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16. ABSTRACT

This study was prompted by the impending prioritization of Washington State Department of Transportation (WSDOT) highway mobility projects for the 1997-1999 biennium. The ranking procedure that was analyzed and refined in the study is based on a methodology called "Technique for Order Preference by Similarity to Ideal Solution," commonly known as TOPSIS; it is the final step in WSDOT's current process for prioritizing proposed projects.

The report used the WSDOT programming method as a case study of one flexible framework for assessing projects related to all highway modes. Rank order sensitivity to estimate errors and to various categorical weight distributions was investigated. Furthermore, direct comparisons were made between the WSDOT priority programming method, a WSDOT systems planning method, and a Puget Sound Regional Council project prioritization method. The goals of the report were to inform the policy making debate over assigning subjective category weights and selecting pertinent categories of criteria, and to investigate the range of acceptable error in project performance predictions. In so doing, the reliability and adequacy of the WSDOT ranking methodology was also assessed.

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Research Project T9903, Task 53
Mobility Improvements

A SENSITIVITY ANALYSIS AND IMPLEMENTATION REVIEW OF THE MOBILITY IMPROVEMENTS PRIORITIZATION METHOD

by

Tracy L. Reed
Graduate Research Assistant
Department of Civil Engineering
University of Washington

G. Scott Rutherford
Professor
Department of Civil Engineering
University of Washington

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Patrick E. Morin
Priority Management Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

May 1997

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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GLOSSARY

AHP	- Analytic hierarchy process
ANOVA	- Analysis of variance
B/C	- Benefit-cost ratio
BCA	- Benefit cost analysis
CAAA	- Clean Air Act Amendment
CEA	- Cost-effectiveness analysis
CMAQ	- Congestion Mitigation and Air Quality
CMTY	- Community support
COST-EFF	- Cost-efficiency
FTA	- Federal Transit Authority
GP	- Goal programming
HOV	- High occupancy vehicle
IRR	- Internal rate-of-return
ISTEA	- Intermodal Surface Transportation Efficiency Act
LP	- Linear programming
MAD	- Mean absolute difference in rank order
MCA	- Multiple criteria analysis
MODEINT	- Mode integration
MODM	- Multiple objective decision-making
MS/OR	- Management science and operations research
MTC	- Minimum tolerance conditions
MTP	- Metropolitan transportation plan
NCHRP	- National Cooperative Highway Research Program
NPV	- Net present value
NPV/C	- Net present value to cost ratio
PSRC	- Puget Sound Regional Council
RCW	- Registered code of Washington
SOV	- Single occupancy vehicle
STP	- Surface Transportation Program
STPP	- State Transportation Policy Plan
TIP	- Transportation improvement program
TOPSIS	- Technique for Order Preference by Similarity to Ideal Solution
TPB	- Transportation Policy Board
TDM	- Transportation demand management
TSM	- Transportation system management
UW	- University of Washington
WATR	- Water quality and permitting
WETS	- Wetlands
WSDOT	- Washington State Department of Transportation
WSTC	- Washington State Transportation Commission

PREFACE

This project used the Washington State Department of Transportation (WSDOT) statewide priority programming methods to study project rank correlation in the Puget Sound region, and it analyzed the sensitivity of WSDOT's mobility improvements prioritization method to a reasonable range of expected scoring errors or variations in implementation. This method is considered to be an example of a flexible framework for assessing projects related to all highway modes. The results of the first biennium of implementation were summarized and were used in the sensitivity analysis to determine the robustness of the mobility improvements prioritization method to a reasonable range of input variations. Modifications to the ranking algorithm were not investigated; instead, this report concerns aspects of implementation, including criteria selection, prediction and scoring errors, categorical weight distribution, and rank correlation with other programming methods.

This research was contemporaneous with that conducted by Barnes (1996), in which several methodological aspects were investigated and, in fact, modified. Both studies aimed to address several issues raised by WSDOT during the first biennium of implementating the mobility improvements prioritization method. However, the methodological changes of Barnes (1996) were narrowly focused on mitigating an observed sensitivity to project mix. In particular, Barnes's research improved rank order consistency by introducing scoring constraints and standardized project ideals by normalizing or truncating three criteria categories. The resulting algorithm, TOPSIS-8, was a new version of the TOPSIS-6 ranking algorithm studied in this report. [Section 4.3 comments on and specifies the revisions.]

Thus, the two efforts were complementary. This project aimed to improve our understanding of the influence of non-monetary criteria on project rank order, the need for accuracy in scoring procedures, and the impact of eliminating or adding new criteria.

However, WSDOT should not utilize the conclusions of this research without verifying each against the new algorithm.

CHAPTER ONE: INTRODUCTION

1.1 PROBLEM STATEMENT

Transportation project prioritization is the critical step in linking policy objectives to program implementation, yet no single priority assessment technique has been widely accepted by public agencies as effective and practicable (Alexander and Beimborn 1987, Simon et al. 1988). In fact, the literature reveals a general consensus that commonly used programming procedures are, for the most part, inadequate. Engineering performance standards, cost-effectiveness measures, various multiple-objective decision making methods, benefit cost analysis, and optimization model approaches have been developed and utilized to varying degrees of popularity.

Priority programming can be defined as the process of rank ordering projects so that a finite, and usually financially constrained, subset may be selected. It is a constantly evolving art that has become more difficult and with increasingly limited transportation budgets. Most recently, the passage of the federal Intermodal Surface Transportation Efficiency Act of 1991 ("Summary" 1992), as well as growth management and commute-trip reduction legislation in Washington state ("Chapter" 1991), has required that transportation project evaluations respond to the emergent public interest in multimodal trade-offs. Most project evaluations must now combine project efficiency or effectiveness calculations with measures of environmental, social, and economic impacts. This need to meet multiple objectives by simultaneously evaluating an often large number of disparate criteria has made the project selection process increasingly difficult. Appraisal techniques have responded to this need and become more sophisticated over time, but a full-range of quantifiable criteria are still rarely employed in any single project prioritization method (Rutherford 1994).

The variety of assumptions, regions, project types, system objectives, and institutional arrangements, as well as the long-term nature of road investments given an uncertain future, are frequently cited as shortcomings of applied priority assessment techniques and typical operating environments (Pearman 1983, Niemeier et al. 1995, Alexander and Beimborn 1987, McFarland and Memmot 1987). Different prioritization methods often provide conflicting results. Methods can be over-sensitive to minor variations in procedure or inputs (Alexander and Beimborn 1987) or, conversely, may lack the capability to discriminate among independent projects beyond rough subsets of high, medium, and low scoring groups (Schaffer and Fricker 1987, Niemeier et al. 1995, and "Call" 1995).

This project used the Washington State Department of Transportation (WSDOT) statewide priority programming methods as a case study of a flexible framework for assessing projects related to all highway modes. Sensitivity analysis was conducted to determine the robustness of the WSDOT model to a reasonable range of expected error in project scores. The relationship between rank order differences caused by random errors and those caused by subjective category weight assignments were also explored. Direct comparisons of rank ordering were made among the WSDOT priority programming method, a WSDOT systems planning method, and a regional prioritization method. This study aimed to inform the policy-making debate over criteria category weight assignment, and selection of pertinent categories of criteria, and to expose the limit of acceptable error in project performance predictions. Ongoing efforts to extend the basic WSDOT framework to multimodal evaluations such as inter-city rail versus parallel highway investment will also benefit from the results.

A survey of transportation project programming methods in chapter two includes a detailed review of two methods currently used by other regional agencies. The WSDOT Category C prioritization method, now replaced by the mobility method, is referenced. This

discussion identifies important components and concepts that were incorporated into the WSDOT's mobility ranking methodology. Chapters three and four describe the mobility prioritization methodology and the 1995-97 biennial implementation process, respectively. Chapter five outlines the statistical framework of the sensitivity analysis, followed by a discussion of the results in chapter six. Chapter seven compares the rank ordering of three prioritization methods. Chapter eight concludes with a brief summary and suggestions for further research.

1.2 BACKGROUND

Since 1988, the state of Washington has been actively defining statewide transportation policies to facilitate the implementation of a multimodal transportation system for moving both people and goods. Numerous forums have been conducted to discuss issues, to develop consensus on both policies and strategies, and to generate opportunities for public input in an ongoing, joint effort on the parts of the Washington State Transportation Commission (WSTC) and the state legislature. The resulting document, the *Transportation Policy Plan for Washington State* (1994), sets forth the broad vision and statewide transportation goals that direct long-range planning. The plan also summarizes action strategies on a wide range of issues, including urban and rural mobility, transportation and land use planning, infrastructure preservation, freight and goods movement, environmental impact, energy consumption, transportation finance, bicycle transportation, private-public partnerships, and public transportation. The plan provides a new framework for evaluating statewide transportation needs on the basis of clearly defined service objectives. It is supported by a simultaneously revised Public Highways and Transportation governing code, Title 47 (1994). Transportation project selection is one section of the code updated to better translate the policy plan into action.

This Washington State Transportation Priority Programming for Highway Development Law, registered code of Washington (RCW) 47.05, establishes a programming policy for the state highway system based on the "rational selection of projects according to factual need..." The scope of this law was expanded in 1993 to require "...an evaluation of life cycle costs and benefits systematically scheduled to carry out defined objectives within available revenue." RCW 47.05 further mandates that priority selection be applied to projects that are part of a comprehensive, six-year investment program on the basis of needs identified in the state-owned highway component of the statewide multimodal transportation plan. The program must be adopted and periodically revised by the WSTC. Under this law, priority programming applies to state-owned airports and highways, Washington State Ferries, and state-interest public transportation (Figure 1). ("Title" 1994).

In part, the financially constrained statewide multimodal transportation systems plan (hereafter referred to as the "Systems Plan") identifies capacity and operational deficiencies and recommends specific highway improvements and program funding levels to accomplish state transportation policy goals. WSDOT program management regional staff then conduct project scoping for existing deficiencies and a preliminary selection of future deficiencies, followed by project prioritization in each budget category. When projects have been prioritized, the WSTC is responsible for recommending tradeoffs between the budget categories to the state legislature, and on this basis the program "book is built" (is developed). Figure 2 overviews these steps.

Two independent budget categories, preservation (P) and improvement (I), are used to define all of the highway construction sub-programs in accordance with the service objectives of the Systems Plan. Similarly, WSDOT has maintainence (M) and transportation system management (Q) categories of work that are separate from the

highway construction program.[1] Facility type distinctions are minimized within the program, while system policies dictate the sub-categorization of the program.

This case study was limited to WSDOT's 1994 implementation of a new methodology for programming urban and rural mobility improvements in the state highway construction program - I1 (Figure 3). The new programming methodology was developed specifically to link the prioritization of added-capacity transportation improvements with state and national policy objectives. It includes social, environmental, and cost-efficiency evaluation criteria and produces project rankings by applying a multicriteria ranking algorithm. To date, WSDOT has used the process to evaluate highway related projects (including high-occupancy vehicle (HOV) lanes), but the process and ranking algorithm are designed to be flexible and potentially multimodal.

The following types of projects are considered typical mobility improvements in this prioritization study:

- passing lanes
- interchanges
- geometric intersection improvements
- general purpose widening
- additional high-occupancy vehicle lanes and facilities
- park-and-ride lots
- transportation system management (e.g., surveillance control and driver information technologies)
- arterial, frontage road, and ramp improvements
- bridge improvements associated with proposed projects.

---

[1] It is interesting to note that highway construction accounted for approximately 50 percent of the total 1995-1997 authorized budget (i.e., ~$1.3 billion of $2.6 billion total) and that improvement projects received 65.8 percent of these appropriations (i.e., $853.8 million of $1.3 billion), while the remaining 34.2 percent went to preservation projects (*Key* 1995).

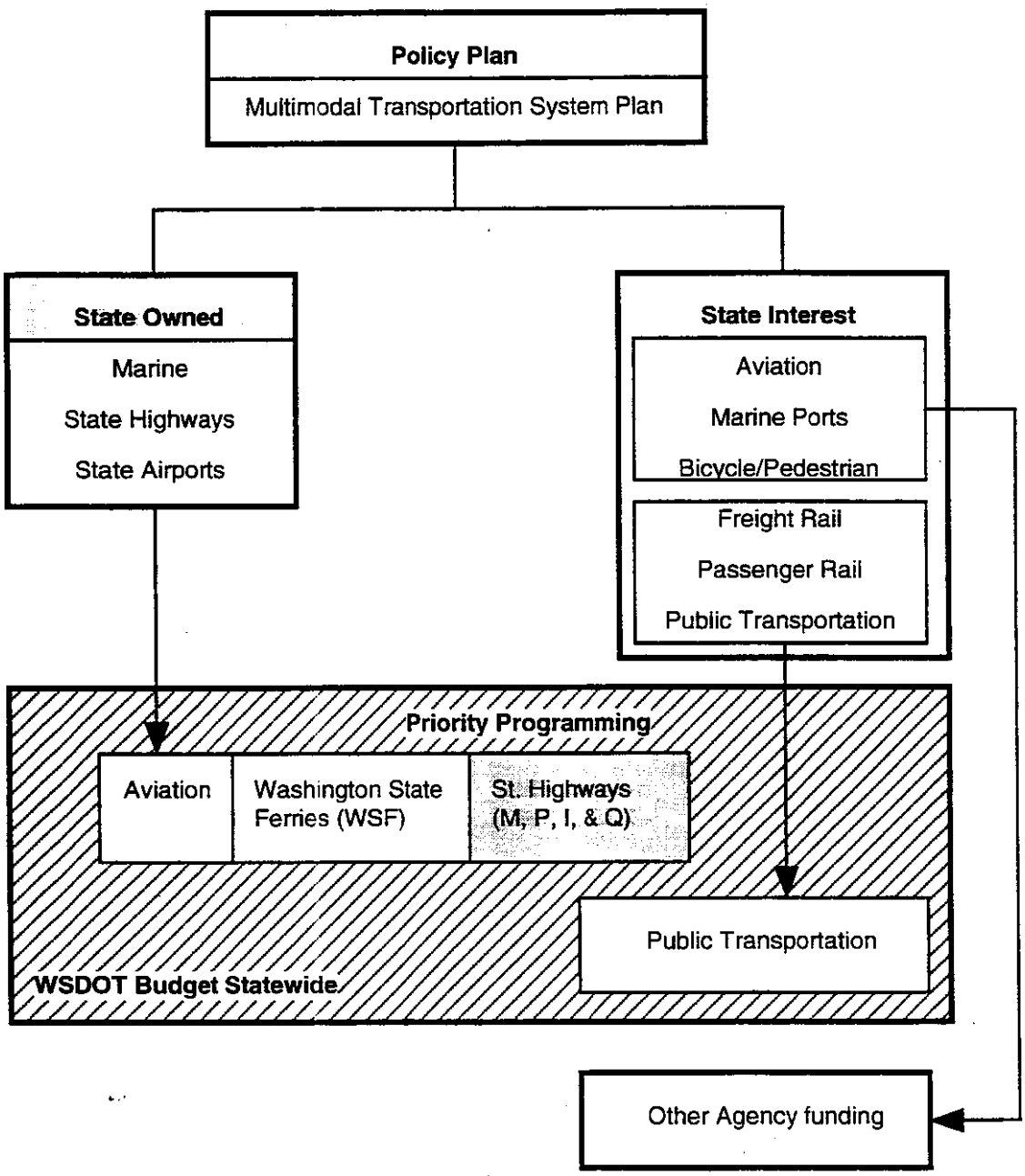


Figure 1. Washington State Multimodal Transportation Plan Structure (Programming 1994)

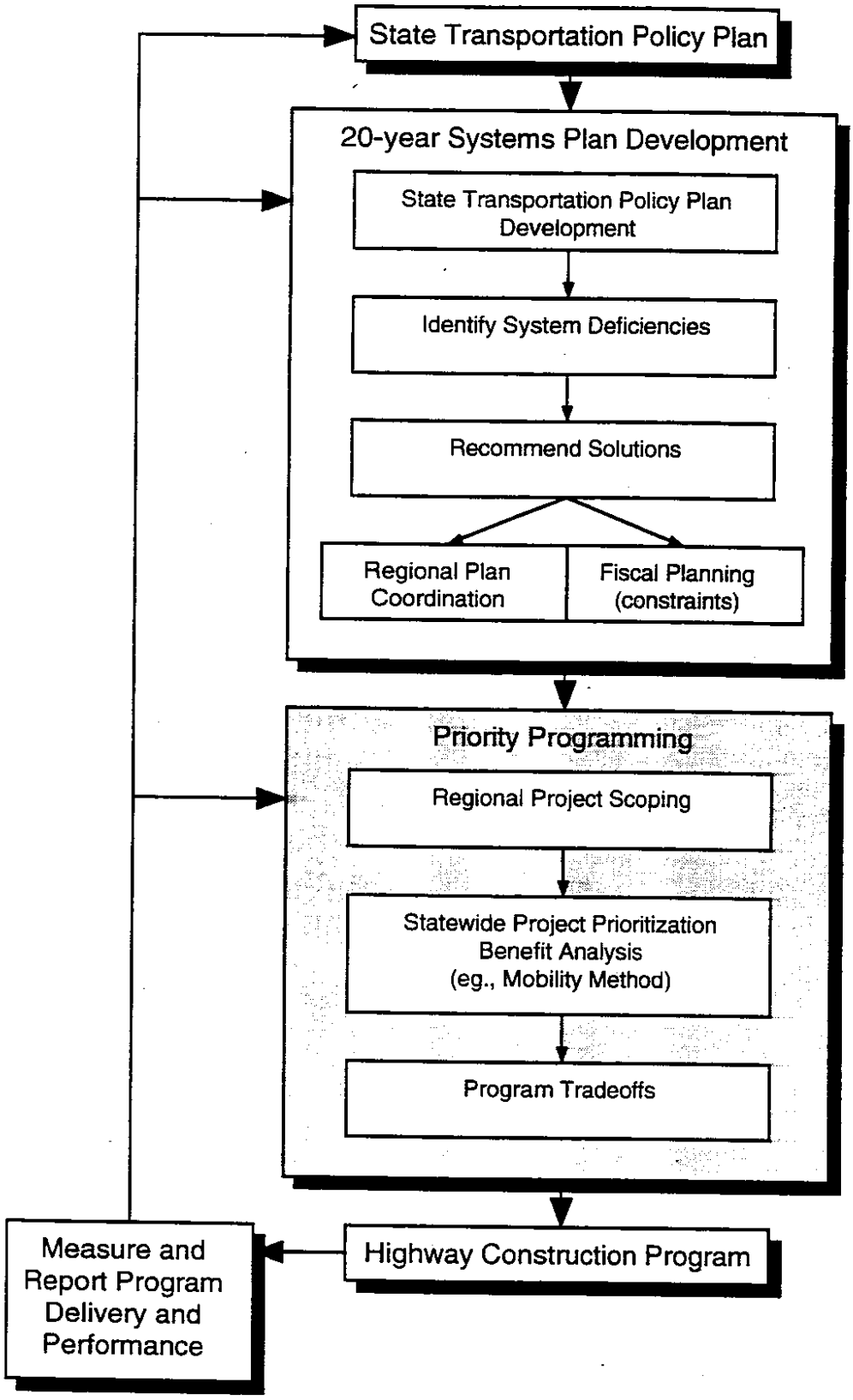


Figure 2. Washington State Transportation Policy Plan Implementation
(Morin 1995, *Key* 1995)

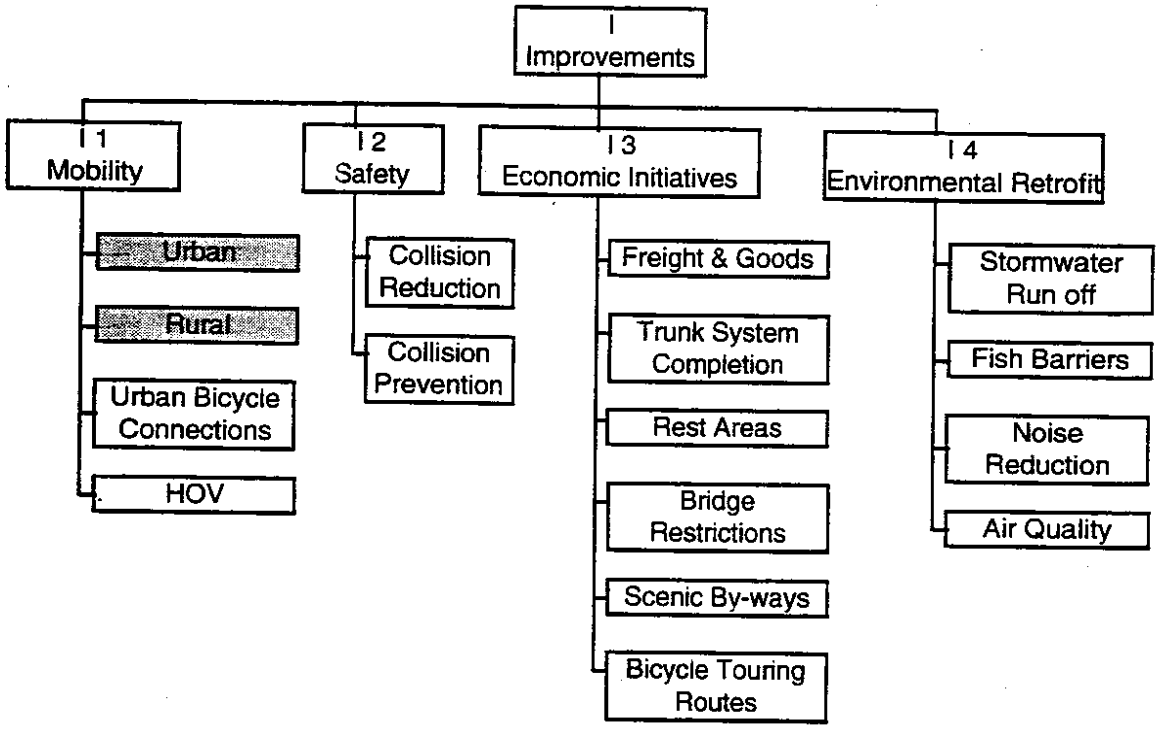


Figure 3. State Highway Improvement Program Structure (Programming 1994*)*

CHAPTER TWO: SURVEY OF PRIORITIZATION METHODS

Fundamentally, systemic procedures for transportation project appraisal aim to provide decision-makers with all the relevant information on the impacts, trade-offs, and uncertainties associated with every competing proposal. Prioritization methodologies are not intended to replace professional management of transport programs. On the contrary, they are tools that should reflect agency policy guidelines by objectively promoting projects that achieve defined service objectives. The complexity of this task is not to be under-estimated particularly when there are strict financial constraints. As Tolley and Turton (1995) point out, project prioritization is a highly politicized issue, since decisions over what to measure and how to measure it drive the whole concept. It is essential to present the information in a clear and useful way. A method must be understandable so that citizens may comment on the evaluation while politicians weigh the relevant factors among competing priorities and determine the package of proposals that best meets policy objectives.

Therefore, there is a need for a clearly defined methodology that promotes consistent examination of the technical issues while allowing for subjective judgments. Although the method should be comprehensive in examining project impacts, it should also be relatively cost effective and easy to execute (Leleur 1995, Simon et al. 1988). Thus, any prioritization system must focus on factors that differentiate one project from another without resorting to a "black box" technique with which only a few individuals are familiar (Shaffer and Fricker 1987).

