	Service
3	Highway Department Cost
4	Location
5	Safety
6	Environmental

Interstate Safety Improvements, Non-Interstate Safety Improvements, Sight Distance Corrections, New and Modernized Signing, New and Modernized Lighting, Intersection Improvements, New and Modernized Signalization, and Railroad Grade Crossing Improvements

Rank	Impact Category
1	Safety
2	Condition
3	Service
4	Highway Department Cost
5	Road User Cost
6	Location

Small Structure Replacement

Rank	Impact Category
1	Condition
2	Safety
3	Highway Department
4	Service
5	Location

Table 8.3 (continued)

Road Replacement, Road Reconstruction, Road Rehabilitation, and Bridge Reconstruction

Rank	Impact Category
1	Condition
2	Safety
3	Service
4	Highway Department Cost
5	Road User Cost
6	Location
7	Social
8	Environmental

Erosion and Slide Control

Rank	Impact Category
1	Safety
2	Condition
3	Service
4	Highway Department Cost
5	Location
6	Environmental
7	Social

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The successive subsetting technique has been developed to set priorities for highway improvement projects within work categories. It can do this using imprecise and subjective data. In addition, the technique is very flexible and simple to use. The use of a computer is not even necessary. Exact measures of importance between different impact types do not need to be known in advance. The specific grouping of projects are determined after individual values for priority evaluation measures are plotted and their distribution over all projects is known. Then using the data, the projects must be separated into groups having similar priority evaluation measures. The decision maker must only have a general understanding of how the data were gathered and the limits of accuracy of the individual measurements.

One problem which may develop using this technique is that for work categories having a large number of projects, it may be difficult to separate each project into its own group. This problem may be resolved in several ways. Either more priority evaluation measures may be applied to produce a greater number of subsetting steps, or a greater number of subgroups may be made in each subsetting step.

APPLICATIONS AND EXTENSIONS OF THE SUCCESSIVE SUBSETTING TECHNIQUE

The successive subsetting technique, although its use has been demonstrated specifically for the bridge replacement and road replacement work categories in the study, has been designed to be applicable to all work categories in the IDOH Highway Improvement Program. All that must be done is to adjust the priority evaluation measures to meet the specific categories' priorities and data availability. The procedure does not require highly accurate data. It has been specifically designed for situations where much of the input data is subjective in nature. Useful results may be obtained using the data presently available. This has been exemplified in the sample problems. The importance of each impact type must also be ranked relative to all other categories. The priority evaluation measures must be adjusted for each type of work category.

Since the relative priorities of each of the projects are ranked using the subsetting technique, it is easy to determine which projects should be added or deleted in case of adjustments in the overall budget level after the program has already been developed.

Although this technique was developed to determine relative priorities for scheduling of already approved projects, it can also be used as a sufficiency rating technique to determine which sections of roadway or structures are in greatest need for improvement. Projects would then be developed for the sections with the greatest need. This application would require that condition inventories be made for all sections of roadway or structures in the region of interest.

An important aspect of the subsetting technique is that it may also reveal which projects may not be in the appropriate work category. For instance, several projects in the bridge replacement sample problem were determined to be in relatively good condition. It would be better if these projects could be placed in a less costly work category. For example, bridge replacement projects having bridges in relatively good condition could be moved to the bridge maintenance category. This recategorizing of projects could reduce overall highway improvement costs as well as reduce the number of backlogged projects in some categories. Less important projects could also be placed in job categories requiring less extensive work. A bridge that might have a relatively low priority in a bridge replacement category may receive a relatively high priority in a bridge rehabilitation or bridge maintenance category.

As has already been discussed, this technique can isolate which projects have data discrepancies. Projects that have both high and low ratings within the same impact category should be reexamined to determine the true condition of the existing structure or roadway section.

The simplicity and straightforwardness of this procedure should make it applicable for use both by more technically trained personnel and by less technically trained personnel. As a result , it could be used at both state and local levels of jurisdiction as well as central and district levels of state highway offices The graphical format should make it easily understandable by the layman

In addition, the flexibility of this technique should make it applicable for both manual and computerized procedures. If computerized, it would be most useful to input trade-off curves after the distributions of individual project priority evaluation measures have been plotted.

RECOMMENDATIONS FOR FUTURE RESEARCH

In developing this priority setting technique, several needs have been discovered that either need future research or greater priority within the IDOH.

The first recommendation is for a centralized data base within the IDOH. At the present time, it is very difficult to locate all available data on a given project or project location. Each division within the IDOH has its own filing system. While it may seem appropriate that each division has data pertaining to its own greatest needs, one must remember that highway projects have overlapping impacts. Changes in design may be necessary, due to both safety aspects and environmental impacts. Therefore, a centralized data base that is periodically updated would greatly facilitate the planning and programming functions.

In using the subsetting technique, priority evaluation measures are considered in order of significance.

Consequently, the category used first is the most significant as to what priority a given project receives Therefore it is recommended that more objective and precise measurements be determined for the types of impacts that have the greatest significance.

A specific example is in the work category of bridge replacement No objective data exists for the most important evaluation measure; physical condition. Only subjective and relatively inaccurate estimates of bridge condition are available. Research needs to be done to determine non-destructive, objective tests for bridge condition and remaining life.

It is possible that the Pavement Management System could be combined with the subsetting technique to produce a highway management system. Careful, detailed research has already been done into the physical condition of road pavements for the resurfacing work category. This could be expanded to include more extensive roadway improvement categories and also include more important priority measures such as roadway service, construction cost, and safety.

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