This survey generally describes the most common project appraisal techniques applied to transportation priority programming and discusses two methodologies in detail. They are the WSDOT systems planning prioritization technique and the Puget Sound Regional Council's regional project development process. These two approaches are

relevant because to differing degrees they concern the same geographic area, projects, and operating environment as the WSDOT mobility prioritization method. However, methodological differences have led to inconsistent priority ranks for certain projects, as discussed in Chapter 7.

Such competition and conflict among agencies with overlapping jurisdictions is common in transportation planning and perhaps unavoidable on a statewide basis. State departments of transportation must work with diverse regional agencies that encompass differing system objectives, social values, and prioritization methods. In Washington state, this issue of institutional coordination is at the forefront of the debate among planners in highly urbanized areas and, therefore, strong motivation for the sensitivity analysis and comparative research of this study.

Prioritization techniques can be grouped into four categories: (1) cost effectiveness and performance standard evaluation, (2) benefit-cost analysis, (3) multiple criteria matrix analyses[2], and (4) optimization models. Despite the fact that prominent highway planning manuals clearly recommend the use of benefit-cost analysis in practice, many unique techniques of each type are utilized. Method examples are included where appropriate.

[Note that terminology used to categorize methods is not absolutely defined in the literature. For instance, this review acknowledges *multiple-objective decision making* (MODM) as a type of planning environment, not an explicitly defined prioritization methodology. Figure 4 shows how MODM can be distinguished from each other term discussed here.]

---

[2] Also simply referred to as multiple criteria analysis (MCA).

2.1 COST-EFFECTIVENESS AND PERFORMANCE STANDARD EVALUATION

Cost-effectiveness and performance standard evaluation methods attempt to focus on the crucial factors that motivate any transportation improvement project. Both approaches rely on pre-determined minimum or maximum tolerance levels to evaluate projects. Performance standards, highway sufficiency ratings, and minimum tolerance conditions (MTCs) are three common terms that describe the same type of service or physical condition evaluation technique.

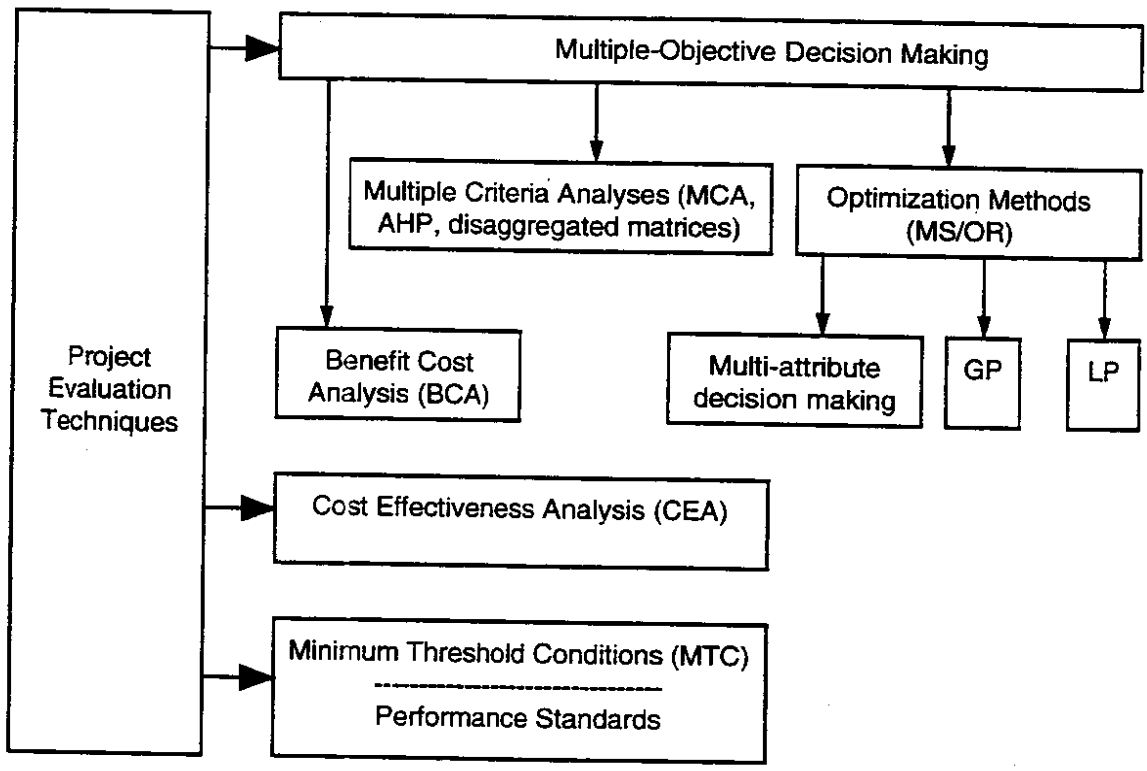


Figure 4. Evaluation Typology

Cost-effectiveness techniques are related in terms of forcing a comparison of affordability for each increment of improved conditions. By definition cost-effectiveness measures examine the price of marginal improvements (Dorfman 1993). The common approach, as clearly stated by Lewis (1991), is to divide the capital cost of a proposed improvement by the projected change in sufficiency rating.

Most highway agencies in the United States use this method to rank proposed construction projects. In one U.S. Department of Transportation study Gomez-Ibanez and O'Keefe (1985) determined that highway agencies often use minimum physical condition rules to guide investment decisions and that these rules are often excessively simple. They argued that society at large suffers social economic losses amounting to more than 10 percent of the value of the transportation investment when project costs are not considered. However, assessing priorities on the basis of cost-effectiveness measures is difficult unless there is some strong justification for the choice of target level and also a concrete understanding of the unit magnitude. The goal of clearly differentiating among projects can remain elusive, given this uncertainty in the measure and the need, in a modern multiple-objective planning environment, to simultaneously interpret the quality of several project components. Not surprisingly then, Gomez-Ibanez and O'Keefe (1985) concluded that benefit cost analysis (BCA) is a much preferred investment rule and that by including assessment of project costs, MTC methods can more closely approximate BCA results. In this way, cost-effectiveness measures are still preferable to applying minimum tolerance condition rules alone.

Cost-effectiveness measures are also viewed as an alternative to specifying monetary values for every type of non-market benefit associated with improved transportation and a sophisticated benefit-cost analysis. This simplification is their strength and also their weakness. For example, a central component of competitive appraisals for transit projects is the cost-per-new-rider expected to be attracted to the improved system

(*Estimating* 1995). This attempt to maximize the number of travellers attracted to transit for each dollar spent on facilities does not, however, convey any information about the net economic impact of the investments. In fact, case studies presented by David Lewis (1991) have shown that very different investment decisions with sizeable reductions in social welfare, economic productivity, and living standards can result when cost-effectiveness tests are used instead of benefit-cost analyses. A more sophisticated alternative is to estimate the net monetary value of the smoother, faster ride or transfer (for example) to each individual user and potential user, while also accounting for externalities and the different pricing and subsidy structure of a rail mode versus any other mode in a full benefit-cost analysis. Improving assessment of such an array of environmental and other non-market benefits is a highly active area of research; however, a great deal of controversy remains over such full-cost accounting (*Least* 1995, "Revised" 1994, *Estimating* 1995, *Transportation* 1992), and the study process can be time consuming and expensive.

In the highway case, pavement management systems that rely on a mixture of subjective and objective pavement quality, or serviceability, ratings and pre-determined thresholds to guide repaving programs are good examples of typical MTC investment rules. In this case study on mobility improvements, the WSDOT systems planning mobility ranking is a clear example of applied MTCs and is described as follows. For an illustration of how engineering performance standards can be modified to approximate multiple objective benefit-cost analysis, the reader is referred to the now-defunct Category C prioritization formula that preceded the mobility prioritization methodology in programming capacity improvement projects for the WSDOT program. This formula and justifications for developing a new approach are discussed in detail by Reed et al. (1995).

WSDOT Systems Planning Prioritization

As previously introduced, the WSDOT Systems Plan identifies deficiencies and recommends specific, financially feasible highway improvements over a 20-year planning

horizon. A prioritization system for evaluating these proposed improvements is required to guide biennial project development and legislative budget requests for programs and regional districts. The statewide ranking formula for capacity and operational solutions relied on a worst-first severity indicator for highway congestion scaled by a trip purpose cost factor. This needs-based criterion was an equation that took into account the present demand, the degree of need versus pre-determined highway level of service objectives, and the cost of moving people and goods. No weight was applied to the parameters, and the index was calculated as follows:

$$Index = (ADT / lane) * \left[\frac{(V/C)_{forecast}}{(V/C)_{objective}} \right] * \left[(1-T)(AVO) + (2.25)(T) \right]$$

where the average daily traffic (*ADT*) per lane was multiplied by the expected deficiency ratio and then scaled by the present day passenger and truck use. *T*, was the truck percentage provided by the state data office; the average vehicle occupancy (*AVO*) was roughly estimated for urban and rural routes in terms of passenger cars and set to be 1.0 for trucks. Traffic volume growth forecasts were adjusted to account for transportation demand management (TDM) effects but not the systemwide or local effects of implementing a given construction project. The cost factor of 2.25 was a ratio of hourly truck trip travel time value ($22.50/hr.) to regular commute trip value ($10/hr.), an estimate based on 1990 state population and employment figures. The resulting index was divided by 1000 (a scaling factor) to form a "mobility ranking" for proposed system plan solutions. (Stone 1995).

Clearly, the mobility ranking formula simply indicated severity of congestion, its expected growth, and future distance from a desired level of service (or minimum threshold condition). It did not actually evaluate the efficacy of any proposed solution except large-scale transportation demand management. This was the greatest weakness in using the formula to prioritize projects; there was no explicit analysis of effectiveness. The proposed conceptual solutions were assumed to be solutions.

In the Puget Sound region, the state's most urbanized four-county area, policy evaluation criteria were also rated for each conceptual solution. Fourteen criteria were derived from objectives defined in the *Transportation Policy Plan for Washington State* (1994) and the metropolitan planning organization's *VISION 2020* plan (1990). Generally stated, the criteria assessed consistency with local comprehensive plans, promotion of a multimodal system, reduction of single occupancy vehicle travel to centers, appropriateness of roadway expansion, and intermodal freight mobility. The degree of support for each objective was subjectively evaluated and assigned a point score.

- Minimally or not supportive - 0. points
- Moderately supportive - 0.5 points
- Significantly supportive - 1.0 points

The sum for each project was scaled by a multiplier of 7.5 for comparison with the mobility needs index. In this way, each index carried 50 percent of the weight for the regional rank order without modifying the mobility ranking score:

$$Regional\ Rank\ Order_{PSRC} = PolicyIndex_{PSRC} + MobilityRanking$$

while regional preferences for the final statewide rank order still explicitly accounted for the final rank order. (Stone 1995).

$$\text{Final Score}_{PSRC} = 0.5(PolicyIndex_{PSRC}) + 0.5(MobilityRanking)$$

$$\text{Final Score}_{OTHER} = MobilityRanking$$

These regional modifications constituted an improvement to the general systems planning prioritization formula. Albeit subjectively, the policy index evaluated individual project attributes and the project's efficacy as a solution. In this case, the subjective criteria countered the negative skew and kurtosis of the mobility ranking scores, thereby spreading out the distribution of final scores and better distinguishing each project. The results from 1995-97 show that the systems plan ranked distribution became an approximately normal

distribution, with a mean of 34.5 and standard error equal to 15.5 (ranging from 10.2 to 70.75) when policy criteria were combined with the mobility rank. Otherwise, approximately half of all the Puget Sound region projects would have had a final mobility ranking score of between 10 and 25 on an unbounded scale ranging from 6.1 to 77.70 (i.e., be negatively skewed) (Stone 1995).

Another consequence, discussed further in chapter seven, is that the mix of high ranking projects became more multimodal in nature. Many projects with high-occupancy vehicle, access, or transit-related components in the urban centers ranked higher than projects exclusively focused on improving general purpose facilities where the severity of congestion measured by the mobility rank was greater. Obviously, the equal weight assigned to policy considerations had a great effect and was a significant departure from the otherwise recommended ranking method. As such, the combined scoring process demonstrated the importance of maintaining flexibility to conform with regional objectives for any prioritization process. However, it also raised the question of consistency in the results, inter-jurisdictional coordination, and cost.

When the systems planning lists were used to justify legislative budget requests, the discussion focused on system needs and deficiencies because it was not known what investment level would be economically prudent and effective. This is a weakness of using MTC investment rules, one not overcome by merging subjectively assessed multiple-criteria analysis into the method. In fact, regional budget allocations, 20-year financial planning for each WSDOT region, and mobility project prioritization were consequently based on methodologically inconsistent rankings. These inconsistencies (which are further discussed in chapter seven) could potentially be controversial for the agency, even though the rank order produced by the systems planning method is not binding and was developed only as a managerial guide.

2.2 BENEFIT-COST ANALYSIS

Benefit-cost analysis (BCA) is one of the oldest and most highly recommended methodologies for evaluating public infrastructure projects. Indeed, a statement of purpose for BCA as a basis for decision making is perhaps most succintly outlined in the United States Flood Control Act of 1936. There it states "...that the Federal Government should improve or participate...if the benefits to whomsoever they may accrue are in excess of the estimated costs..." ("Flood" 1940). Today, the term BCA refers to an array of techniques for assessing the economic desirability and social value of proposed projects with long service lives and many kinds of side effects. Practically speaking, it refers to methods that estimate benefits and and weigh them against each other in the same terms, money. Positive effects are referred to as *benefits*, whereas negative effects are *disbenefits*, and *costs* include the capital required to construct, finance, operate, and maintain the project over time (White et al. 1989).

Costs, unlike benefits, can be readily quantified for transportation projects. They constitute a balance sheet of expenditures and incomes associated with the proposal over its expected life or the planning horizon. On the other hand, quantifying the dollar value of disparate benefits and disbenefits for a diverse public draws suspicion and controversy to BCA. Selecting an appropriate discount rate to represent the opportunity cost of capital is similarly difficult. The traditional categories of user benefits assessed for transportation project evaluation are

- accident savings
- user operating cost savings
- travel time savings.

Including travel time savings as a monetary benefit is complicated because it requires assigning a dollar value to time. The level of aggregation regarding personal and commercial time expenditures causes the most difficulties. As shown by this Washington

state case study and others (see chapter 4 for a discussion), travel time savings and accident savings together historically account for more than 80 percent of transportation benefits. Analysts argue that this combination ultimately raises productivity and economic output by reducing work time losses, but this connection of public infrastructure improvements to national or regional economic growth, competitiveness, or productivity remains largely intuitive (Smith 1994).

Still, the analyst is faced with the fact that reductions in travel time are concrete benefits of transportation improvements, and if these estimated cost savings were omitted from a BCA formula, few projects would be defined as economically efficient (e.g., having greater benefits than costs). Since the goal of BCA is to ascertain a project's true economic efficiency and it is desirable to comprehensively account for all the disparate benefits of a project, analytic risks such as assigning dollar values to time or human life and limb are usually encouraged. Conveniently, the methods currently acceptable usually reveal enough return on the taxpayer's investment to satisfy the political needs of decision makers. Unfortunately, analysts rarely take the risk of monetizing the value of externalities such as community and environmental impacts, which are likely to reveal substantial disbenefits. (Gomez-Ibanez and O'Keefe 1985, *Least* 1995, *Estimating* 1995).

The idea is that unless transportation investments yield economic or social welfare gains that exceed the costs of achieving them, they will make no net contribution to society. Commonly, project efficiency and the view of relevant components are narrowly framed in terms of economic growth, thus methodologically paralleling private sector conditions (Lewis 1991). On the other hand, the goal can be so broadly stated in terms of pareto optimality, the condition under which all interested individuals receive benefits exceeding their shares of the costs, that it becomes impossible to meet the standard completely (Dorfman 1993). Regardless, BCA analysis encompasses several measures aimed at revealing socio-economic worth.

Common BCA techniques, or base measures of worth, are net present value (NPV), benefit-cost ratios (B/C), and internal rate of return (IRR). Another useful criterion is the net present value-cost ratio (NPV/C). Each of the measures, as defined below, can be computed once the annual equivalent of benefits and costs have been established. Alternatively, the present worths of each benefit and cost may be computed seperately and summed before the overall economic measure is computed. Use of equivalent present-day values is designed to compensate for different rates of benefit or cost accrual over a project's service life. Notation for the equations in this section is applied generally and based on work by White et al. (1989).

B_{jt} = the benefits accrued by project j at the end of period t
C_{jt} = the costs accrued by project j at the end of period t
n = the analysis period (i.e., planning horizon)
i = appropriate discount rate (i.e., interest rate)

1. Net Present Value

Net present value is simply the present value of benefits minus the present value of costs. It is given by the following equation.

$$NPV = \sum_{t=0}^{n} \left(\frac{B_{jt} - C_{jt}}{(1-i)^t} \right)$$

Projects are considered economically efficient when the NPV is positive. Theoretically, projects with a high NPV return more to society than do similar projects with a low NPV. So, NPV would need to be maximized for use in prioritizing projects. However, it is limited as a criterion by the measure's implicit assumption that any program's capital resources are *unlimited* (Lewis 1991). This limitation is due to the fact that the greatest combined NPV (per dollar invested) cannot be ascertained by linear NPV ranking alone.

2. Benefit-Cost Ratio

Planners calculate B/C by simply dividing the present value of project benefits by the present value of project costs. It may be expressed as

$$BenefitCostRatio = \frac{\sum_{t=1}^{n} B_{jt}(1-i)^{-t}}{\sum_{t=0}^{n} C_{jt}(1-i)^{-t}}$$

In general, projects are considered economically efficient when the B/C is equal to or greater than 1.0. Like NPV, higher ratios are preferred to low B/C results, and the criterion can be maximized in a ranking algorithm if applied to independent projects. However, unlike NPV, B/C is not a calculation of *net* worth and can be optimized by means of a descending linear ranking alone. Furthermore, B/C is often limited by a narrow range of computed benefit-cost ratios, which can make differentiating among projects difficult.

3. Internal Rate of Return

The IRR is the discount rate at which net present value is zero. In other words, it is the opportunity cost-of-capital level at which the costs and benefits would be of the same magnitude. The following equation must be solved for i^*_j, the rate of return for project j.

$$0 = \sum_{t=0}^{n} \left(\frac{B_{jt} - C_{jt}}{\left(1 - i_j^*\right)^t} \right) \quad \text{where, } i_j^* = InternalRa\ te\ of\ Return$$

Higher rates are preferred to lower rates, assuming that the project capital could otherwise be invested elsewhere. However, unlike the other measures of worth, interpretating the IRR requires setting a pre-determined hurdle rate to qualify for investment. One decision rule, for example, might be to invest when the IRR exceeds the social discount rate. In any case, results biased toward short lifespan investments are to be expected (Rehfeld-Jacobsen 1995). The IRR is also subject to mathematical anomalies in solving the n-degree

polynomial; multiple roots may be derived (White et. al. 1989, Wohl 1979). Consequently, it is a useful criterion for evaluating whether a single project is economically productive but not for comparing sets of independent projects (or mutually exclusive projects that meet the hurdle rate).

4. Net Present Value-Cost Ratio

The NPV/C represents the net benefit expected per dollar of capital investment, given by the following equation.

$$NetPresentValue\ to\ CostRatio = \frac{NPV}{\sum_{t=0}^{n} C_{jt}(1-i)^{-t}}$$

NPV/C analysis has been characterized as a search for the biggest "bang for the buck," i.e., expected yield per dollar of capital invested (Lewis 1991). This criterion implies a prioritization method that would ration capital under financially constrained programming scenarios by a linearly descending NPV/C rank order. Like NPV and B/C, high NPV/C results are preferred over low ones, but only economically productive, independent projects (those with an NPV of greater than zero) may be compared. If projects are mutually interdependent, complementary, or contradictory, they must be grouped into larger plans.

General Comments

Measures of optimal timing such as the first year rate-of-return or first year benefit (both are expressed as percentages and use hurdle rates similar to IRR) and pay-back period (number of years until capital outlay is recouped in benefits) are complementary techniques that are particularly useful for project alternatives analysis and planning. However, for use as an investment rule in programming projects, the BCA should assess the comparative economic worth of a project. Selecting a single economic criterion is key to avoiding the pitfalls of double-counting policy goals and to easily accomodating large sets

of independent projects. To guide executive planners, the National Cooperative Highway Research Program (NCHRP) has published a primer on transportation and economic development (Lewis 1991). In it Lewis concludes that "...only net present value may be regarded as the basis for establishing, categorically, whether or not a prospective investment is economically worthwhile." However, he also implies, and is strongly echoed by the Commission of the European Communities Directorate General for Transport (Leleur 1996), that when the goal is to build a program under financial constraints (as in this case study), NPV/C is the best project selection measure.

Several prominent highway planning manuals clearly recommend the use of benefit-cost analysis in practice. Two of the most well known are the American Association of State Highway and Transportation Officials' 1977 manual on user benefit analysis for highway improvements (commonly known as the 'red book') and the computerized Highway Investment Analysis Package distributed by the Federal Highway Administration (*Highway* 1979). However, U.S. Department of Transportation researchers determined that as of 1985 sophisticated benefit-cost analyses were usually reserved for large-scale alternatives analysis. In fact, they argued that most techniques for estimating aggregate investment needs or for distinguishing large sets of projects were overly simplified and in need of improvement (Gomez-Ibanez and O'Keefe 1985). Although recent NCHRP surveys indicate that this description is still generally accurate (Rutherford 1994), it could be further argued that we are experiencing a reversal of trends in the 1990s.

Generalizations on transportation planning trends since the 1950s are well known and oft-stated (e.g., Meyer and Miller 1984, Leleur 1995). Basically, after much development and use of BCA to justify the U.S. Interstate highway system, its popularity as an evaluation methodology abruptly declined in the 1970s. A variety of multi-criteria analysis techniques were then developed to avoid the difficulties of monetary valuation and to broaden the scope of impact evaluation. Herein lies the reversal of trends. Since the

1980s when investment rules used in practice received a great deal of attention and review, full-cost accounting has become a highly active area of research again. Now, the range of benefits and disbenefits that can be quantified in monetary terms and accepted by the public is ever-increasing. Also, typical categories of benefits are more likely to be measured on a per person, rather than per vehicle, basis than in the past. These trends bode well for improved multimodal BCA, but multi-criteria analysis methods that merge subjective criteria with approximate cost factors are still the most common priority programming technique.

2.3 MULTIPLE CRITERIA MATRIX ANALYSIS

Diversity of prioritzation criteria and methods can be considered the most prominent characteristic of project evaluations of this type. Multiple criteria matrix analysis methods typically utilize a wide range of categorical criteria that are subjectively analyzed and that may include technically quantified effectiveness measures. Costs and cost effectiveness are not always taken into account. The methods usually employ a staged approach that uses screening criteria, scoring criteria, and some type of programming criteria or policy driven modification to determine final priorities. Applications specifically developed for regional and statewide programming typically rely on an overall, weighted score. In other cases, results may be presented to decision-makers in an entirely disaggregated format with text, graphics, color or varied numerical scales. Simultaneity in matrix evaluation can also be avoided. The problem of simultaneously evaluating several kinds of criteria and measures can be avoided by using matrix analysis. Successive subsetting techniques also enable avoidance of this problem. These techniques, such as the analytic hierarchy process for instance, use weighted criteria to sequentially evaluate and subdivide project groups (Shaffer and Fricker 1987, Marshall and Oliver 1995). Regardless, the relative importance of each policy goal and set of criteria is determined by decision makers instead of

engineering or economic experts. In this way, the overarching multiple criteria methods are generally transparent and responsive to political oversight.

Despite this transparency of values, rank orders based on multiple criteria matrix analysis methods can be difficult to defend and comprehend. Often, large proportions of projects are clumped together in rough subsets and many projects are tied in rank order. The reason that one project is selected over another may be obscure or clearly political. Thus, subjectivity is both a strength and a weakness. Even when the final score is a ratio of the weighted sum of criteria scores divided by project cost and a full-range of quantifiable criteria are employed, the economic prudence of the resulting program is difficult to ascertain.

The state of the practice in Washington state is not unique among this category of evaluation methods. For that reason, the Puget Sound Regional Council's (PSRC) regional project development process is described here to illustrate one common manifestation of regional project prioritzation with matrix analysis. Later in chapter seven the rank correlation between regional results produced by this method and WSDOT mobility programming is also examined.

PSRC Regional Project Development Process

The Puget Sound Regional Council manages development of the three-year, four-county transportation improvement program (TIP) in the most highly urbanized area of Washington state. However, as metropolitan planning organization for King, Kitsap, Pierce and Snohomish counties the PSRC's primary role in regional programming is coordination among overlapping jurisdictions not competitive prioritization of projects. Figure 5 overviews the regional programming process. The council provides executive policy oversight to maintain consistency with long-range transportation and air quality plans and determines programmatic allocations of certain federal ISTEA funds. By law the final responsibility for approving TIP project selection lies with PSRC (in consultation with

the State of Washington), but it only administers project prioritization in two federal programs. PSRC conducts these individual project evaluations through a regionally competitive application process for federal Surface Transportation Program (STP) and Congestion Mitigation and Air Quality (CMAQ) funds. It also manages a separate countywide appropriation for the same two programs. In delegating a portion of these funds and prioritization responsibility to each county the council hopes to ensure unique attention to local needs. PSRC outlines some stipulations for each county's prioritization process but otherwise just reviews the fiscal balance. The remaining portion of STP and CMAQ funds is distributed through the PSRC's two-stage regional project development process, overviewed by Figure 5 and described below.

Stage 1

The first stage is a screening process that uses policy criteria to produce a short list of projects. A transportation policy board (TPB) conducts the scoring process. Its stated purpose is to fund just a few large-scale projects and some innovative small-scale projects that support the metropolitan transportation plan. Guidelines direct applicants to give priority consideration to any project that directly supports (1) improved mobility within the hierarchy of designated centers or along major connecting corridors, and/or (2) sustained or improved economic vitality for the region ("Call" 1995). In 1995, the four broad categories of regionally significant projects solicited were as follows:

1. Critical projects that optimize or manage the use of existing facilities or services (e.g., major bridge rehabilitation safety or seismic retrofit, signal interconnect projects).
2. Travel demand management or system management projects that address congestion and environmental objectives (e.g., planning study for transportation pricing, freight access studies, major pedestrian projects).

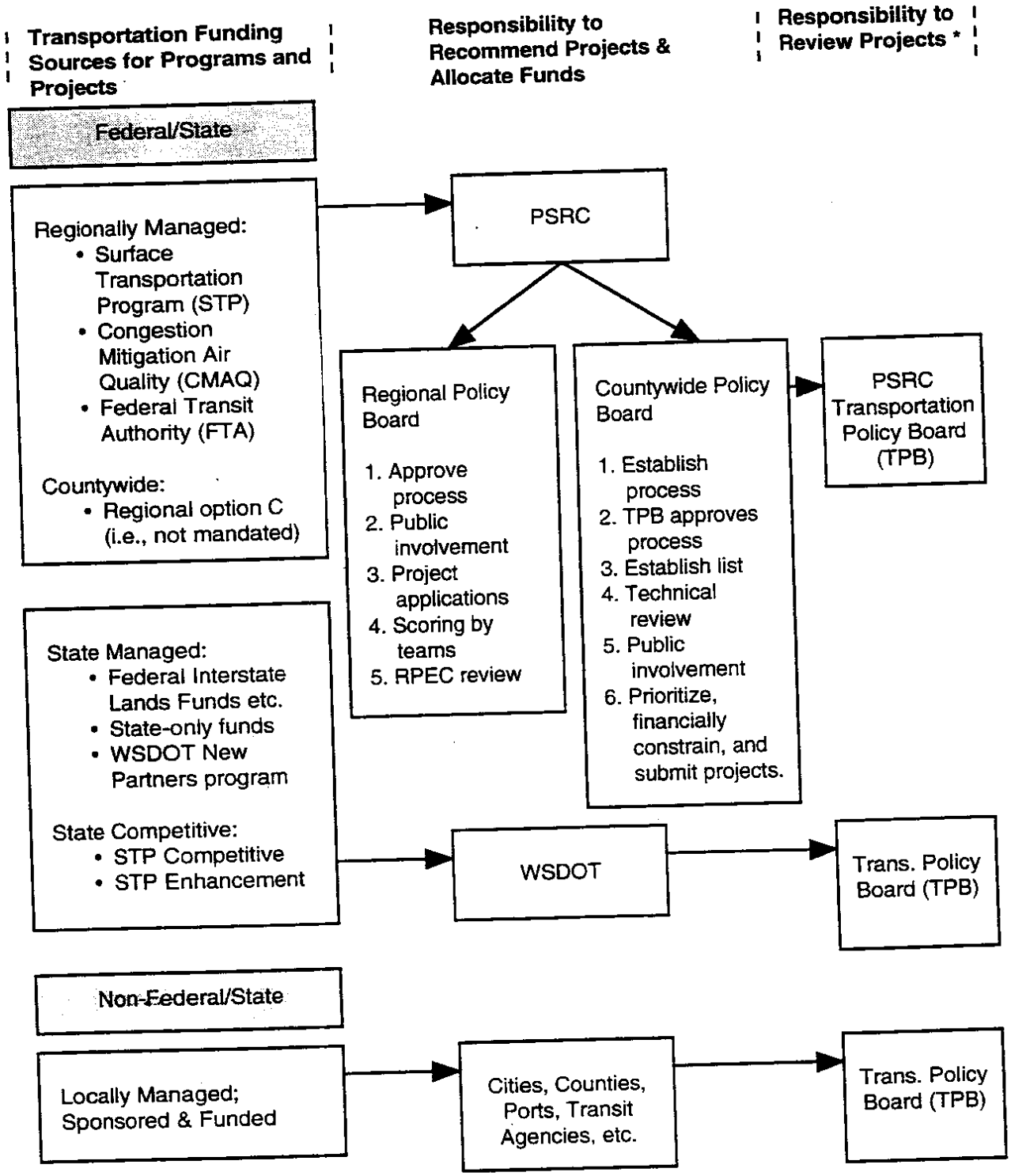
3. Projects that focus on supporting transit and pedestrian-oriented land-use patterns (e.g., pedestrian bridge projects, transportation elements of regional center or urban corridor re/development).

4. Transportation capacity expansion projects that offer greater mobility options (e.g., multimodal center or terminals, passenger ferries, new arterials as "missing links," advance land acquisition, HOV lane projects, intermodal freight access improvements).

Criteria may be refined each time the process is used for TIP prioritization. At a minimum, the projects must be specifically on or support the metropolitan transportation system as defined by the long-range regional plans. The screening criteria consist of the following six questions, which focus on identifying the primary beneficiaries.

- Does the project improve mobility within planned centers or along corridors connecting these centers?
- Does the project help sustain or encourage continued economic vitality for the region?
- Does the project improve system performance, efficiency, or effectiveness?
- Does the project reduce reliance on single-occupant vehicles?
- Does the project improve or provide new multimodal or intermodal access to ports, airports, or centers?
- Does the project support air quality goals by reducing vehicle miles travelled, trips and congestion levels, or by improving multimodal travel speeds?

The scores in this stage are based on the magnitude of impacts (i.e., high, medium, low, or not applicable) and criterion weight. Exhibit 1 shows the scoring matrix. PSRC maintains consistent ratings by assigning one staff person per criterion to evaluate every project against that particular goal. A regional project evaluation committee of technicians,



* All projects/programs must be financially feasible, consistent with the Regional Plan (MTP) and meet air quality requirements. Final approval for regional TIP is responsibility of PSRC Executive Board.

Figure 5. Overview of Puget Sound Regional Programming Process ("Call" 1995)

First Stage Regional Project Evaluation*

Criteria	Weights	Rating				Totals
		High (x3)	Medium (x2)	Low (x1)	N/A (x0)	Maximum Potential Score
1. Improve Mobility/ Centers	5					15
2. Economic Vitality	5					15
3. Improve System Performance	5					15
4. SOV Reduction	5					15
5. Accessibility	5					15
6. Air Quality Benefit	5					15
Maximum Screening Evaluation Score:						***90***

* (Weight)*(Ratings) = Total Screening Evaluation Score

Exhibit 1. PSRC Project Screening Matrix

representatives from related regional agencies (e.g., the air quality control agency), and volunteers oversees the screening process.

PSRC limits the amount of funds that may be requested from the regional competitive process by each countywide area, effectively limiting the number of submittals. Projects successful in avoiding the first stage cut are eligible to submit a more detailed application and undergo further technical and policy evaluation. The goal is to ensure that all modes and areas of impact are examined fairly in view of the regional vision.

Stage 2

The second stage of technical scoring and review is informed by a revised project application that contains more complete project data. The evaluation criteria are the same for STP and CMAQ applications. but the criteria weights differ. In 1995, every criteria category received equal weight with one exception. Air quality and energy benefit criteria weight was over three times greater when applied to CMAQ projects than to STP projects. Likewise, the other criteria received lower, but still equal weights. In this way, PSRC simplifies the prioritization process but still distinguishes CMAQ's programmatic intent of assisting regions in attaining national ambient air quality standards from STP goals.

The technical criteria focus on the same policy areas as the screening criteria, but the review is more detailed and the full range of environmental impacts and total project costs are also assessed. Exhibit 2 shows the technical evaluation matrix. Note how system performance and mode impacts are subdivided and compared in terms of preservation needs, traffic congestion level, safety and security conditions, and travel delays. Improvements or time advantages for alternative modes are explicitly preferred in several categories, rather than being separately scored in a single category. Regarding air quality, PSRC employs an impact model to estimate three types of measures for each project: (1) number of vehicle trips, (2) vehicle miles travelled, and (3) Environmental Protection Agency regulated pollutant levels. All such continuous data are converted to categorical high, medium and low scores to enable the final multiple-criteria ranking.

The cost-effectiveness portion of the technical score is the last evaluation step. PSRC divides total project costs by a sub-total of all the other scores. The ratio is in turn categorized, assigned a point value, and then added into the total project score. As a measure, its considered to be a proxy for benefit-cost analysis and is a common feature of matrix analyses. Overall, total project scores are generally high if the projected emission

reductions are also high. Because of the equivalent criteria weights, cost is not a significant factor in determining the relative rank.

General Comments

Notable in the PSRC process is that benefit disaggregation per user group shapes every criterion, but it is not explicitly conveyed by the end score. The final score distributions do suffer from an inability to distinguish between rough subsets of high, medium, and low projects that is typical of MCA evaluation methods. Thus, the motivation for decisions remains vague despite significant prioritization effort. Although complete transparency may not be attainable in any political context, it is a question of degree. One of PSRC's stated goals is to ensure that policy achievement drives the process. Toward this end, a transportation policy board and the executive board of PSRC set project priority after reviewing both the screening and technical scores. Thus, non-quantifiables and political bargains, such as demonstrating a commitment to improved mode-integration and balance, or avoiding potential public opposition still tend to determine the final outcome. As long as the executive decision-makers can access the disaggregated information by being directly involved in the prioritization process, PSRC is taking advantage of a primary strength of the methodology group.

2.4 OPTIMIZATION MODELS

Multiple criteria decision making and the optimal allocation of scarce resources are central foci in field of management science and operations research (MS/OR). Mathematical and hueristic models are used to provide a quantitative basis for decision making for a variety of applied engineering problems. So-called *soft* approaches that focus on problem structuring, disperse and conflicting goals, uncertainty, negotiations and strategy also exist (Rosenhead 1989; Borges 1996). In terms of the financially constrained priority

Second Stage Regional Project Evaluation*

Criteria	Weights		Rating				Totals	
	STP	CMAQ	High (x3)	Medium (x2)	Low (x1)	N/A (x0)	Maximum Potential Score	
							STP	CMAQ
1.Preservation	4	3					12	9
2. Traffic Congestion	4	3					12	9
3. Mobility/ Connectivity	4	3					12	9
4. Safety and Security	4	3					12	9
5. Efficiency & Reliability	4	3					12	9
6. Accessibility	4	3					12	9
7. Economic Benefit	4	3					12	9
8. Air Quality/ Energy Benefit	4	13					12	39
9. Other Environmetal Benefit	4	3					12	9
10. Cost Assessment	4	3					12	9
Maximum Technical Evaluation Score:							***120***	***120***

(Weight)(Ratings) = Total Technical Evaluation Score

Exhibit 2. PSRC Technical Evaluation Matrix

programming problem, optimization methods are concerned with allocation of available funds. Since the early 1970s, transportation planners have formulated linear (LP) and goal (GP) programming methodologies to assist decision makers in project selection or

scheduling; some rely on integer extensions of LP[3] (Niemeier et al. 1995). Non-linear utility theory might also be similarly used in facilitating trade-offs when risk or uncertainty is a significant factor in selecting alternatives (Marshall and Oliver 1995). However, these so-called *hard* methods have not been widely used.

Definitions

Basically, LP methodologies define an objective function to represent any project's (or attribute's) contribution to program (or design) effectiveness in terms of decision variables and contribution coefficients. The objective function is maximized or minimized (depending on the formulation) subject to several constraints. The following *canonical* formulation is an example (Schniederjans 1995):

$$\text{Minimize: } Z = \sum_{j=1}^{n} c_j x_j$$

$$\text{subject to: } \sum_{j=1}^{n} a_{ij} x_j \geq b_{ij} \text{ for } i = 1, \ldots, m$$

$$x_j \geq 0, \text{ for } j = 1, \ldots, n \text{ (i.e., non-negativity)}$$

where the $x_1, x_2, \ldots, x_n$ are non-negative decision variables, and the contribution coefficients $c_1, c_2, \ldots, c_n$ represent the marginal contribution to Z per each unit of the decision variables (e.g., subjective weight). This example's only objective is to minimize the objective function, Z. There are m constraints, where a_{ij} are technological coefficients representing the per unit usage of x_j required to attain at least the specified level of the right-hand side coefficient, b_{ij}, a budget for instance. The LP model implicitly requires proportionality and additivity among the specified coefficients, as well as independence from the contribution coefficients.

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[3] Integer programming is usually described as an extension or special case of LP where the decision variables are constrained to be non-negative integer values; GP is also commonly considered an extension of LP because of its subsequent origins, but integer extensions of GP also exist. For the purposes of this paper, GP is considered a unique category of mathematical programming parallel to LP.

LP model constraints can be inequality, equality, and less/greater-than-or-equal-to expressions. In the foregoing example the model solution allows for negative deviation, or *slack*, from the right-hand side coefficient, b_{ij}. But when one or more conflicting constraints must be considered, as is common in multiple objective decision making, infeasible solutions may result. In other words, there are cases in which the LP can not be solved without formulaic adjustment. GP, on the other hand, recognizes that in practice multiple goals are not always simultaneously achievable. The GP methodology is to minimize decision variable deviation from the desired levels, b_{ij}. Thus, an *achievement* (i.e., objective) function is constructed by minimizing total deviation from the goals. The modern formulation of such a GP model, as presented by Schniederjans (1995), shows that GP's distinguishing characteristic is a lack of decision variables in the objective function:

$$\text{Minimize: } Z = \sum_{i \in m} \left(d_i^+ + d_i^-\right)$$

$$\text{subject to: } \sum_{j=1}^{n} a_{ij} x_j - \left(d_i^+\right) + \left(d_i^-\right) = b_i, \text{ for } i = 1, \ldots, m$$

$$x_j, d_i^+, d_i^- \geq 0, \text{ for } i = 1, \ldots m;\ j = 1, \ldots, n \text{ (i.e., non - negativity)}$$

where d_i^+ is a positive deviation variable, d_i^- is the negative deviation variable, and the value of Z is a summation of all deviations. This equation recognizes the analyst's control over which deviation variables should be evaluated, where i is an element of all m possible deviation variables, in the generally formulated achievement function.

General Comments

Optimization methods have several advantages. By definition, they directly maximize project benefits and minimize costs, and so the objective function can utilize a single index of cost efficiency or may be designed to regard individual benefits and costs as decision variables. Evaluation criteria of disparate units can be handled simultaneously. For

example, they can work with measures of investment timing (e.g., IRR) alongside measures of cost efficiency (e.g., NPV) and non-monetized environmental impacts (e.g., physical acerage or pollutant levels). Furthermore, and most relevant to this case study, sensitivity analyses can be quickly and easily performed from the feasible solution. It is not usually necessary to re-run or re-formulate the model. Indeed, some computer codes for linear programming automatically compute the range of constraint and coefficient values in which the solution remains optimal and feasible (Kolman and Beck 1995).

Significant managerial benefits exist as well. For instance, Niemeier et al. (1995) have demonstrated several potentials for LP and GP in their work with five transportation programming optimization models. (1) Goals achievement can be clearly quantified and illustrated on a program basis where specific objectives exist, thus enabling thorough program and process monitoring. (2) When there is funding flexibility, budgetary trade-offs can be facilitated by modifying performance levels in the constraints. (3) Funding deficiencies can be similarly illustrated when there is insufficient funding to accomplish any of the agency goals. (4) Methodologically, LP and GP methods are also extremely flexible in accommodating new managerial complexities (e.g., multi-year budgeting and spatial equity).

The disadvantages, however, are clear and significant. First, the problems must be strongly structured to begin with; the evaluation criteria and unique relationships to some measurement of program performance must be known to formulate the objective function. As previously stated in terms of monetary impact-valuation, this can be difficult. Second, defining the constraints or goal achievement levels requires a large degree of institutional consensus, even when long-range plans and objectives exist to guide the process. Third, transparency is easily lost, despite the fact that the OR analyst must work closely with executive decisionmakers regarding the sensitivity of various parameters, such as budget constraints. Last, projects are not rank ordered. Instead, subsets are selected to represent

the 'best' use of available funds. Thus, the public is likely to view the evaluation process as a "black box" open to significant manipulation, since mathematical programs are often incomprehensible to non-engineers (Shaffer and Fricker 1987). Overall, it is not too surprising that optimization methods are not common practice in the controversial and broadly political arena of transportation programming.

2.5 IMPLICATIONS FOR THE CASE STUDY

Of all the reviewed case studies of regional priority programming methods a few papers stand out for their relevance to this project. First, Alexander and Beimborn (1987) explicitly described various measures of rank order difference and analysis of influential steps in prioritization algorithms. Second, the survey results in Rutherford's status report (1994) on multimodal prioritization methods throughout North America provided a context for the other West Coast methods and WSDOT's pre-existing Category C formula examined in the early stages of this study (Reed et al. 1995). Third, Niemeier et al. (1995) represents the earliest work on formulating the mobility programming algorithm presently used by WSDOT.

Overall, the literature review confirms that there is no single, best means of prioritizing transportation projects. Indeed, there are advantages and disadvantages in every case, but most agency methods are overly simplified. It is possible to infer which components are most critical given financial constraints. They are (based on Simon et al. 1988):

- emphasis on criteria that distinguish among projects and reflect the most critical policy objectives
- adaptability to changing objectives
- consideration of project costs, problem severity, and solution efficacy
- reliance on readily available data
- simple execution.

In general, it is also good practice to

- identify implicit value judgments
- develop methods in consultation with politicians
- know the sensitivity of selections to uncertain parameters
- recognize the output as a guide, not the ultimate "right" answer.

The WSDOT mobility prioritization method was developed in accordance with these components and principles. The associated algorithm, *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS), ranks projects using benefit-cost, plus other continuous and categorical criteria of disparate units. It is related to classic optimization models in the way preferred alternatives are selected because of their closeness to an ideal solution and on the basis of conflicting objectives or incommensurate attributes. However, optimization models usually emphasize design of alternatives rather than preference decision making. As a normative model, TOPSIS is better classified under a separate branch of multiple criteria analysis (Yoon and Hwang 1995). The WSDOT programming process and method are described in chapters three and four as part of this case study.

It is hoped that this literature review has helped to explain (1) the need for a thorough sensitivity analysis, and (2) how two different agencies, WSDOT and PSRC, as well as two departments in the same agency, WSDOT planning and programming, can rationally select quite different prioritization methods. This project aimed to reveal the consequences.

CHAPTER THREE: WSDOT PRIORITY PROGRAMMING METHODOLOGY

This chapter overviews Washington state transportation policies and identifies how these policies formed the basis for the WSDOT priority programming system and selection of mobility project evaluation criteria. The mobility ranking methodology described in this chapter includes a screening process, evaluation criteria and preference ordering method, and program trade-off structure.

3.1 STATE TRANSPORTATION POLICY

Since 1988, the Washington State Legislature has revised state transportation policy significantly. In fact, a new chapter was added to the Public Highways and Transportation Title, RCW 47.06. This chapter specifies the following functions as part of WSDOT's role in transportation planning:

1) ongoing coordination and development of statewide transportation policies that guide all Washington transportation providers
2) ongoing development of a statewide multimodal transportation plan that includes both state-owned and state-interest facilities and services
3) coordination of state high-capacity transportation planning and regional transportation planning programs
4) performance of special transportation planning studies that affect state transportation facilities or relate to those of statewide significance.

Mobility project prioritization is required to be directly related to state transportation goals. Policy documents associated with the first task (as outlined above) guided development of the new ranking methodology and selection of evaluation criteria. The second task of

developing the statewide multimodal transportation plan ultimately served as the project screening process for WSDOT's mobility improvement program.

The state transportation policy plan (STPP) sets forth a vision and statewide transportation goals consistent with state growth management mandates. Updating it is an ongoing, joint effort on the parts of the WSTC and the state legislature. Because the STPP is an evolving document, the underlying planning and programming processes have to be flexible enough to respond to legislative direction.

The present mobility project evaluation criteria respond directly to overall goals and specific policies associated with delivery of the WSDOT's Urban and Rural Mobility program. Broadly defined, the program goal is to ensure mobility alternatives that afford safe, reliable, convenient access to employment, educational, recreational, cultural, and social opportunities in both urban and rural environments.

Specifically, state policy emphasizes regional coordination in the planning and delivery of transportation programs, in planning capacity improvements the safe and cost-effective movement of people and goods, and in promoting cost-effective alternatives to SOVs (including transportation demand management and transportation system management). As discussed in chapter one, WSDOT's highway improvement program for state-owned facilities is divided into four categories:

I1. Mobility
I2. Safety
I3. Economic initiatives
I4. Environmental retrofit.

Note that preservation projects are distinguished in a separate program. The Systems Plan service objectives were further incorporated in this recent program restructuring by minimizing facility type distinctions within the programs. For example, all types of preservation projects are distinguished in a separate program independent of improvements.

Still, many policy objectives in one sub-program have implications for the program decisions in another. A complete list of general STPP goals is provided in Exhibit 3. This list is representative of the comprehensive documentation used in developing the evaluation criteria. In addition, mobility sub-program policy objectives are detailed in Exhibit 4.

To meet these policy objectives, the new prioritization ranking methodology and evaluation criteria were designed to be flexible, yet clearly prioritize projects that

- emphasize the movement of people and goods
- promote alternatives to SOVs
- facilitate smooth intermodal connections
- provide safe, reliable, efficient, convenient access
- reinforce development patterns that reflect regional and local growth management objectives
- avoid or reduce disruption and degradation of the natural environment and heritage resources
- are energy efficient
- are consistent with state, regional, and local comprehensive plans
- are cost-effective.

Influence on Programming

As transportation policy and funding strategies changed, WSDOT needed and was mandated by RCW 47.05 to develop a new approach to project prioritization ("Title" 1994). The systems planning process as reviewed in section 1.2 provides the framework for priority programming. Once deficiencies have been identified and various solutions have been recommended in the Systems Plan, planners conduct the first level of project prioritization in each program area. This prioritization leads to a rank ordered list that is used to financially constrain the plan and help guide each WSDOT region in selecting projects to develop for preliminary scoping and, eventually, to submit for the biennial

STATE TRANSPORTATION POLICY PLAN GOALS

PROTECTING OUR INVESTMENTS

1) Preserve and maintain transportation systems needed today and in the future.

PERSONAL MOBILITY

2) Provide personal mobility choices for urban, rural and intercity travel that are safe, reliable, affordable, and convenient.
3) Provide access to employment, commerce, education, health care, recreation, heritage resources, and social opportunities.
4) Provide facilities and services to make transfers between modes efficient and effective.
5) Reduce the impacts of congestion on personal mobility.
6) Reinforce a sense of Washington as a statewide community.

TRANSPORTATION SUPPORT FOR ECONOMIC OPPORTUNITY

7) Provide access that is safe, reliable, affordable, and convenient to industrial, commercial and intermodal sites for people, goods, and services.
8) Support domestic and international trade.
9) Support Washington's business and industry.
10) Reduce the impacts of congestion on freight mobility.

ENVIRONMENTAL PROTECTION AND ENERGY CONSERVATION

11) Design new and improve existing transportation systems to avoid the disruption and degradation of the natural environment and heritage resources; work toward systems that are aesthetically pleasing and energy efficient.
12) Conserve scarce resources.
13) Reduce pollutants from transportation systems.

WORKING TOGETHER

Develop an institutional framework for transportation that:

14) Encourages opportunities for public-private partnerships.
15) Promotes greater sharing and coordination of technical expertise and services between state and local governments.
16) Promotes mutual understanding and public participation in transportation decision making.
17) Facilitates interjurisdictional and regional coordination.
18) Integrates land use planning and transportation planning.
19) Supports innovative research and development.

TRANSPORTATION FINANCE

20) Ensure funding to responsibly achieve the state's transportation goals.

Exhibit 3. State Transportation Policy Plan Goals (Transportation 1994)

Goal: Personal Mobility

Urban Mobility Policy

1) Require regional coordination in the planning and delivery of transportation programs in urban areas.
2) Emphasize the movement of people and goods, rather than vehicles, in planning for capacity improvements to a regional transportation system.
3) Provide for cost-efficient alternatives to one-person vehicles, including transit and ridesharing, to ensure a high level of mobility.
4) Require land use planning and development to be coordinated with state, regional, and local transportation planning and investments.
5) Recognize demand management (parking fees, toll roads, flex-time, peak travel restrictions) as a major strategy to reduce congestion.
6) Require transportation improvements to be made reasonably concurrent with economic development, so economic growth does not contribute to the deterioration of existing transportation services.
7) Provide flexibility for different urban regions to adopt their own specific solutions to urban mobility problems.
8) Determine and provide the desirable levels of accessibility for the elderly and persons with disabilities.

Rural Mobility Policy

1) Provide effective and efficient rural transportation systems.
2) Coordinate the delivery and funding to federal, state, and local rural public transportation programs, integration social service, health care, and transportation objectives.
3) Establish and operate intermodel connection terminals at the community level.
4) Provide desirable levels of accessibility for the elderly and persons with disabilities.
5) Emphasize the movement of people and goods.

Exhibit 4. State Transportation Policy Plan Objectives Associated with Urban and Rural Mobility Sub-programs (Transportation 1994)

program. Section 2.1 describes and evaluates the Systems Plan prioritization method applied to improvement projects.

Ranking and evaluation methods are different for each of the four improvement sub-programs (i.e., mobility, safety, economic initiatives, and environmental retrofit, see Figure 3). The mobility sub-program even includes two methods defined for certain facility types: urban bicycle connections and core high-occupancy vehicle projects. However, this round of prioritization forms the basis for the top-level trade-off process of actually allocating funds. The mobility program tends to be one of the most controversial because there is more freedom in the financing, many high-cost high-visibility projects, and few remaining funds to distribute, since the WSTC prioritizes maintanence, preservation and safety projects over congestion-related projects (Morin 1995).

Before 1993, these types of projects were evaluated as Category C. Review of this previous formula revealed that it was well suited for evaluating highway-related projects that were similar in nature and whose primary purpose was to move vehicles (Reed et al. 1995). But the prevailing emphasis on multi-modal planning required criteria that were applicable across a range of project types and costs. Obviously, the new system policies required changes in the evaluation criteria and, in this case, a new algorithm. WSDOT needed a mathematical formula that would be flexible enough to accommodate any number or type of criteria in order to respond to changes in state transportation policy without changing the basic prioritization framework.

3.2 MOBILITY PRIORITIZATION METHOD

The most basic components of a prioritization process are the formal ranking method (i.e., mathematical algorithm) and a set of evaluation criteria. In addition to being flexible enough to accommodate changing goals, the ranking algorithm must operate independently of the evaluation criteria. Evaluation criteria should reflect state policy goals

and objectives, should be measurable, and should have data requirements that are not unreasonable.

The first step in the prioritization process (Figure 6) is the submission of project requests from WSDOT districts each of which is accompanied by a project description sheet (Appendix A). Project requests must address a need identified in the Statewide Systems Plan. As such, the financially constrained Systems Plan for Highway Improvements functions as the statutory screening criterion. Project requests that are not in the Systems Plan are not considered for prioritization in the current biennium. Evaluation criteria parameters are calculated for eligible proposals in five major categories: cost efficiency, community support, environmental impact, mode integration, and land use. Project requests are ultimately ranked by means of a geometrically derived priority index.

Each ensuing step—(2) project screening, (3) application of project evaluation criteria, and (4) application of the TOPSIS ranking algorithm developed in 1980 by K. Paul Yoon and Ching-Lai Hwang—is discussed in the following sections.

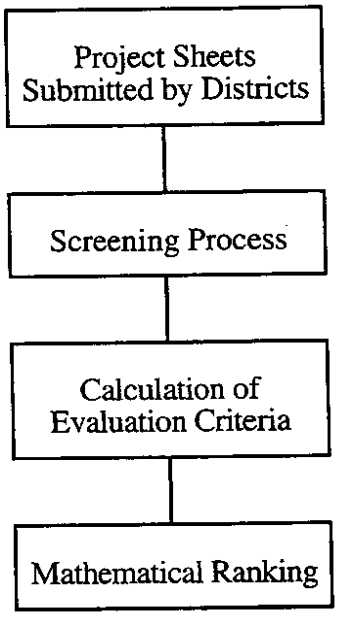

Figure 6. Mobility Prioritization Process

Screening Criteria

There are two elements in the state-owned facilities component of the statewide multimodal transportation plan: a state highway system plan and a state ferry system plan. The state highway system plan identifies needs and recommends specific, financially feasible improvements to preserve the highway system's structural integrity; to ensure acceptable operating conditions; and to provide enhanced access to scenic, recreational, and cultural resources. The state highway system plan contains the following elements ("Title" 1994:47.06):

System Preservation—establishes structural preservation objectives, identifies current and future deficiencies, and recommends program funding levels and specific actions

Capacity and Operational—establishes operational objectives, identifies current and future deficiencies, and recommends program funding levels and specific improvements

Scenic and Recreational Highways—identifies and recommends designated routes, provides enhanced destination access, and recommends management strategies

Paths and Trails—identifies non-motorized needs.

The Capacity and Operational element functions as the statutory screening criterion in the Urban and Rural Mobility categories. All proposals that provide recommended improvements from the financially constrained plan pass the initial screening. Because the state highway systems plan must meet air quality conformity requirements, any proposal that worsens air quality in non-attainment areas fails the initial screening. Furthermore, project submittals generated from the within the WSDOT for each biennium are expected to focus on addressing existing deficiencies. However, if outside agencies, such as metropolitan planning organizations, wish to address anticipated, as opposed to existing, deficiencies, the WSDOT will also consider those proposals.

Evaluation Criteria

Evaluation criteria may be continuous (e.g., benefit-cost analysis) or categorical (e.g., yes/no questions or placement by type). Evaluation criteria and the statewide policy objectives served are overviewed in the following sections. Appendix A contains the detailed worksheets and 1995-97 scoring guidelines. Evaluation criteria are grouped into five major categories: cost efficiency, community support, environmental impact, mode integration, and land use.

Cost-Efficiency

The state transportation policy plan (*Transportation* 1994) clearly suggests that project selection be based on relative cost-efficiency in moving people and goods. Sections 2.1 and 2.2 presented several types of economic criteria. However, many of those traditional techniques used to measure capital costs and efficiency are not useful for the prioritization process, or they would entail an excessive data collection burden and significant error accumulation.

In developing the mobility prioritization method, researchers considered, but did not pursue, the following types of measures: sufficiency ratings, level of service standards, and traditional cost per unit of interest criteria. These measurements were not recommended because they do not account for the monetary value of benefits and have been shown to systematically underestimate transportation investments' contribution to economic growth and productivity (Lewis 1991). Another drawback of such traditional prioritization criteria is that they cannot be uniformly applied to improvements that span multiple modes (Rutherford 1994). For these reasons, WSDOT needed a single, continuous measure of project worth aimed at assessing progress toward state economic objectives. As stated, these objectives encompass provision of personal and commercial mobility that is safe, reliable, accessible, and efficient.

The research team selected a benefit-cost type criterion for several reasons, also described in section 2.5. First, these measures could be directly and easily related to STPP policies. Second, these criteria could be quantified on the basis of data already available. Third, input data for the calculations could be refined incrementally as the management systems required under ISTEA are implemented. Furthermore, the criteria selected for consideration could be applied to all types of mobility projects.

Selecting the appropriate criterion depended on budgetary constraints and on whether projects to be compared were location-independent or mutually exclusive (Wright and Paquette 1987). WSDOT has required that proposals be independent submittals. In other words, no project is an alternative "version" of another; each addresses a wholly separate need. This independence focuses the project evaluation process on supporting program tradeoffs with relative comparisons of different combinations of projects. On this basis, the internal rate-of-return was eliminated. While the selected criteria would still have to identify which projects were economically justified (i.e., expected to produce greater benefits than costs), a minimum rate-of-return could be assured if alternatives with a negative net present value (NPV) were dropped before prioritization.

In order to use NPV to measure cost-efficiency in the programming process, it would be necessary to optimize NPV within budget limits. However, WSDOT's objectives extend beyond superficial costs and encompass hidden costs and benefits insofar as they incorporate alternative mode promotion, intermodal design, growth management, non-monetizable environmental impacts, and community support. Therefore, it was essential to include other quantitative measures for project impacts that could not be assigned a consistent monetary value. While cost-efficiency is a major WSDOT objective, the final prioritization could not be based on economic criteria alone, and NPV was eliminated.

Alternatively, NPV/C and B/C ratios may both serve as measures of worth that allow linear ranking of projects. They are also designed to eliminate discrimination against

proposals with unusually high project costs. As described in section 2.2, NPV is the most comprehensive measure of productivity and economic merit. Of course, the NPV/C ratio retains these advantages. However, B/C ratio has an advantage over the NPV/C ratio in that the B/C ratio is more easily understood and is still a suitable approximation of the present worth per dollar invested. For these reasons, researchers determined B/C to be the most appropriate measure of cost efficiency for mobility projects. As will be shown in section 4.2, B/C provides adequate differentiation between generally cost-efficient projects (B/C >1.0).

Computing the Benefit-Cost Ratio. Most important in *calculating* costs and benefits is first *defining* the project's costs and benefits. A discount rate and an analysis period must also be selected. Accuracy depends on consistency in computations. Consequently, WSDOT appointed a technical advisory committee of engineers from each region to determine appropriate unit values and to ensure consistent computations. Expected error ranges are discussed in section 5.3.

In general, submitted cost estimates do not always reflect consistent analytical methods. WSDOT addressed this concern by clearly identifying which costs should be factored into each submittal and by requiring itemization. Project costs are grouped into four major categories:

- construction (including right-of-way)
- environmental retrofit
- preliminary engineering
- annual operating and maintenance.

Construction costs include environmental analysis, mitigation costs, and right-of-way expenditures. Right-of-way acquisition, grading/drainage, and structure costs are reduced to account for the residual value associated with an expected investment service life beyond 20 years. Environmental retrofit costs include elements that address *pre-existing*

conditions. A separate environmental retrofit program is intended to fund this type of work; therefore, WSDOT subtracts these costs from the cost efficiency calculation so that project rank is not negatively affected. Annual operating and maintenance costs are based on historical trends in the region.

Benefits must also be treated consistently across projects, in terms of both categorization and application. WSDOT benefit calculations rely on traditional benefit-cost analysis categories:

- accident savings
- user operating-cost savings
- travel time savings.

Travel time savings is the most significant source of user benefits, historically accounting for 77 to 86 percent of interstate system benefits ("Benefits" 1970). Table 1 shows how it averaged 55 percent of WSDOT mobility project benefits in the first biennium of programming. In theory this magnitude, in combination with accident savings, is justified because productivity and economic output are ultimately raised by reducing work time losses (Meyer and Miller 1984, Lewis 1991). Estimates of travel time savings and user cost savings are combined through a single procedure based on volume-to-capacity ratios over 20 years. In keeping with WSDOT's emphasis on passenger travel, travel time savings and user operating-cost savings are computed on the basis of person trips rather than vehicle trips. Some environmental retrofit costs are compensated with environmental benefits; an example is a 4:1 monetary benefit to cost ratio for fish barrier removal. (*Technical* 1994, "Daily" 1994).

Including travel time savings as a monetary benefit is complicated because it requires assigning a monetary value to time. It also requires distinguishing between personal and commercial time expenditures. For now, WSDOT has defined statewide estimates of average travel time values that are differentiated by trip purpose (e.g., general

Table 1. WSDOT Mobility Program Benefit Proportions

Project Benefit Categories	Mean Percentage of Total Benefit §
Aggregate User Benefits*	88 %
Travel time savings	55 %
Vehicle operating savings	33 %
Safety Benefits†	11 %
Other ††	1 %

* both travel time savings and vehicle operating savings are monetized based on estimated delay reductions.

† Based on projected accident reduction due to project improvements.

†† Includes credit for the costs of environmental retrofit as appropriate.

§ Averaged over 193 urban and rural mobility projects in the 1995-1997 biennium.

vs. commercial travel) and by average vehicle occupancy, region, and facility type (e.g., non-commercial travel in HOV vs. general purpose lanes). Where more accurate local counts are available, they will be used (*Technical* 1994). In the long term, as traffic management systems become operational, the occupancy parameter could be computed on the basis of observed values.

Because of the debate over their value and appropriateness, other significant, non-quantifiable costs and risks associated with transportation projects are not typically monetized. The following four recommended categories of criteria are included in the mobility prioritization framework to ensure that these important impact areas and benefits are taken into account: community support, environmental impact, mode integration, and land use. As market values become more established, WSDOT will monetize and incorporate these risk criteria into the cost-efficiency calculation.

Community Support

Assessment of community support has always been a central component of WSDOT's screening process for proposed improvement projects. Accordingly, it was addressed specifically on previous WSDOT category C submittal forms. The Systems Plan, described as a statutory screen in the previous section, is subject to substantial public comment and participation throughout the planning process. However, strong community support for improvement proposals cannot be taken for granted in every case. Moreover, state transportation policy goals generally emphasize cooperation, economic development, and shared financial responsibility. This category of criteria aims at gauging the degree of support for, or opposition to, the project and its potential local impacts.

The community support criteria specifically serve the following state policy objectives: 1) encourage public-private partnerships; 2) provide access to employment, commerce, education, health care, recreation, heritage resources, and social opportunities; and 3) promote mutual understanding and public participation in transportation decision making (*Transportation* 1994). The magnitude of financial contributions and endorsements from other agencies is also evaluated. This adds extra emphasis to interjurisdictional coordination otherwise assessed in the land use category of criteria. Although addressing local government support in both categories might be considered "double counting," the WSDOT Program Management staff and the Washington State Transportation Commission deemed it critical to include each type of measure.

Community support criteria consist primarily of categorical questions supplemented and scaled by qualitative assessments regarding public and private participation, endorsement, or opposition; disruption of cohesive neighborhoods; and physical displacement. These yes/no categorizations are supplemented and scaled by means of qualitative assessments. WSDOT's criteria specifically promote

- projects with minimal or no opposition
- official endorsements
- financial involvement of the private sector, special programs, and local governments
- preservation of existing access within neighborhood and business areas.
- communication with the public.

Points are, for example, accrued by proposed projects that would displace homes, farms, or businesses, while points are withheld from proposals on the basis of the percentage of contributed financing. The total community support score is the sum of points accrued in this category and is minimized in the TOPSIS ranking algorithm. Thus, projects with the most community support and the least physical impact receive lower total scores than projects that are insensitive to local sentiment and conditions.

Environmental Impact

As section 3.1 outlined, transportation policy objectives in Washington state aim to avoid or minimize damage to the natural environment and heritage resources and to favor energy-conservative transportation strategies. Other state and federal guidelines such as ISTEA, state and federal clean air acts and amendments (CAAA), the National and State Environmental Policy, and the 1990 Washington State Growth Management Act further support these STPP goals. This legislation requires systemic consideration of environmental factors before an agency commits to transportation improvement projects. However, historically, environmental impacts were not assessed until after prioritization and approval (Washington 1992). Washington state law, RCW 47.01.280, now requires that WSDOT involve the relevant permitting agencies in the project scoping phase, a requirement intended to avoid cost overruns and unforeseen delays. In this way, potential environmental impacts are sketched at the outset of project development and preliminary permits are approved, which improves impact assessment before prioritization. Thus,

including environmental criteria is considered critical to achieving WSDOT programming goals.

The environmental criteria addressed are wetland encroachment, water quality and resource related permitting, and noise impacts. Researchers selected these three topic areas because they are generally the most controversial, the most closely regulated, and the most potentially expensive impacts of transportation projects that can also be readily quantified.

Criteria that assess other environmental areas such as air quality and energy conservation are obviously absent from this category of criteria but are not entirely ignored. The programming process depends on the 1991 Washington State Clean Air Act "Conformity Rule," which requires that WSDOT and the Washington State Department of Ecology ensure that transportation plans, programs, and projects conform to the State Implementation Plan (which complies with federal CAAA). Because the conformity rule applies to the Systems Plan, the screening process excludes any proposal expected to have negative air quality impacts from prioritization. Similarly, energy efficiency is indirectly measured by the cost efficiency and mode integration categories of criteria. Proposals that promote alternatives to SOV travel, improve the operating efficiency of the transportation system, and decrease congestion are favored in these categories.

WSDOT's environmental criteria serve the following WSDOT policy objectives: 1) to support federal and state "no net loss" policies by protecting, restoring, and enhancing natural wetlands adversely impacted by transportation related construction, maintenance, and operations; 2) to minimize and control levels of harmful pollutants generated by transportation activities from entering surface and ground water resources; 3) to protect, restore, and enhance, where feasible, fish and wildlife habitat and populations within transportation corridors; 4) to avoid, minimize, or mitigate impacts of transportation projects on heritage resources; and 5) to minimize noise impacts from transportation systems and facilities. The criteria and scoring processes for the environmental sub-

categories (wetlands, water quality and permitting, and noise) are described below. Appendix A and Reed et al. (1995) further document the criteria.

Wetlands. This category is designed to assess proposed projects' likely encroachment on classified wetlands and associated buffers in accordance with federal, state, and local regulations. This is a risk assessment, while direct wetland mitigation costs are added to the construction cost estimate. The wetlands criteria favor the following:

- advance project planning
- avoidance of classified wetlands
- "no net loss" of state wetland area.

Points accrue on the basis of (1) the actual wetlands acreage likely to be affected by project construction, and (2) a multiplier that reflects Washington State Department of Ecology and GMA-mandated replacement ratios (*Environmental* 1993). The total score reflects calculations in each of four wetland categories and an associated buffers category. The TOPSIS algorithm minimizes the wetlands score so that projects with low scores or no net impacts, rank favorably.

Water Quality and Permitting. The purpose of these criteria is twofold: (1) to assess potential watershed impact, and (2) to measure the risk and staff time associated with the permitting requirements for proposed projects. Mitigation costs, as for each environmental impact, are included in the cost-efficiency calculation. The criteria favor

- advance project planning and environmental review
- interjurisdictional coordination
- avoidance of sensitive areas and water sources
- minimization of total impervious surface area.

The evaluation criteria consist primarily of categorical questions regarding the project's proximity to sensitive areas, resource lands, waterways, and water sources. Point assignment is variable and depends on the relative risk per item or duration of associated

permit review. The measures are quite conservative. For example, all impervious surface area within the maximum estimated distance required for pollutant filtration is quantified. On the other hand, when required permits are obtained for the needed duration before programming evaluation, then the project is not penalized. Projects that avoid watershed impacts and that have preliminary environmental agency approval receive lower scores than do roadway expansions in sensitive areas with uncertain permitting prognoses. Like both other environmental categories, water quality and permitting scores are minimized in the TOPSIS ranking algorithm.

Noise. The noise sub-category is aimed at assessing potential impacts and the associated risk to project implementation. Again, mitigation costs are part of the cost-efficiency calculation. The noise criterion favors

- transportation system management without lane expansion
- avoidance of significant traffic noise impacts
- mitigation of retrofit for existing impacts.

Noise impacts are estimated by calculating a single, continuous measure of noise level risk associated with each project. The risk factor is based on the number and proximity of receptors per type of improvement (new or existing roadways) and is justified on the basis of ambient noise levels and acoustics. Geographic variability is not factored into the noise criteria. Low scores are favorable. Thus, projects that propose significant road widening or lane additions near multiple receptors are penalized with higher scores than projects that avoid roadway expansion and maintain existing setbacks from homes, businesses, and schools. Consequently, most projects likely to increase traffic volumes and speed rank poorly in this sub-category.

Mode Integration

Washington state's transportation policy aims at development of a multi-modal transportation network that (1) facilitates smooth intermodal connections for people, goods,

and services and (2) promotes alternatives to single occupancy vehicle (SOV) travel (*Transportation* 1994). Moreover, ISTEA requires more multimodal planning on the part of state departments of transportation. Given these goals, the mode integration criteria are designed to encourage multimodal characteristics in every project. The criteria specifically favor

- more efficient use of existing capacity
- connectivity between existing systems (e.g., intermodal terminals)
- integration of modes (e.g., park-and-ride lots)
- better packaged projects.

Projects are penalized for not incorporating such attributes. The evaluation criteria categorically determine whether projects improve intermodal freight transfers, include non-motorized facilities, support or extend HOV system development, link or extend the network of SOV alternatives, or preserve existing roadway capacity by means of transportation system or demand management. The total mode integration score equals the sum of points accrued and is minimized in the TOPSIS ranking algorithm. Consequently, low scores are favorable.

Land Use

State policy clearly emphasizes that mobility projects should be planned to provide convenient, multimodal accessibility and to better integrate land-use and transportation planning by coinciding with preferred growth patterns. Accordingly, the land-use criteria specifically encourage

- coordination between WSDOT engineers and local planners
- convenient transit accessibility
- connectivity between urban activity centers
- transportation development that reinforces land-use/urban design plans.

Categorical land-use criteria regarding site location and transit routes are combined with a required synthesis of associated regulations/standards dictated by local governments adjacent to the project limits. Projects are rewarded for coinciding with existing or planned transit thoroughfares and/or for connecting areas of mixed-use or high intensity commercial use. In part, this category simply quantifies the screening criteria so that there is not much differentiation between projects, since inconsistent planning is a fatal flaw.

The total score is maximized in the TOPSIS ranking algorithm. Consequently, higher scoring projects that integrate land use and transportation improvements rank more favorably than projects designed without regard to such goals. Appendix A and Reed et al. (1995) further document the scoring procedure.

Ranking Algorithm

Chapter two reviews many mathematical methods for ranking projects. However, ranking groups of projects that are independent and exclusive of the previous set from biennium to biennium, and that may be composed of very different improvement types, presents a unique problem. Several alternative algorithms were developed by Niemeier et al. (1995) and were discussed in a recently updated review of options for WSDOT (Barnes 1996). The TOPSIS algorithm for ranking projects with multiple and conflicting attributes was selected. It still seems to be the most suitable choice for WSDOT mobility project programming and is discussed below.

Technique for Order Preference by Similarity to Ideal Solution

The TOPSIS method is one of the most commonly used means of helping decision-makers evaluate elements (projects in this case) with multiple, incommensurate, and often conflicting attributes (Yoon and Hwang, 1995). Clearly, mobility project programming fits in this category. TOPSIS is based on the rational principle that best choice is the alternative most similar to an ideal solution. In practice, the ideal is usually a composite alternative

constructed from all the best attribute ratings attained within the project set. Thus it is considered a perceived, not absolute ideal. A negative-ideal, or hypothetical "worst" project, is similarly constructed. Similarities are then determined by multi-dimensional Euclidean distances from these ideals.

In all, there are six distinct steps in the TOPSIS method:

1) Calculate normalized ratings.
2) Calculate weighted normalized ratings.
3) Identify positive-ideal and negative-ideal solutions.
4) Calculate separation measures (Euclidean distances).
5) Calculate similarities to the positive-ideal solution
6) Rank preference ordering.

The preference order is represented by a so-called priority index number for each project. The top ranking project has the shortest Euclidean distance from, or the highest percentage of similarity to, the positive-ideal. Appendix B and Barnes (1996) further summarize Hwang and Yoon's (1981) step-by-step explanation of the TOPSIS concept and mathematical basis.

Suitability and 1996 Modifications

TOPSIS-6 was the first mobility ranking algorithm developed for WSDOT. It is a macro program that uses Hwang and Yoon's concept and operates within Excel. TOPSIS-6 properly maximizes or minimizes project scores before calculating a priority index for each project, sorts projects in descending rank order, and indicates the list of projects that may be funded according to a user-input budget limitation for the programming cycle. Appendix C contains the annotated TOPSIS-6 code and an illustration of macro execution.

Researchers recommended the TOPSIS method for several reasons. First, it is flexible. The ranking algorithm is independent of the criteria; in other words, any relevant measure can be used to rank projects. Criteria can be modified or expanded easily to reflect

changes in transportation policy each biennium. Second, the best and worst projects each biennium are dependent on that particular group composition, as well as on current policy objectives. Third, the methodology was meant to allow planners to identify and scrutinize projects with relatively similar total scores by producing an evenly distributed priority index. However one biennium of implementation showed, as documented by Barnes (1996), that the project rankings were too sensitive to changes in the ideal projects for WSDOT programming purposes.

In response, maximum and minimum scores that do not vary from year to year were devised. In this way, projects submitted in any two bienniums or tested against a regional subset of a complete statewide list are evaluated by the same standard. UW researchers originally considered this particular modification to be too rigid and arbitrary. Justification for retracting this opinion and modifying TOPSIS was that in working with local communities, WSDOT regional staff required reliable rank ordering early in the programming process. Barnes (1996) showed that constraining the ideals used in TOPSIS makes the regional sub-set rankings more sequentially consistent with the ultimate statewide rank order, thus the change. WSDOT's modified algorithm is called TOPSIS-8.

The standard ideals were devised by setting limits on the previously unbounded criteria scoring scales (i.e.. cost efficiency, wetlands, and noise criteria). These new score conversions executed by TOPSIS-8 were based on descriptive statistics and correlation with the original unbounded 1995-97 ranking results. Section 4.3 comments on and specifies the revisions. Note that future policy changes might logically necessitate changes in the evaluation standards in the same way that would obviously be required if the criteria categories were eliminated or scaled differently.

3.3 PROGRAM TRADE-OFFS

Once the projects have been prioritized, the WSTC is responsible for recommending funding trade-offs between each budget category to the state legislature. On this basis the program "book is built" (is developed). Figure 2 in section 1.2 previously overviewed this whole process. Though the TOPSIS generated ranks are typically adhered to, some deviations from priority order are to be expected during legislative deliberations or from WSDOT program directors before the budget request process. Coordinating construction and staff efforts across budget categories is one common reason for deviations. To allow for and respect this kind of professional judgment, WSDOT policy maintains that the WSTC must review the change only when such desired deviations are "significantly" out of TOPSIS rank order (Morin 1995). In this way, the method results do not constitute the ultimate "right" answer but instead are considered a tool for determining the best package.

The mobility programming method is designed, as required in the recent WSDOT restructuring, to inform the program trade-off process. For example, once prioritized, the lists are used to determine how many projects could be built and for what cost, given any particular budget allocation. This can be accomplished quickly and easily once priority order has been established. Furthermore, it is possible to determine an optimal funding level on the bais of overall program cost effectiveness. In doing so, project cost efficiency is isolated and, arguably, over-emphasized. However, strict financial constraints may justify the exercise, since benefit-cost analyses in other programs such as maintainence, safety, and perservation similarly inform this competition for scare funding. Figures 12 and 13 in section 4.3 illustrate how the points of increasing, constant, or decreasing program cost effectiveness can be determined.

CHAPTER FOUR: 1995-1997 IMPLEMENTATION

The first biennium in which WSDOT program and prioritization restructuring took effect was 1995-1997. Top-level administrators were involved in determining the mobility prioritization criteria category weights required by the TOPSIS ranking algorithm. Some preliminary sensitivity analysis was conducted at this early stage, but no objective measures were used to analyze differences in rank. This chapter overviews the process of weighting the proposed evaluation criteria and describes the mobility ranking results and implementation issues generated during the 1995-97 programming cycle. These observations are referred to in the following chapter.

4.1 CATEGORICAL WEIGHT ASSIGNMENT

Evaluation criteria were weighted by means of a Delphi decision-making session conducted for the WSDOT Program Management Division. Participants were geographically balanced and selected from planning, project development, and local programs. Representatives included two WSDOT district administrators, three assistant secretaries, three WSTC Commissioners, and the Transportation Improvement Board (which allocates local matching funds). Because the multiple evaluation criteria assess potentially conflicting objectives, it was important to structure the decision-making process in a way that would allow the participants to develop consensus. The Delphi technique (Linstone and Turoff 1977) allows comparison of group judgment to individual contributions, provides an opportunity for individuals to discuss and revise their views, and ensures some degree of anonymity. The results of three rounds of discussion and weight assignment were later adopted by the WSTC, which was responsible for establishing the final weights. Table 2 summarizes the final weights for the 1995-97

biennium, while standard deviations and major discussion points are documented in Appendix D.

Table 2. Final Weight Assigned to Evaluation Criteria Categories ("Mobility" 1993)

CATEGORY	*WEIGHT*
Cost-efficiency Safety Freight/Goods Energy conservation High-occupancy vehicles	65 %
Community Support	14 %
Environment Wetlands Water quality and permitting Noise	8 %
Mode Integration	7 %
Land Use	6
%	
TOTAL:	*100 %*

Preliminary Sensitivity Analysis

Prior to the Delphi analysis session, six weighting scenarios were applied to a test data set based on 1993-1995 project lists. The purpose of this testing was to determine the range of category weights likely to affect project rank and then to convey this to the decision-making committee. The six weighting scenarios are summarized below:

1) Cost-efficiency criteria receive 70 percent of the weight; the remaining 30 percent is equally divided among the other four categories.

2) Community support criteria receive 70 percent of the weight, and the remaining 30 percent is equally divided among the other four categories.

3) 70 percent of the weight is divided equally among the three environmental criteria, and the remaining 30 percent is divided equally among the remaining four categories.

4) Mode integration criteria receive 70 percent of the weight; the remaining 30 percent is equally divided among the other four categories.

5) Land use criteria receive 70 percent of the weight; the remaining 30 percent is equally divided among the other four categories.

6) Each category is assigned a weight representing the average compiled from a questionnaire distributed among WSDOT district program managers and staff as follows:

   Cost efficiency=46%, Community support=18%, Environment=15%, Mode integration=11%, and Land use=10%.

Researchers manually tracked projects by type, district, and previously calculated rank (from a modified version of WSDOT's Category C cost-effectiveness and rating factor formula). No single objective measure of difference was utilized.

The conclusion was that if approximately 50 to 70 percent of weight (with the balance of the weight divided equally) were applied to a single category, such as cost efficiency, the remaining four criteria categories would have minimal effect on the resulting rank order. However, further investigation showed that if the remaining criteria jointly combined for a relatively negative weight greater than 30 percent, then the effect on the ranking would be noticeable, but not dramatic. For example, it was fairly common under this type of scenario for projects to appear in locally reverse order (i.e., a project ranked seventh would switch places with the eighth while a project previously ranked ninth might appear as the sixth). In only one case, attributed to a relatively extreme wetlands score, did a score from a single category with less than 10 percent of the weight affect the final project ranking significantly.

The sensitivity analyses of this project aimed to objectively quantify such differences in rank order and to explore these same weighting scenarios with a numeric measure.

4.2 1995-1997 PROJECT RANKING RESULTS

This section presents the mobility ranking results from the 1995-97 programming cycle. The distribution of project scores is analyzed with histograms and in comparison to accumulated program cost. Appendix E lists all of the urban and rural mobility projects in rank order, including project costs and criteria scores. Table 3 reiterates the criteria categories, relative weights, the possible range of scores, and whether each criterion is maximized or minimized by TOPSIS-6. Given these data, the positive-ideal and negative-ideal projects are ascertained for each sub-program and included in Table 3 for reference.

Table 3. Criteria and Ranking Parameters

	Criteria:						
	Cost-Efficiency	Cmty Support	Wetlands	Water Quality	Noise	Mode Integration	Land Use
Weight	0.65	0.14	0.0267	0.0267	0.0266	0.07	0.08
Score Range	0-∞	0-17	0-∞	0-41	0-∞	0-10	0-19
Maximized / Minimized	max.	min.	min.	min.	min.	min.	max.
Positive Ideals:							
Rural sub-program	55.54	1	0	0	0	3	14
Urban sub-program	291.79	0	0	0	0	1	14
Negative Ideals:							
Rural sub-program	0.12	10	43.5	30	1318	10	0
Urban sub-program	0.01	8	121.65	30	1008	10	3

Descriptive Statistics

Histograms are a convenient way of summarizing the frequency distribution of continuous variables. Each interval bar in the histogram is identified by its midpoint on the x-axis, and the bar height reflects the number of cases with variable values in that class interval. The narrower the interval, the more closely a histogram approximates the continuous distribution (Sokal and Rohlf 1995). Appendix F contains histograms that describe the score distributions for each criteria category, project costs, and net present value. When the frequency distribution is skewed because of outlying scores, a second truncated histogram is included to better illustrate values near the distribution mode for these categories (e.g., noise). Other descriptive statistics complement the histograms.

Table 4 contains the most interesting and relevant measures grouped according to what they quantify: central tendency, dispersion, and shape (Norusis 1993). Measures of central tendency describe the location of distributions; arithmetic means are greatly influenced by outliers, whereas the median is not. They are usually close in value for symmetric distributions. Measures of dispersion and shape describe dissimilarities between two distributions and departures from normality, respectively. The formal indexes of skewness and kurtosis help compare distributions across categories. For instance, the urban land use scores are negatively skewed (i.e., with a greater tail toward the smaller values, to the left) and also leptokurtic (more peaked, with more cases clustered around the central point than in a normal distribution). Rural land-use scores have a similar, though more normally peaked, pattern. Water quality and permitting scores in both sub-programs are, on the contrary, platykurtic (flatter, with more extreme values than in the normal distribution). Combined, however, these statistics can be misleading, especially in the unbounded categories. The rural noise, urban wetlands, and urban cost efficiency scores are supposedly very leptokurtic, but they are also very positively skewed by extremely high

Table 4. Summary Statistics

	Criteria:							
	Cost-Efficiency	Cmty Support	Wetlands	Water Quality	Noise	Mode Int.	Land Use	Cost (millions)
Central Tendency								
Rural - mean	4.9	4.2	4.0	12.0	55.9	8.4	10.1	7.7
median	1.2	4.0	0.60	11.0	1.0	9.0	11.0	2.6
Urban -mean	13.7	3.9	4.6	10.6	114.7	7.3	12.2	18.8
median	2.9	4.0	0.50	10.0	33.0	8.0	13.0	6.4
Dispersion								
Rural - std.deviation	9.8	1.6	8.4	8.1	186.9	1.6	3.9	9.6
range	55.4	10.0	43.5	30.0	1318.0	7.0	14.0	38.2
Urban -std.deviation	38.4	2.1	15.6	8.1	186.9	2.2	2.2	48.8
range	291.8	8.0	121.7	30.0	1008.0	9.0	11.0	421.0
Shape								
Rural - skewness	3.3	0.67	3.3	0.30	5.5	-1.6	-1.2	1.7
kurtosis	12.3	2.6	11.0	-0.70	34.3	2.9	1.0	2.1
Urban - skewness	5.8	0.16	6.2	0.61	2.5	-0.61	-1.3	6.4
kurtosis	36.9	-0.53	41.4	-0.49	7.2	-0.53	2.4	47.5

outlying values. In these cases it is more generally informative to refer to the truncated histograms instead.

Figure 7 is the urban community support histogram extracted from Appendix F to show the most normally distributed case. Though these scores are still a bit flatter than normal and positively skewed, it is considered negligible. Likewise, statistical tests show that urban mode integration, as well as both sets of water quality and permitting scores, is approximately normally distributed, although visual inspection of the rural water quality data suggests that they may actually be bimodal (i.e., have two peaks).

As previously mentioned in section 3.1, WSDOT's mobility programs are fairly controversial and contain a relatively wide variety of projects. Figures 8 and 9 illustrate this variety for each sub-program. Notice that realignments and truck climbing lanes are

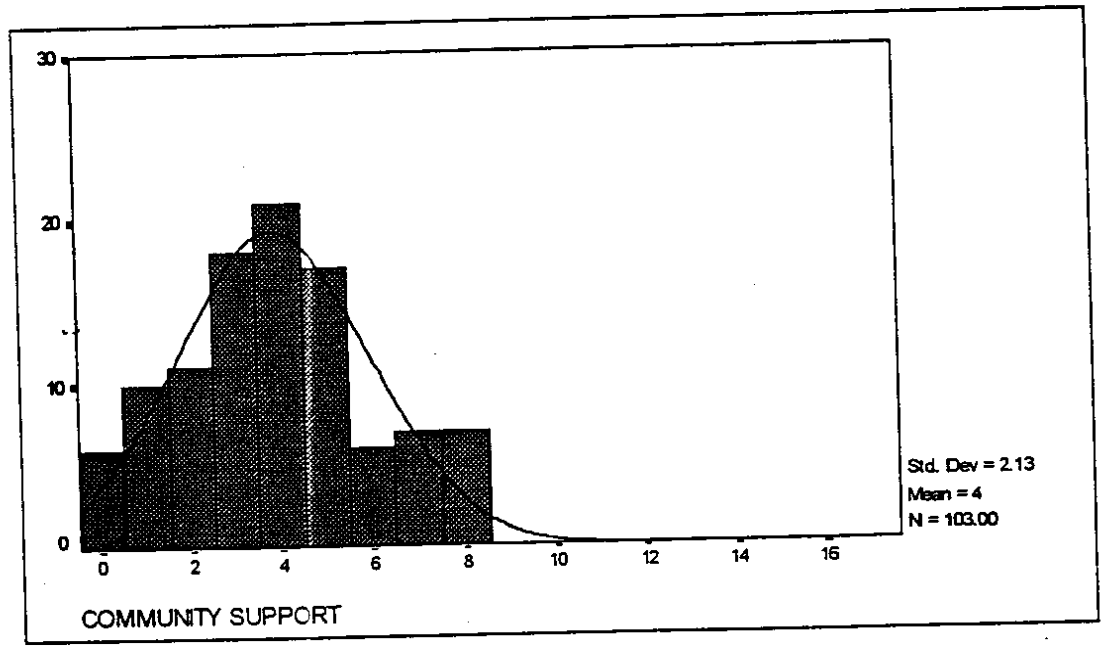

Figure 7. Example Histogram

characteristic rural projects, whereas the urban sub-program contains twice as many intersection and channelization improvements. The histograms in Appendix F show that, in general, project costs are characteristically skewed toward higher costs by outlying values (a shape statistic indicated by a shorter left tail, as indicated by the smaller median) and yet are leptokurtic about the mean. Despite this slight peak, histograms do verify that the cost efficiency criterion still adequately differentiates among mobility projects if the distribution is truncated by removing the outliers.[4]

Percentiles are another useful summary statistic. Table 5 contains the score distributions analyzed by the 25th, 50th, and 75th percentiles. Otherwise known as Tukey's hinges, or the first, second and third quartiles because they divide the distribution

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[4] Note the relevance of this conclusion in terms of Barnes' (1996) modifications to the algorithm, i.e., Topsis-8. Refer to section 3.2 and 4.3 for further discussion.

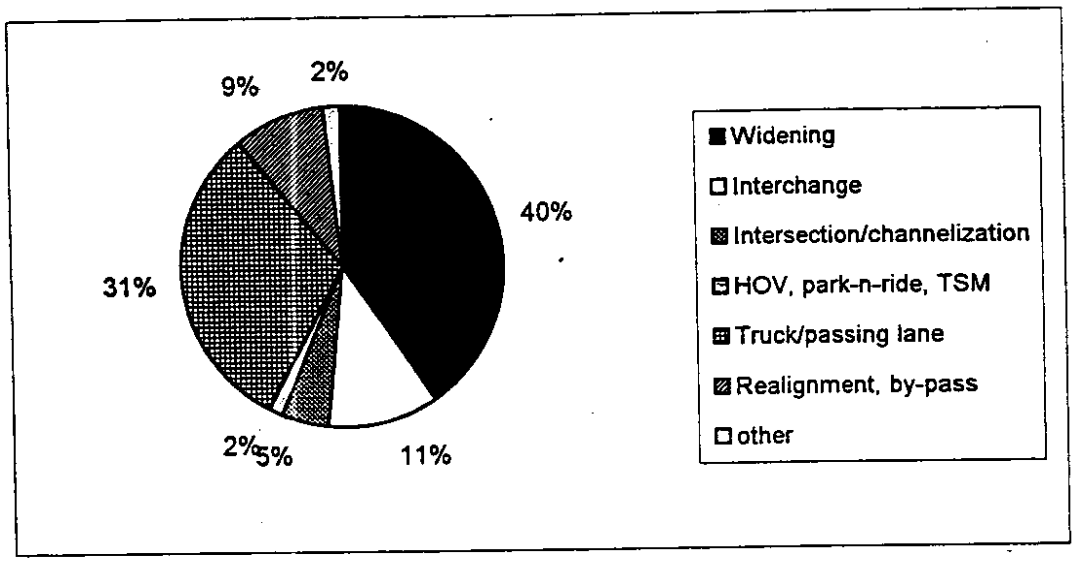

Figure 8. Rural Project Type Distribution

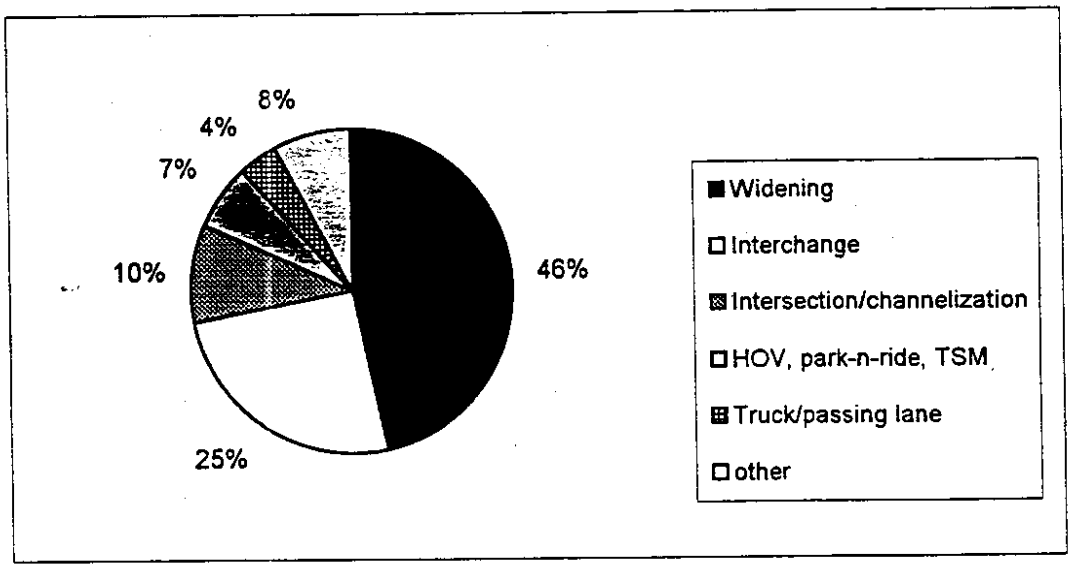

Figure 9. Urban Project Type Distribution

*Table 5. Score Distribution by Percentiles**

	Criteria:							
	Cost-Efficiency	Cmty Support	Wetlands	Water Quality	Noise	Mode Int.	Land Use	Cost (millions)
RURAL†								
First quartile	< 0.5	< 4.0	< 0.5	< 6.5	0.0	< 8.0	< 9.0	< 1.1
Mid quartile (25-75%)	0.5 -3.5	4.0 -5.0	0.5 -2.5	6.5 -15.3	0.0 -20.0	8.0 -9.0	9.0 -13.5	1.1 -12.3
Fourth quartile	>3.5	>5.0	>2.5	>15.3	>20	> 9.0	>13.5	>12.3
10 percentile	< 0.3	< 2.0	< 0.5	< 1.0	0.0	< 6.5	< 4.5	< 0.6
90 percentile	18.9	6.0	11.9	24.0	107.0	10.0	14.0	22.4
URBAN††								
First quartile	< 1.2	< 2.0	< 0.5	< 4.0	< 0.5	< 6.0	< 11.0	< 3.1
Mid quartile (25-75%)	1.2 -10.2	2.0 -5.0	0.5 -2.0	4.0 -15.3	0.5-131.5	6.0 -9.0	11.0-14.0	3.1 -15.1
Fourth quartile	>10.2	>5.0	>2.0	>15.3	>131.5	>9.0	>14.0	>15.1
10 percentile	< 0.3	< 1.0	0.0	< 1.0	0.0	< 4.0	< 9.0	< 0.7
90 percentile	>28.7	7.0	10.5	23.0	387.0	10.0	14.0	30.6

* Note: percentiles do not account for whether the category score is maximized or minimized; thus, quantiles (first, second, etc.) are not in preference order.
† 64 valid observations. †† 103 valid observations.

into four parts containing the same number of cases, they are the most commonly reported percentiles (Norusis 1993). Naturally, the 25th and 75th describe the values between which 50 percent of projects fall and, thus, provide numeric context for the ideals listed in Table 3.

The scoring observations most interesting to this study are as follows:

- Score distributions in the unbounded categories (cost efficiency, wetlands, noise) are not symmetric about the mean. They are the most skewed and most leptokurtic distributions. Therefore, these categories act as "red flags" regarding exceptional or high-risk projects.
- Urban project score variance is about twice as high as that of rural projects in the bounded categories (community support, water quality and permitting, mode integration, land use). Variance in both is rather low.

- There is significant grouping of scores, sometimes in the "extremes" of the scoring range, or apparently bimodally, but none of the data appear uniformly distributed.

Consider the following examples of clumped scores:

1) Half of the all rural projects and 25 percent of the urban projects receive the most favorable noise score of zero, whereas half of all the urban projects earn noise scores lower than 33.

2) Half of all rural projects receive one of only two different integer scores in mode integration (i.e., an 8 or 9 out of 10) and in community support (i.e., a 4 or 5 on a scale of 0-17). At least half of all rural projects receive an 11 or 14 in the land-use categories.

3) At least 95 percent of all community support scores are favorable at less than 8, although the category limit is 17. Likewise, at least 95 percent of all rural projects score poorly and receive less than half the possible points for mode integration; it is almost 90 percent for urban projects (though with nearly twice as much variance).

4.3 IMPLEMENTATION ISSUES

The first biennium of prioritized results raised several issues needing clarification. Those that developed into major concerns for WSDOT and remain, include the following:

- consistency of rank ordering among different project sets or between different methods and agencies (e.g., statewide vs. regional rankings)
- understanding the influence of including non-monetary criteria
- the extent of accuracy needed in the scoring procedures
- the impact of eliminating or adding categories of criteria.

The first two issues were, in large part, addressed by Barnes's (1996) research into improving rank consistency by constraining the unbounded criteria categories. TOPSIS-8, the resulting version of WSDOT's ranking algorithm, normalizes the wetlands and noise scores, truncates the cost efficiency scores by introducing an upper threshold, and standardizes the theoretical positive and negative ideals for any programming cycle or project mix. These actions were instituted because rank correlation between the statewide lists and regional subsets improved markedly. Barnes also observed the reciprocity of utilizing an upper B/C threshold and the indirect influence of the non-monetary criteria. However, some uncertainty remains over how much the non-monetary criteria affect the project rank ordering and, indeed, whether they are even worthwhile criteria.

This point can be answered in several ways. It can be addressed by, first, prioritizing the project lists in terms of accumulated costs and, second, with an alternative optimization routine (this section). Chapters 5 and 6 explore, third, how robust the method is to variation in each category and the chosen category weight distribution. Obviously, these two chapters also answer the last two administrative concerns, while chapter 7 explores the results of unique prioritization methods used by different agencies.

The Economic Influence of Non-Monetary Criteria

The criteria used to evaluate project community support and environmental impacts are primarily assessments of the risk. The mode integration and land-use categories on the other hand, are justified on the basis of WSDOT's policy agenda. As discussed in the literature review some professionals believe that these types of non-monetized criteria are irrelevant under tight fiscal constraints. However, WSDOT's method is designed to achieve a reasonable balance.

The effectiveness of the mobility prioritization method in capturing the intent of WSDOT policy makers is convincingly illustrated by graphing the results. Figures 10 and 11 depict the relationship between the priority order output from the ranking algorithm and

each project's benefit-cost ratio. The figures also simultaneously show how the biennial Mobility program costs accumulate in the urban and rural sub-programs. These costs are just sequential sums of the total present value costs for each project estimated over 20 years. The TOPSIS-6 algorithm and all five categories of criteria described in chapter 3 were used to calculate the rank order, assuming statewide competition. The cost efficiency criterion (B/C) is illustrated to show the strong relationship between the final rank order and the most heavily weighted category of criteria, with the percentage of projects ranked in descending B/C order (Barnes 1996) superimposed. Note how this kind of graphic would illustrate correspondence with policy goals (insofar as the weights represent these goals), no matter which category was the most heavily weighted category.

A more compelling observation in terms of the economic influence of the non-monetary criteria concerns the overall *program* cost-effectiveness. Figures 12 and 13 illustrate this relationship between monetary benefits and total accumulated costs (i.e., B/C). Projects are listed along the abscissa in descending priority order using all five categories of criteria. Note the difference in scale. The point is that each program's cost effectiveness reaches a plateau (or point) where continued investment in priority order does not increase the measurable monetary benefit more than the associated increase in costs (i.e., where the slope of the accumulated benefit curve is less than or equal to the slope of the accumulated cost curve, $b_B < b_C$ or $b_B = b_C$). The urban mobility program would not reach the point of decreasing effectiveness (Z, Figure 12) until 94 projects were funded. The rural mobility program, on the other hand, would reach a plateau beginning with the project ranked 20th (*X-Y*, fig. 10) and would reach the point of decreasing effectiveness (Z, Figure 13) after 48 projects were funded. These curves could be utilized to trade off program funding on the basis of measured cost effectiveness only. For example, if the goal were to maximize the total accumulated benefit per dollar invested while still programming in priority order, it would not be advisable for WSDOT to invest beyond the point of equal

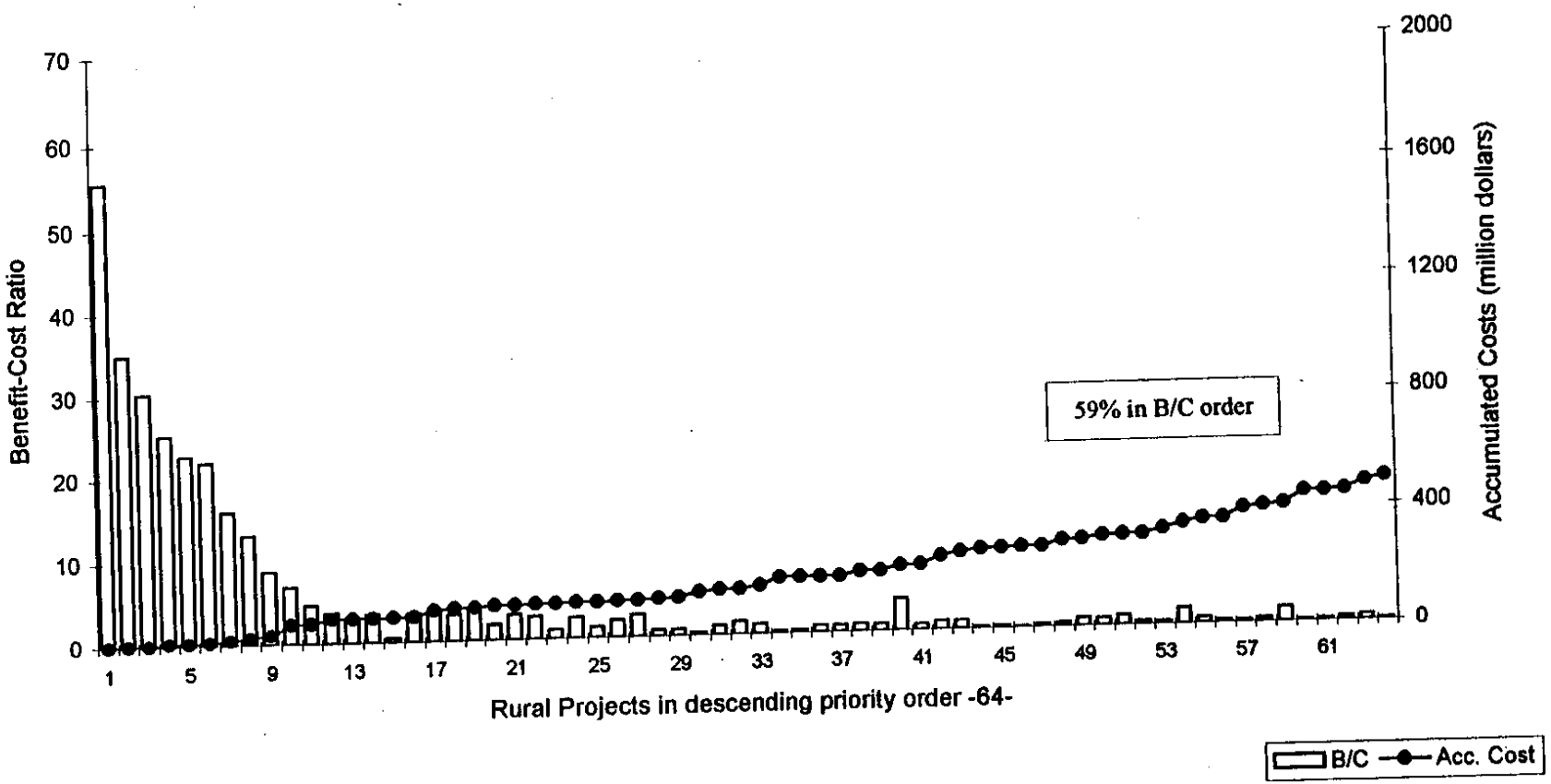

Figure 10. Statewide Prioritization Rural Mobility Program, 1995-97

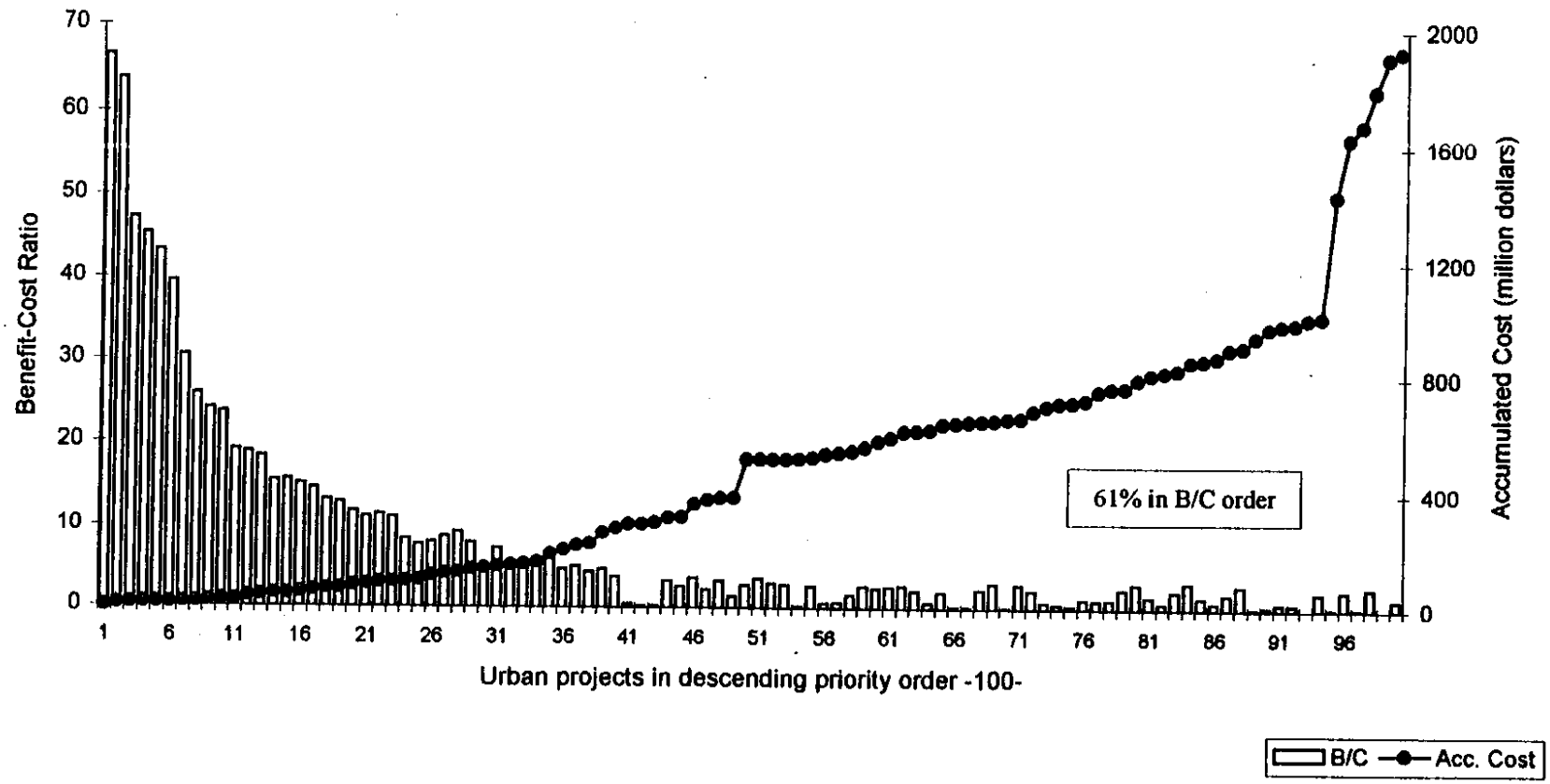

Figure 11. Statewide Prioritization Urban Mobility Program, 1995-97

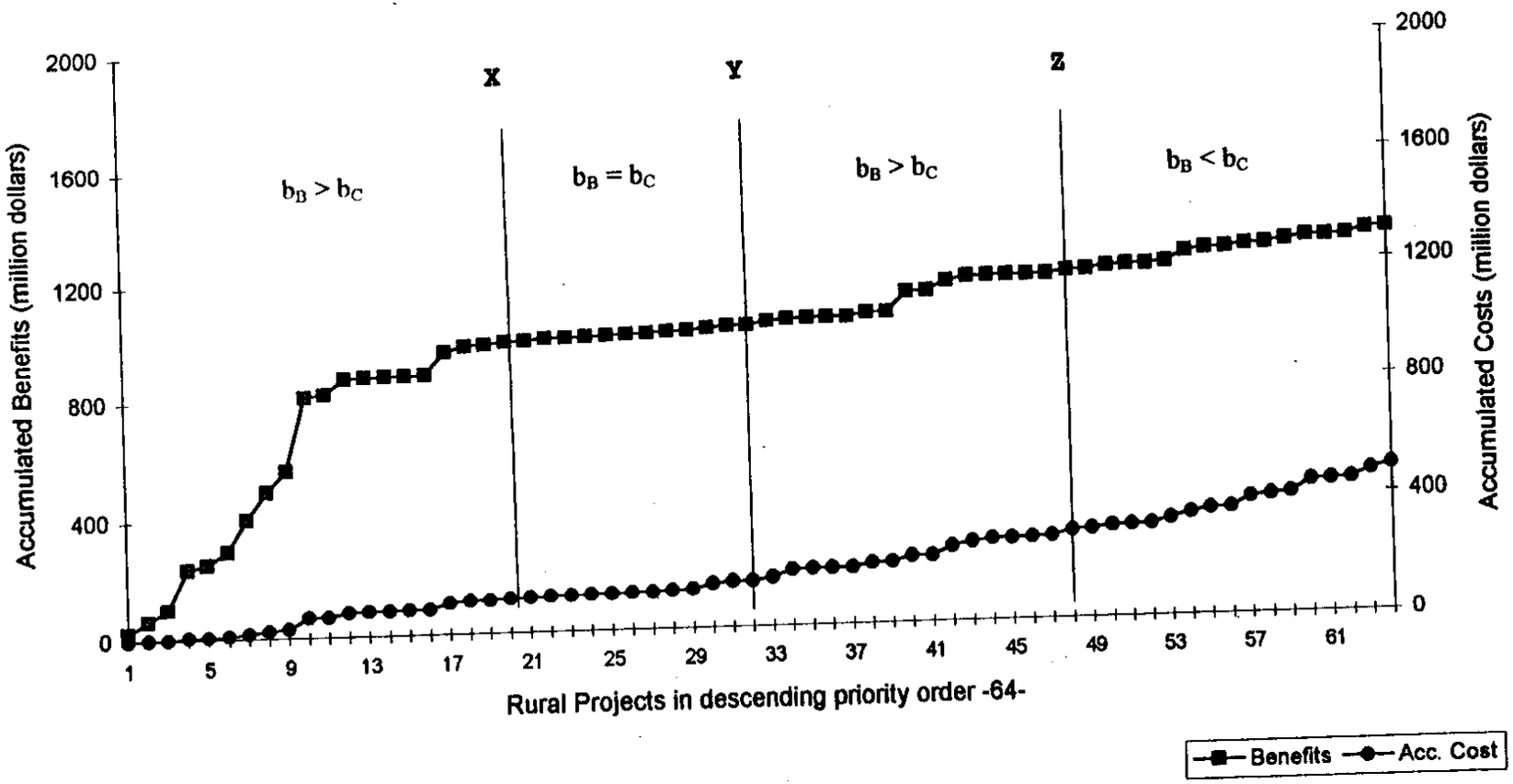

Figure 12. Overall Rural Mobility Program Cost-Effectiveness, 1995-97

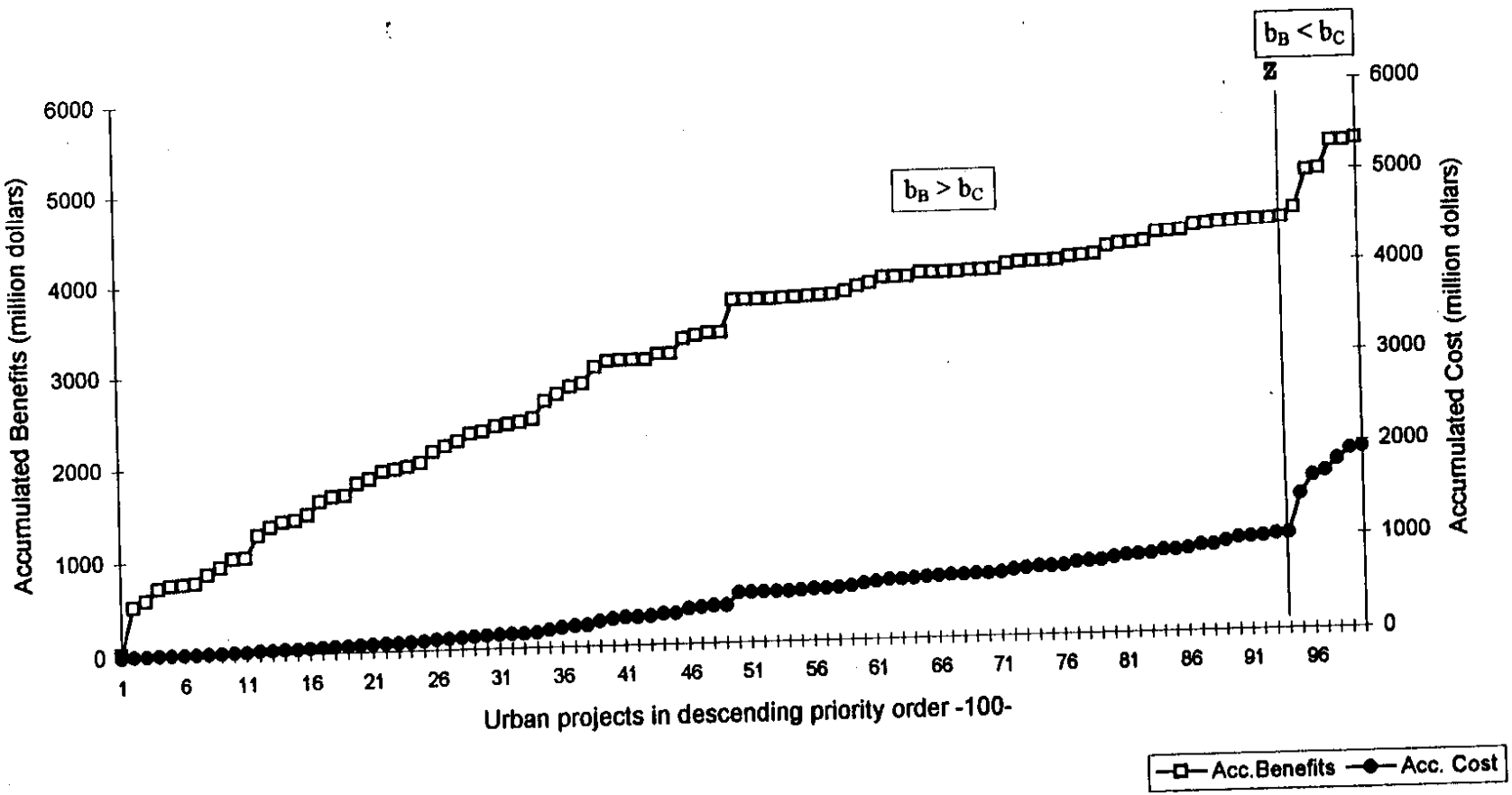

Figure 13. Overall Urban Mobility Program Cost Effectiveness, 1995-97
[Note difference in scale]

slope or decreasing effectiveness in any biennium. Thus, WSDOT could respond to the greater need for mobility improvements in urban areas without sacrificing the comparative integrity of a statewide rural investment program.

Alternative Economic Ranking and Budget Comparisons

Selecting projects by an alternative economic ranking is another way to demonstrate the magnitude of economic efficiency loss caused by including multiple non-monetary evaluation criteria in the prioritization algorithm. In fact, the efficiency loss is small when judged by overall economic worth (i.e., NPV). Appendix G contains tables that compare selections on the basis of the 1995-1997 mobility method versus optimizing program investment by maximizing (1) net present value or (2) the benefit-cost ratio. The budget levels of $120 and $150 million are arbitrary (though based on preliminary WSDOT projections), and the project NPV figures come from a simple conversion of the original data.

Table 6 summarizes the total net present worth for each alternative method and allocation in both the rural and urban sub-programs. The percentage of deviation from the WSDOT mobility method base case is the most telling column. As expected (e.g., Wright and Paquette 1987), the optimized net present value provides the greatest net benefit return in both cases but by a rather narrow margin. In the rural sub-program, the respective differences of $12.3 and $56.7 million amount to 1.4 and 6.5 percent greater returns (per different budget level), respectively, than would the WSDOT mobility method. Similarly, optimizing NPV in the urban sub-program selects programs with 5.8 and 5.1 percent greater net worths respective to each budget level. Notice that the total NPV outweighs project costs in every case, whereas ranking projects in strict B/C order would generally produce much lower economic worth in both sub-programs (i.e., negative percent changes

in total NPV in every case except the rural sub-program with the $150 million investment level). Aside from these facts, two main conclusions are drawn from this exercise.

First, by comparing program benefits at different budget levels it becomes clear that there is not necessarily a linear relationship between investment level and economic returns. In fact, Miller et al. (1987) have shown in a similar sensitivity analysis of a safety project prioritization model that the budget size does affect the solution set sensitivity to errors such as underreporting and constant parameter selection (e.g., discount rate and accident costs). Similar characteristics were found in this WSDOT case study. Inspection of the tables in

*Table 6. Summary Results for Alternative Method Example**

Ranking Method	Total Cost (dollars)	Total NPV (dollars)	Unspent Funds (dollars)	Total No. Funded.	Percent Change in NPV
Budget Allocation: $120,000,000					
RURAL					
Mobility Prioritization	119.816,492	867,214,242	183,508	20	0.00 %
Optimized NPV	119.914,202	879,552,123	85,798	20	1.42 %
Optimized B/C	119,516,063	722,627,971	483,937	30	-16.67 %
URBAN					
Mobility Prioritization	114,601,449	2,866,641,064	5,398,551	29	0.00 %
Optimized NPV	119,936,650	3,032,500,894	63,350	31	5.79 %
Optimized B/C	119,731,229	2,861,479,229	268,771	38	-0.18 %
Budget Allocation: $150,000,000					
RURAL					
Mobility Prioritization	133,260,493	876,510,366	16,739,507	29	0.00 %
Optimized NPV	149,908,063	933,181,671	91,937	28	6.47 %
Optimized B/C	149,461,583	929,502,500	538,417	27	6.05 %
URBAN					
Mobility Prioritization	147,505,179	3,094,662,872	2,494,821	34	0.00 %
Optimized NPV	149,779,708	3,253,660,539	220,292	35	5.14 %
Optimized B/C	149,791,801	2,687,868,988	208,199	44	-13.15 %

* Results compiled for example lists in Appendix G.

Appendix G suggests that lower levels of funding produce more stable results than are measured in this section. This is because the top ranking portions of each project list do not shift position enough to drop out of the funded set. Ultimately, two important points have implications for interpreting the results of chapter six. First, measures specific to the top ranking portion of the project set are likely to be the most reliable and second, the sensitivity analysis would best be conducted across a range of investment levels.

Second, explaining the reasons that alternative methods of economic optimization produce different project sets is very difficult. Manual comparisons of the lists require examining which percentile the category scores of each project fall into for every discrepancy in project selection. Then, on the basis of score extremes and their associated category weight, the analyst must describe why the WSDOT mobility method prefers one project over another. This means of comparison is unsatisfactorily vague and tedious; see Niemeier et al. (1996) or Exhibit G-1 for an example. Summary Table 6 best illustrates the main point that including non-monetary criteria reduced economic worth by less than 6.5 percent in 1995-1997 while it actually, with one exception, produced a more cost-effective program than ranking in strict B/C order would have produced.

General Comments on the Dataset

Implementation of the methodology took one year and was coordinated through a WSDOT technical advisory committee that helped establish consistent evaluation guidelines across project types, improve communications, and set constant parameters for benefit-cost analysis (e.g., value of travel time). The committee proved to be very important in making the implementation a success because the need for certain guidance was difficult to predict before the technical analysis began. Examples of technical decisions with implications for policy setting included project staging and analysis periods, discount rate selection, regional modeling variations, volume or growth projection coordination, vehicle occupancy

assumptions, benefit-catch area definitions, and benefit evaluation based on weekday peak hour volumes.

On the other hand, two administrative policies in particular had unintended implications for interpreting the mobililty prioritization results. First, WSDOT allowed for financial contributions from local jurisdictions or other agencies to be subtracted from the total project cost. This action manifested a policy goal to encourage local-state partnerships. However, it also undermined attempts to evaluate the overall economic integrity of the Mobility program because the relationship between the most heavily weighted criteria (cost efficiency) and the priority order is very direct. In nearly half of the urban proposals, the prioritization reflected a higher benefit-cost ratio than would otherwise have been calculated if the local contribution had not been subtracted. While the results were internally comparable within this biennium, this point is important to remember when interpreting the results of chapter 7.

Geographic equity is the second policy issue that had a significant effect on the prioritization results. Projects in heavily congested regions tend to generate greater travel time benefits than projects in uncongested regions. However, WSDOT executives disbursed funding in regional allocations on the basis of a different, worst-first (i.e., the Systems Plan rank) prioritization method. The funds are proportioned regionally, not statewide. Consequently, several proposals with low priority statewide were programmed for preliminary engineering and construction in relatively uncongested districts before higher priority projects were programmed in the most heavily congested districts. The implications were not investigated in this case study.

CHAPTER FIVE: SENSITIVITY ANALYSIS METHODOLOGY

This chapter covers the objectives and statistical design of the simulation model used to analyze rank order sensitivity to variation in each category and also among category weight. The simulation was designed to test WSDOT's mobility prioritization method prior to development of TOPSIS-8. However, the sensitivity testing framework outlined in this chapter is a general approach applicable to TOPSIS-8 that is also potentially useful in evaluating other types of prioritization methods. Chapter 6 presents and discusses the simulation results in light of recent algorithm revisions.

5.1 ANALYSIS OBJECTIVES

This sensitivity analysis was meant to inform the policy-making debate over category weight setting, and selection of pertinent categories of criteria, and to expose the limit of acceptable error in project performance predictions. Objective measures of difference between two or more modified ranks were developed and applied. In the process, analyses also clarified to what degree the non-monetary criteria influence project rank ordering.

As presented in section 4.3, the inter-relationships of WSDOT's five specific mobility impact categories remained relatively obscure throughout 1995-1997 programming despite the fact that they were exactly what the prioritization method aimed to represent. Furthermore, there are always uncertainties in the volume forecasts, costs, and impacts that constitute each criterion. Sensitivity analysis results were (1) necessary to determine the extent of accuracy needed in the scoring procedures for maintaining relatively robust results, (2) important because there was still some uncertainty over whether each criteria category is pertinent or whether some might be better converted to screening criteria (e.g.,

community support and land use), and (3) essential for increasing confidence in the strengths of the mobility prioritization methodology.

5.2 SIMULATION FRAMEWORK

The simulation framework had to accomplish two basic tasks: (1) generating and applying incremental variation to the inputs, and (2) measuring the effects on the mobility method output. The output, a prioritized rank order, was known or could easily be calculated. The inputs, on the other hand, did not come from known probability distributions for each category score variable; nor was there enough information to approximate such frequencies. Thus, random error was applied to vary the category scores one at a time; TOPSIS-6 was used to prioritize WSDOT's mobility projects on the basis of these modified inputs; and then summary measures were calculated to describe the difference between original rank order and the simulated ranks with error. The process was iterated 15 times for each level of random error applied and repeated for each independent criteria category.

Iterating the process many times over produced replicate data for each level of error in each category of criteria. An unlimited number of unique summary measures could then be applied. Three objective measures of difference were used in this study: (1) mean absolute deviation, (2) the number of projects dropped out of the funded portion of the original prioritized set, and (3) the total number of projects in that same portion.

In this way, the sensitivity simulation evaluated the effect of categorically independent error. Potential interaction effects caused by simultaneous error variance in two or more criteria categories were not modelled. However, suggestions for revising the design to include this possibility are noted in section 5.3.

Macro programs were written to carry out each simulation task in Microsoft Excel, version 5.0. Appendix H contains the annotated Visual Basic macros and a set of sample

output. The simulation framework is best described as an uncertainty analysis because the variables could not be compared to known probability distributions (Lindeburg 1993).

Adding Error

Random error is assigned differently depending on the type of data involved. WSDOT mobility criteria scores are either positive-valued continuous variables (i.e., benefit-cost ratio, wetlands, noise) or positive-valued categorical scores (i.e., community support, water quality and permitting, mode integration and land use). Project score ranges from the 1995-1997 biennium were assumed to be representative of all future project scores, given the large program size and project type mix. Section 4.2 discussed the actual distributions of these scores, most of which were skewed, some bimodally distributed, and none of which appeared to be uniform.

When applying error, the goal is to model the same type as expected in reality. Given the benefit of the doubt, mobility criteria errors were more likely to be small than they were to occur with equal probability across the integer score range. Even the categorical criteria were not expected to deviate uniformly. Furthermore, in some cases it would be illogical for category scores to be negative, as with benefit-cost ratios. Thus, it was most appropriate to apply normally distributed error on a log scale, effectively constraining the modified data to positive values.

A multiplicative error structure was used. First, a random error set was generated. Second, these errors were added to the natural log of the test data (i.e., actual 1995-1997 project scores). Third, the sums were exponentiated back to the original scale. This error structure was programmed in exponential form as follows:

$$y_i = x_i * \exp(e) \qquad \text{where,} \qquad e \sim N(0,\sigma)$$
$$\sigma = \ln(\text{percent error})$$

Another method of adding multiplicative error is to center the normal error distribution at 1.0 with a standard deviation (σ) equal to percent error. However, because the log scale is

not used, all randomly generated error values that cause negative scores when added to the original data have to be discarded and reselected. This truncates the random normal distribution and is not conventionally recommended (Sampson et al. 1995). Particular to this analysis, normal errors caused the variance among each measure of difference distributions to be much less homogeneous across different error levels. In fact, this increasing variance in absolute difference (with increasing applied errors) was noticeable even by visual inspection.

Expected Error

The reasonable range of error was expected to be different in each category depending on the certainty of the inputs. The cost-efficiency category relies on the widest variety of uncertain estimates and parameters of all WSDOT's other mobility criteria. Benefit-cost variable inputs that are most uncertain include

- volume forecasts
- operating speed measurements
- specification of environmental retrofit benefits
- delay reduction specifications for intelligent transportation systems, park and ride lots, access management, and under saturated conditions.

In fact, one study by Martin and Voorhes Associates showed that uncertain traffic forecasts can easily cause 40 to 50 percent error in project net present value calculations (Ashley 1980). The study also demonstrated that estimating cumulative probability curves is the most thorough means of examining these errors. However, this method is not especially well-suited for use in priority programming because of the significant and individual project modelling effort required.

Several constant parameter values were also debatable. Uncertain constants include value of time, discount rate, accident reduction factor, cost per collision type, and vehicle operating cost specifications. Defining the breadth and level of detail covered by benefit-

cost analysis components also introduced some error. For instance, the benefit-cost ratio for one urban WSDOT project went from 2.82 to 3.55, a change of 26 percent, when the total project cost was adjusted to include the residual value of bridge structures, right-of-way acquisitions, drainage, and grading (Morin 1995).

Estimate certainty for the other continuous criteria was primarily subject to accurate impact assessments, not debate over variation in pre-determined parameters. Errors in criteria categories were caused by incomplete information about the project. This study assumed that the data submitted by WSDOT staff for 1995-1997 projects were as accurate and consistent as possible. Thus, the data represented the "most likely future" in terms of scoring. Consequently, applying incremental percentage of error to the existing project scores was the best way to compare effects in each category and to determine limits beyond which priority order would be significantly altered.

Errors ranging from one-half to twice the best estimate are considered reasonable test values for this type of simulation (Bonsall et al. 1977). However, it was important to ensure that the error levels were comparable across categories. Intermediate results showed that a narrower and categorically adjusted range of error was necessary in order to (1) avoid mathematical exaggeration due to the experiment reliance on lognormal error, and (2) keep the magnitude of summary measures similar, and thus comparable, in this case study.

Simulated Values

Seven error levels ranging from 5 to 35 percent were tested in each category. Two and a half percent error was also tested in all cases. Random errors as high as 70 percent were simulated in the cost-efficiency category. To examine the effect of the WSTC category weight scenario, the following alternative weight distributions were modelled on the base data (i.e., 1995-1997 scores):

1. Five to 25 percent subtracted from the 1995-1997 cost-efficiency weight (0.65), with

a) the rest evenly distributed among the other four categories

b) the difference proportionately redistributed among the other four categories

2. 70 percent in each of the five categories, with

a) the rest evenly distributed among the other four categories

b) the difference proportionately redistributed

3. 50 percent in each of the five categories, with

a) the rest evenly distributed among the other four categories

b) the difference proportionately redistributed

4. Zero percent in each of the five categories, with

a) 100 percent evenly distributed among the other four categories

b) the difference proportionately redistributed

5. Changing the second greatest weight (i.e., community support at 0.14) by transferring 10 percent of each other category's weight in turn, all at-once, and by switching it with the mode integration category weight (0.07).

Measures of Difference

Objective summary statistics were needed to measure the differences of the simulated ranks to the original. Alexander and Beimborn (1987) described several such indicators. They suggested (1) the sum of the squared differences in rank expressed as a fraction of the maximum possible, (2) the percentage of alternatives that exhibit a change in rank greater than or equal to 10 percent of the total number of alternatives, (3) the mean difference in rank, and (4) the number of alternatives that move to either side of a pre-determined cutoff point on the original list.

The first is a rank-order correlation measure similar to Spearman's coefficient, r, in that the known distribution runs from 0.0 (perfect positive correlation) through 0.5 for a random relationship and up to 1.0 (perfect negative correlation). The second measure has a

standardized random value of 0.828 for any number of alternatives, while the third is directly related to the number of prioritized projects. The first measure emphasizes ranks that are far apart, whereas the other two measures are sensitive to small changes in rank ordering. The fourth indicator needs to be related to the specific decision problem. In WSDOT's case, a logical cutoff line would be the point in priority order beyond which only a fraction of the next project's cost could be covered by whatever remains of the anticipated budget allocation.

Three objective measures of difference were used in this part of the study: (1) mean absolute difference in rank, (2) the number of projects dropped out of the funded portion of the original prioritized set (determined by anticipated budget levels, $15 million in this case[5]), and (3) the number of additional projects that could be funded by this same budget allocation. Obviously, the first two mirror Alexander and Beimborn's third and fourth indicators, while the last two form a complementary pair. Table 7 (chapter 6) summarizes the distribution limits for each measure.

Mean absolute difference (MAD) is commonly used to quantify set variations and unlike a mean square measure, it does not exaggerate the differences in rank. It is given by the expression

$$MAD_j = \frac{\sum_{i=1}^{N} \left| \left(x_{ij} - x_{ik} \right) \right|}{N}$$

where, x = rank of project i by method j
$i = \{1...N\}$, $j = \{1...15\}$, k = base rank.

Randomly prioritizing projects from the given set contextualizes the MAD. In the rural mobility sub-program, the maximum absolute deviation was 32, and it had a random value

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[5] WSDOT's earliest anticipated budget was $15 million for each of the urban and rural mobility sub-programs. Because preliminary engineering costs are approximately 10 percent of total project costs, the multiple of $150 million was used to determine the program cut-off with TOPSIS-6. (Morin 1995). [Note that the budget level itself potentially influences the sensitivity analysis conclusion, as discussed in section 4.3.]

of 20.67 (i.e., an average of 21 projects changed their rank order out of 64 places in 15 trials). WSDOT's urban mobility sub-program (with 103 projects) produced a maximum absolute deviation of 51.50 and had a random value of 33.34; note how the deviations grew larger as the total number of alternatives increased.The minimum possible MAD is always zero (i.e., exactly the same rank ordering).

Despite the fact that the funding limit used to segment WSDOT's 1995-1997 rank order was hypothetical, the second measure was referred to as the "number previously funded now dropped." It was dependent on the total number of projects and the cutoff line. In the rural mobility sub-program it could range from zero to 29. A value of zero indicated that the same set of projects were in the top 29, although they could be ordered differently, whereas a value of 29 indicated that a totally different set of projects had moved to replace the top portion. The random value averaged 20 over 15 trials in this program (i.e., 69 percent of the maximum value). Similarly, the urban mobility sub-program measure could range from zero to 34, and the random value was 25 (i.e., 74 percent of the maximum). Rankings that showed values close to zero for this measure indicated a priority program robust to that particular input variation.

The third measure was referred to as the "number of additional projects funded." Like the second measure, it was dependent on the estimate used to determine the programming threshold and varied with project mix and the cost range. In the rural mobility sub-program it could range as high as 17 and would always be greater than or equal to -25 given these 64 projects and budget allocations. The random value for the rural set was -9 (i.e., 38 percent of the maximum), and for urban mobility it was about -24 (i.e., 20 percent of the maximum).[6] The urban mobility sub-program's maximum value was, coincidentally,

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[6] The random values reported in this section are all averages over 15 trials of determining the rank ordering with random numbers generated from a uniform distribution that ranged from zero to one.

also 17, and the minimum would be -34 with this particular set of 103 projects. The variation in this measure was primarily dependent on the project cost range. In the urban sub-program for instance, two projects' costs exceeded the anticipated budget limit, whereas four of the highest cost rural projects could be constructed for less than the $150 million budget limit. This would be expected, since the urban sub-program had a much broader project cost range. Therefore, the minimum and maximum values were the best benchmarks.

Result Significance Testing

The simulation experiment produced data consisting of 15 replicate observations of each summary measure of difference across each treatment. There were two treatments: various error levels and unique category weight scenarios. The treatments were applied independently, not simultaneously. In other words, each summary observation recorded the difference of one treatment. The error treatments were applied to one category at a time rather than to all category scores at once. It was a balanced design with no missing data.

Once the summary measures had been calculated, it was necessary to understand whether the rank differences caused by variance in one criteria category were significantly different from the independent effects of the same error levels in another category. One-way analysis of variance (ANOVA) is the most appropriate test for examining the overall simulation effects across treatments. Single t-tests of significance can be used to examine specific hypotheses regarding two certain observations, but not the variability of a whole combined set of observations. Therefore, a multiple comparisons test called the Bonferroni adjustment was also applied.

Five conditions must be met to validate the ANOVA results. First, the sampling must be random; this condition was arranged by design. Second, the error terms must be independently and identically distributed random normal variables; for this study they were, on a log scale, by design. Third, observation variance should be homogeneous as the error

level increases and also, in order to draw inferences or design an interaction analysis, across categories. Levene tests were used to check this condition in every case. If the variances were significantly different, the data could be log or square root transformed to overcome the problem. Fourth, the observations should be normally distributed. The Shapiro-Wilks and Kolmogorov-Smirnov tests were conducted for each error level to examine variate normality. The consequences of non-normality are not too serious unless the distribution for the measure of difference is especially skewed (Sokal and Rohlf 1995). The data may be transformed if necessary to support statistical inference. Fifth, the main effects must be additive. This was assumed by design, although it might be relevant, as discussed in the next section, to investigate categorical interactions.

One final consideration in this simulation framework was that all the input data were positive. Because of the log scale used in applying error, the presence of all positive inputs could truncate the summary measure distributions if the average values were close to zero. Although the score distributions did show this type of characteristic, it did not seem to be a major issue with the MAD. The other two summary measures of difference were often skewed or uniformly distributed but not because of the positive input. Chapter 6 presents the sensitivity analysis results and comments on these points.

5.3 CATEGORICAL INTERACTION ANALYSIS

The kind of categorically independent simulation conducted for this project provides a good foundation for more detailed sensitivity analysis. It was limited in its description of true error incidence because it did not model potential interaction effects. Consider, for instance, how it might be common for a slight underestimate of wetlands encroachment or number of noise receptors to simultaneously increase total project costs and decrease the B/C ratio by a much greater degree than the environmental score would change. If such interactions did occur, the errors might not be additive and so might combine to effect a

much more significant rank order difference than otherwise predicted by the sensitivity analysis for small errors in environmental scores.

Simulating several scenarios of simultaneous error levels would provide replicate data across categories. The two-way analysis of variance test can be used to determine significance of each case when only two main effects are simulated. However, interaction scenarios across several categories with disparate weights are most likely to be relevant. Even interaction between cost-efficiency and the environmental category scores, the case in point, would involve four score categories. Therefore, a 2^k factorial design would be more appropriate.

CHAPTER SIX: SENSITIVITY ANALYSIS RESULTS

This chapter describes and interprets the sensitivity analysis results from the category independent tests and each weight scenario. Section 6.1 compares the mean measure of difference values for each criteria category and error level, while Appendix I contains the box plots and simulation output. Appendix J includes two sample outputs of the associated ANOVA and descriptive statistics, rather than the complete statistical record. Specifically, it contains one output set for 15 percent error applied to each category and one set for each error level applied to the cost-efficiency category.[7] Appendix K contains sample normal probability plots for each common distribution type revealed through these descriptive analyses. Finally, section 6.2 compares charts of the weight scenario results.

Full-scale sensitivity analyses were conducted on the *rural* mobility sub-program because (a) it was smaller than the urban project set and thus required less computation time, and (b) the rank order deviations due to variant project mix were smaller in magnitude for the rural project set than for the urban sub-program (as shown by Barnes 1996). The latter issue was important because WSDOT removed three outlying exceptions of cost-subsidized projects from the TOPSIS input set by executive decision. Consequently, it was difficult to avoid confusing the sensitivity analysis results with the effect of deviations due to project mix when this urban dataset was modelled. For the purpose of comparison, Appendix L contains preliminary results from an urban mobility sub-program simulation in the cost-efficiency category.

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[7] Note that the entire set of descriptive statistics and significance tests is available from the author upon request.

6.1 CATEGORY INDEPENDENT RESULTS

Category independent results encompassed 15 unique measurements per error level of (1) absolute deviation from the 1995-1997 base case, (2) number of previously funded projects that dropped below the funding cut-off, and (3) the number of projects that could be funded in addition to the original top-29 under the same budget allocation scenario. Error was applied to one category at a time, increasing step-wise by 5 percent. Eight different percentage error levels were applied to every criteria category, and seven additional levels (plus one repetition) were applied in the cost-efficiency category. This amounted to 960 total observations (i.e., eight levels times 15 iterations in seven categories, plus 120 extra in the cost-efficiency category).

Statistical examinations of the summary measure distributions for each category showed that in general, the results did not meet all ANOVA testing requirements. Although most absolute deviation distributions were normally distributed, some were borderline or non-normally skewed because of extreme or outlying values. The count data for the other two summary measures were more likely to consist of two to three unique values than to be normally distributed. With one exception (the wetlands category), homogeneity of variance tests for the absolute deviations showed that observation variance was not equal across percent error levels or at the same error level across different categories. Likewise, observation variances were heterogeneous for both of the "number of projects" summary measures. Still, because the ANOVA test was robust to both of these two deviations and because the simulation was designed to meet all the other requirements, the significance tests were indeed carried out as demonstrated in Appendix J.

In fact, ANOVA tests revealed significant differences among observation means in every case, both across categories for single error levels and across percent error levels in single categories, and by a wide margin. Therefore, the Bonferroni muliple range tests (i.e., modified least squared difference test with 95 percent confidence) proved to be critical

in revealing which category subsets were homogeneous and, consequently, between which subsets the paired means were significant. The results were charted by increasing percentage error level; Figures 14, 15, and 16 show the mean absolute deviations, and the bar charts of Figures 17 and 18 summarize the two mean "number of projects funded" measures.

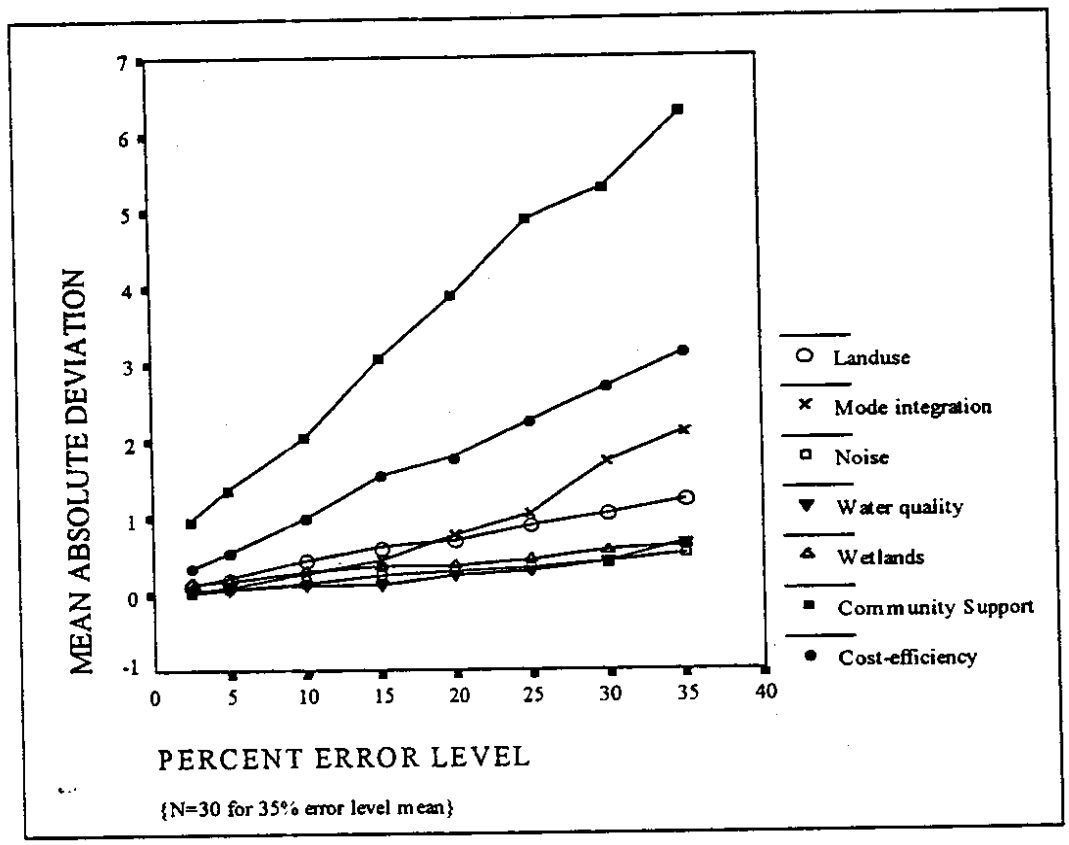


Figure 14. Mean Absolute Deviations in Rank by Percent Error Level

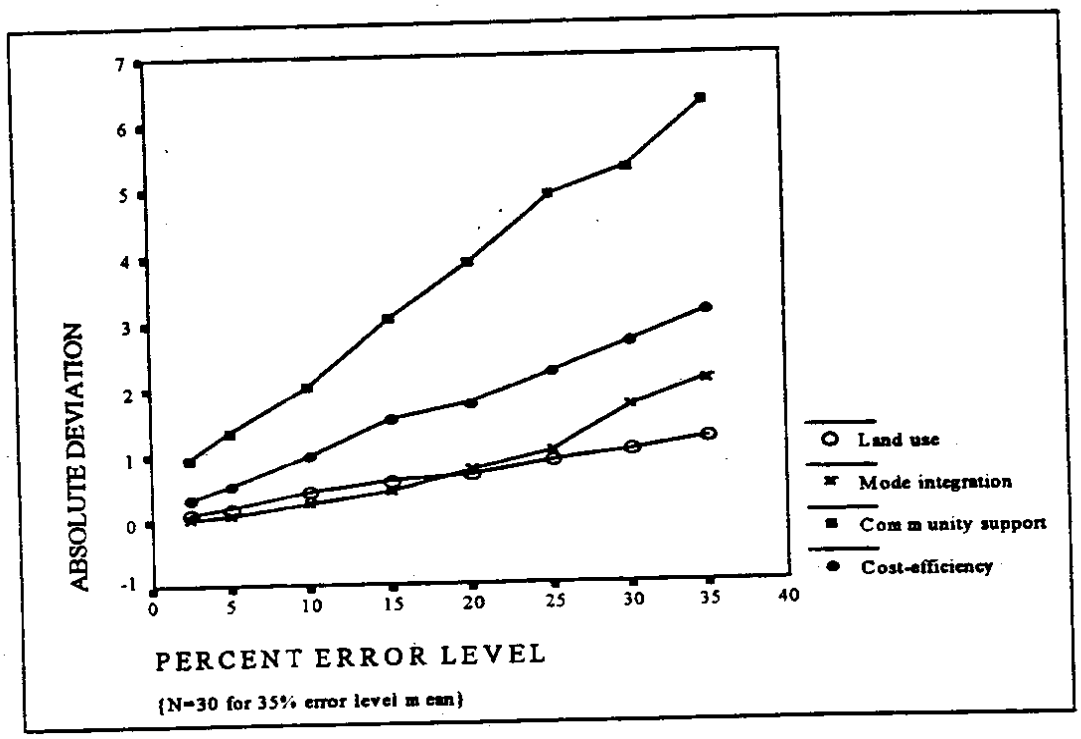


Figure 15. Summary of Four Categories with Greatest Mean Absolute Deviations

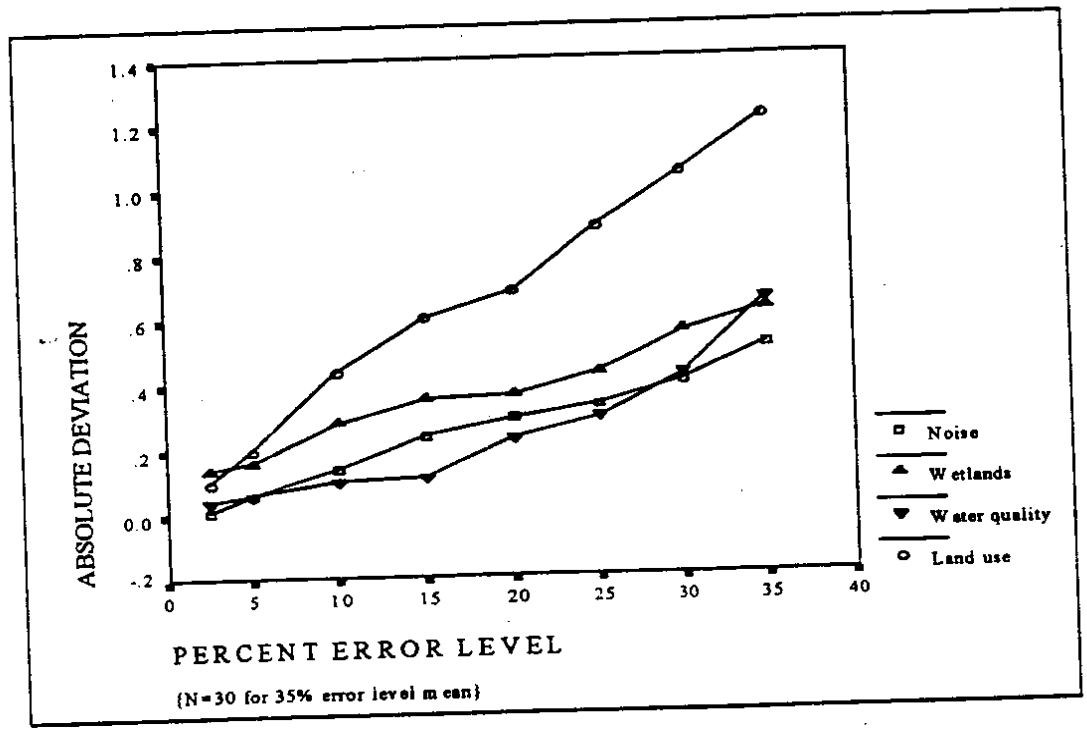
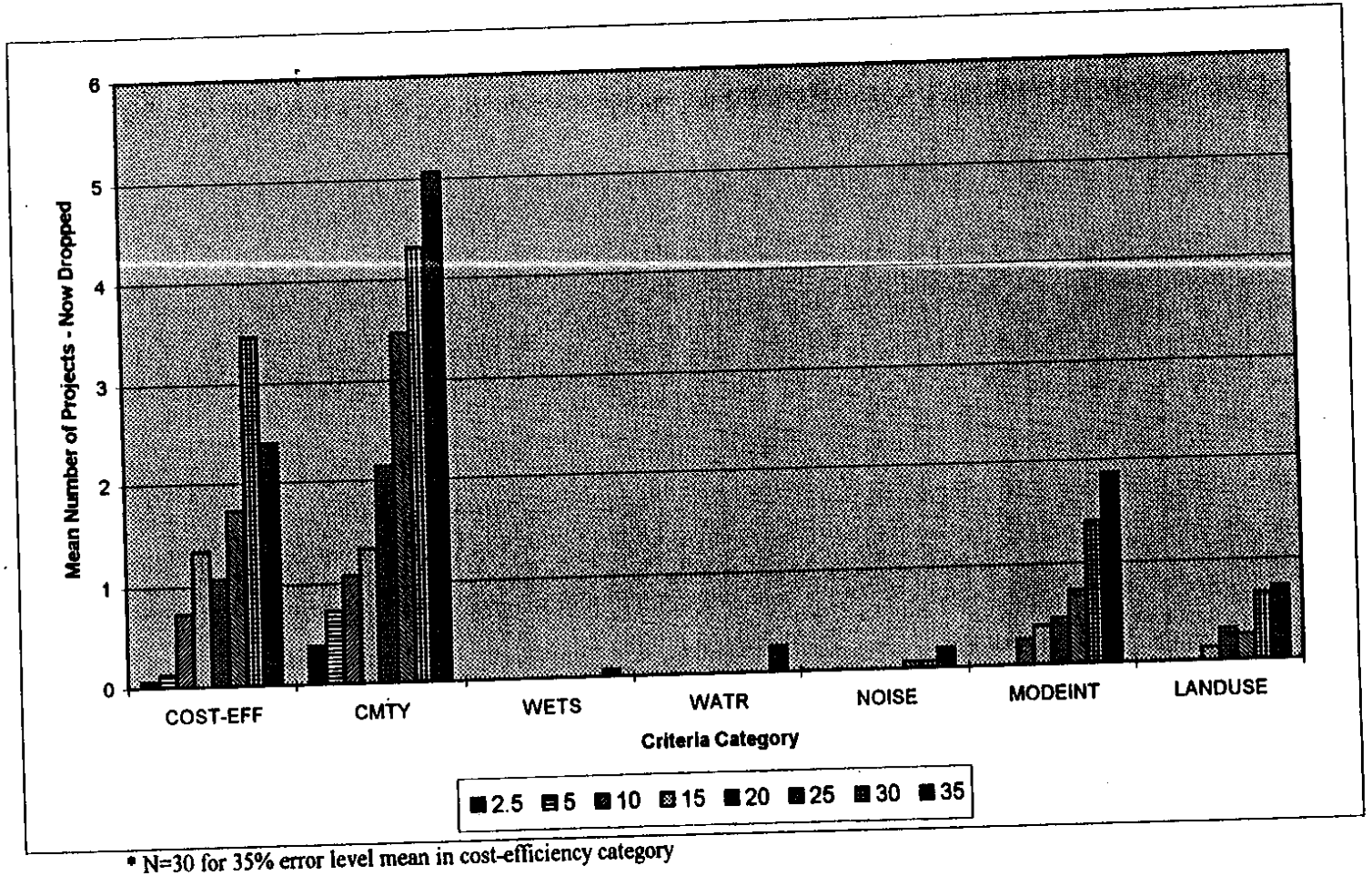
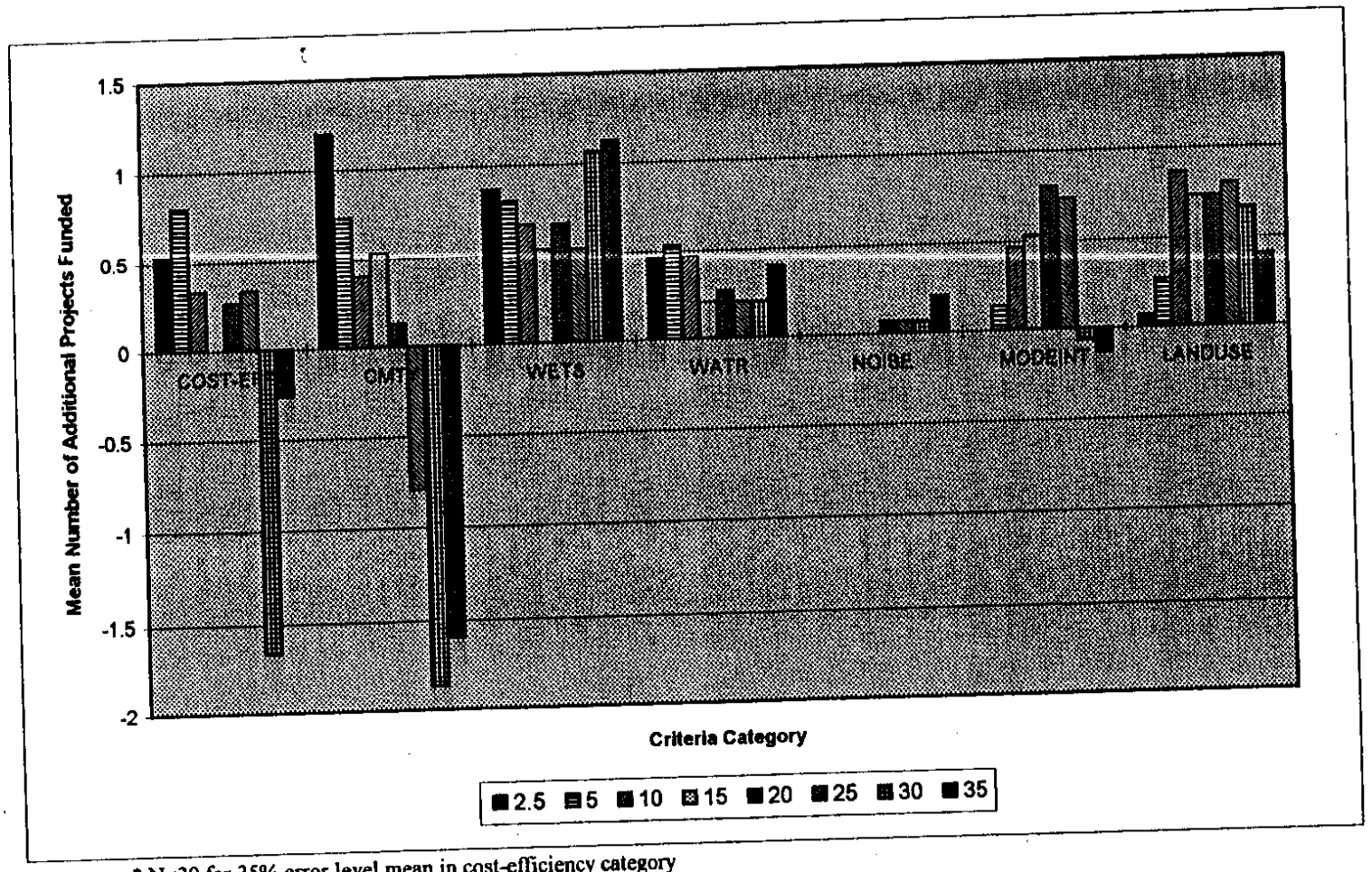


Figure 16. Summary of Four Categories with Lowest Mean Absolute Deviations



* N=30 for 35% error level mean in cost-efficiency category

Figure 17. Mean Number of Previously Funded Projects - Now Dropped



* N=30 for 35% error level mean in cost-efficiency category

Figure 18. Mean Number of Additional Projects Funded

The following conclusions were true in every case:

- Project rank order was most sensitive to (i.e., encountered the greatest rank deviations with) community support input error.
- Cost efficiency was the second most sensitive category.
- There was no significant difference between 2.5 and 5 percent error in any category; associated rank order deviations were noticeable only for the cost-efficiency and community support categories.

Other interesting conclusions include the following:

- Cost-efficiency category—Sensitivity differed between every error level except 2.5 to 5, and 15 to 20 percent.
- Community support category—Sensitivity differed between every error level except 2.5 to 5, and 25 to 30 percent.
- Environmental categories had homogeneous sensitivity with >5 percent error; this sensitivity was significantly lower than all other categories in error simulations of >20 percent.
- Wetlands category—Sensitivity at error levels of >5 percent significantly differed from all other error levels except the two nearest (in magnitude). Except at 35 percent error, wetlands scores were the more sensitive than the other two environmental categories. With small errors, rank order deviations were greater than in mode integration or land use simulations.
- Water quality and permitting category—Sensitivity at error levels of >15 percent significantly differed from that caused by all other error levels except the two nearest (in magnitude).
- Noise category—Though there were several overlapping homogeneous subsets in this category, the 20 percent error level was a reasonable

breaking point in terms of significant differences in sensitivity occurring between levels ≥ 20 percent and those ≤ 20 percent.

- Mode integration category—Sensitivity due to error levels of <15 percent did not significantly differ, while 30 and 35 percent errors caused significant differences from all other levels.
- Land-use category—Sensitivity differed between every error level except 2.5 to 5, and 15 to 20 percent (same as with cost-efficiency).
- The range of rank order deviations never changed by more than 25 percent in the wetlands category. It doubled by 10 percent error in mode integration and land use, by 15 percent error in cost efficiency, and by 25 percent in the other three categories.
- The magnitude of rank order deviations ascended in the same order as increasing category weight with error levels of >15 percent—*except* for the top two (i.e., low to high: environmental, land use, mode integration, cost efficiency, community support).

6.2 SENSITIVITY TO CATEGORY WEIGHT

Nine different category weight scenarios were conducted as descibed in section 5.2 (i.e., two types of weight redistribution under four different scenarios, plus a fifth). Depending on the particular scenario, the results encompassed one unique iteration per percent reduction level, criteria category, or combination thereof. All three summary measures were computed for each iteration. This amounted to 138 observations based on the rural dataset. Error was not applied; hence there were no random elements in this experimental design, and it was inappropriate to run significance tests on the summary measure observations. Absolute differences from the WSTC's 1995-1997 weight

distribution (see Table 2 for original weights) were compared in terms of magnitude and measure range, as recorded in Table 7 and discussed in section 6.1.

Note that lower differences are to be expected with the proportional technique of formulating the weight scenario because the even distribution method is not related to the original weight assignment and does not constitute a *re*distribution of weight. For this reason, the proportional results inform the effect of relative weight relationships, while the even distributions provide information on how the hierarchy of category weights affects rank order.

Figure 19 contains the results of one of the more subtle modifications to the original WSTC weights. The cost efficiency weight was incrementally reduced by removing 5 percent. As expected, the absolute difference was greater in magnitude and less variable when the remaining weight was evenly (simulation #1a, Figure 19) than when a proportionate redistribution was measured (simulation #1b, Figure 19). The proportionate results shared approximately the same range as the mean cost-efficiency values at ≤ 35

*Table 7. Distribution Limits for Study Measures of Difference**

Mobility Sub-program Measure of Difference	Distribution Limit		
	Minimum	Random Value	Maximum
RURAL			
Mean Absolute Difference	0	20.67	32
No.Previously Funded - Dropped*	0	20	29
Number Additional Funded	-25	-9.13	17
URBAN			
Mean Absolute Difference	0	33.34	51.50
No.Previously Funded - Dropped*	0	25	34
Number Additional Funded	-34	-24.13	17

* These limits are only relevant for a budget allocation of $150 million. All are particular to the project sets.

percent error. At least one project changed in the funded set with every incremental percent studied. The number of changes appeared to be smaller yet to accumulate more steadily with proportional redistribution.

Simulations #2 and #3 (Figures 21 and 22), on the other hand, explored large modifications to WSTC's categorical weight scenario. Each category was modelled as the most heavily weighted criteria, with 70 or 50 percent of the weight in turn. Likewise, each category was effectively eliminated from the mobility prioritization method by setting the weight equal to zero, one category at a time. Note that removing 15 percent of the original cost efficiency weight, as done in the first simulation, corresponded directly to assigning 50 percent in that category (simulation #3a, Figure 21).

As might be expected, rearranging the category weight this dramatically resulted in some of the greatest differences of any simulation. In fact, simulation #2a (Figure 20) showed that all three summary measures began to approach the rural sub-program random values (refer to Table 7) when 70 percent of the weight was assigned to community support, mode integration, or land use, with the rest evenly distributed.

Of course, using proportionate redistribution as in simulation #2b (Figure 20) did produce smaller deviations, though they were still greater in magnitude than the mean values for either 20 percent error in community support or 50 percent error in cost efficiency. The difference was especially pronounced with the "number of projects" measures when 70 percent was assigned to categories other than cost efficiency. By referring to Figures 17 and 18, notice that the number of projects "previously funded - now dropped" in simulation #2b (Figure 20) ranged from 1.8 to 29 times greater than the number dropped because of applying error in the WSTC base case (i.e., community support and wetlands score comparisons, respectively). Notice also that the number of "additional projects funded" ran up to 13 times greater than in the base case (i.e., land-use score comparison). This increase in number was so large because the environmental

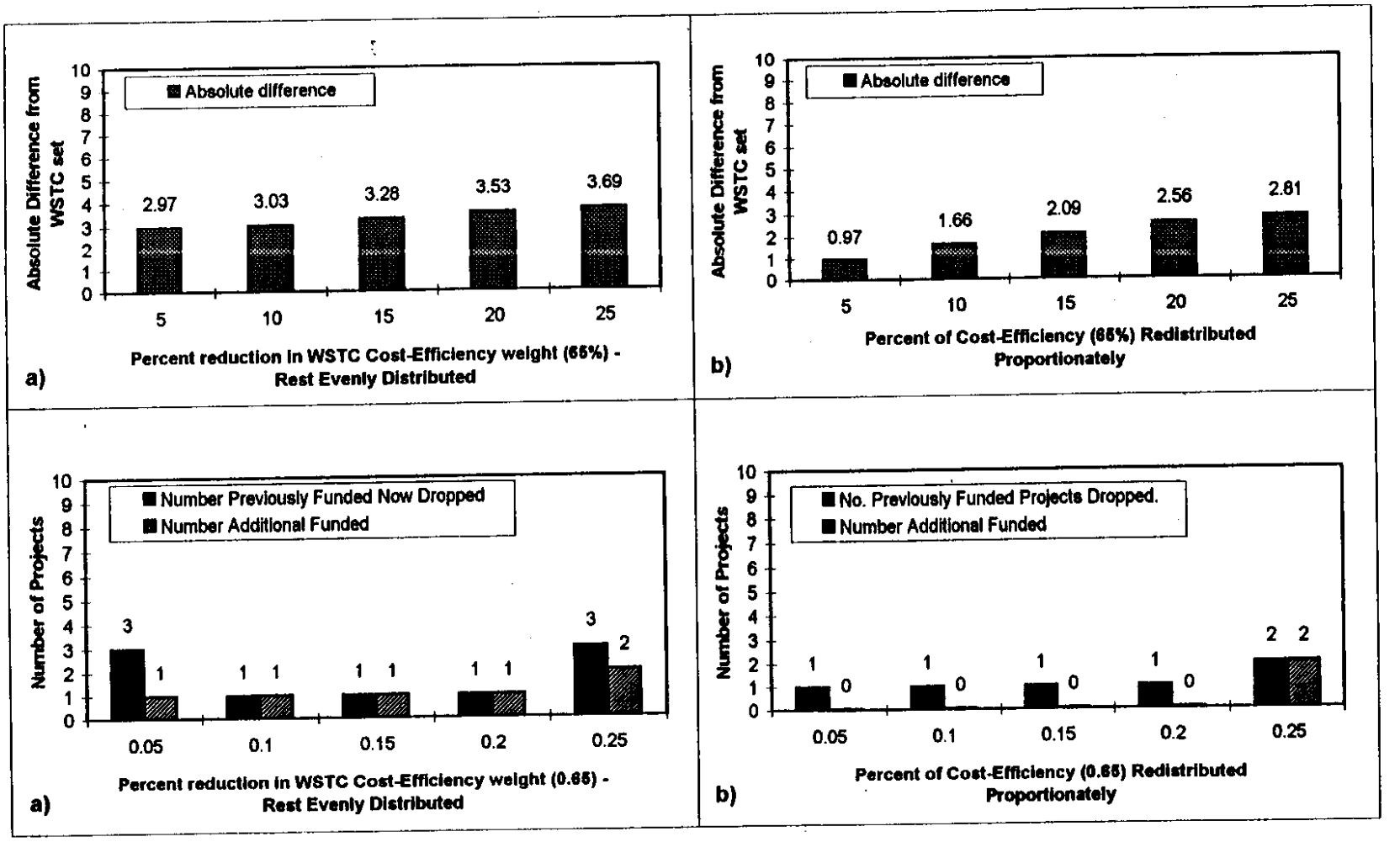


Figure 19. Weight Simulation #1 Results

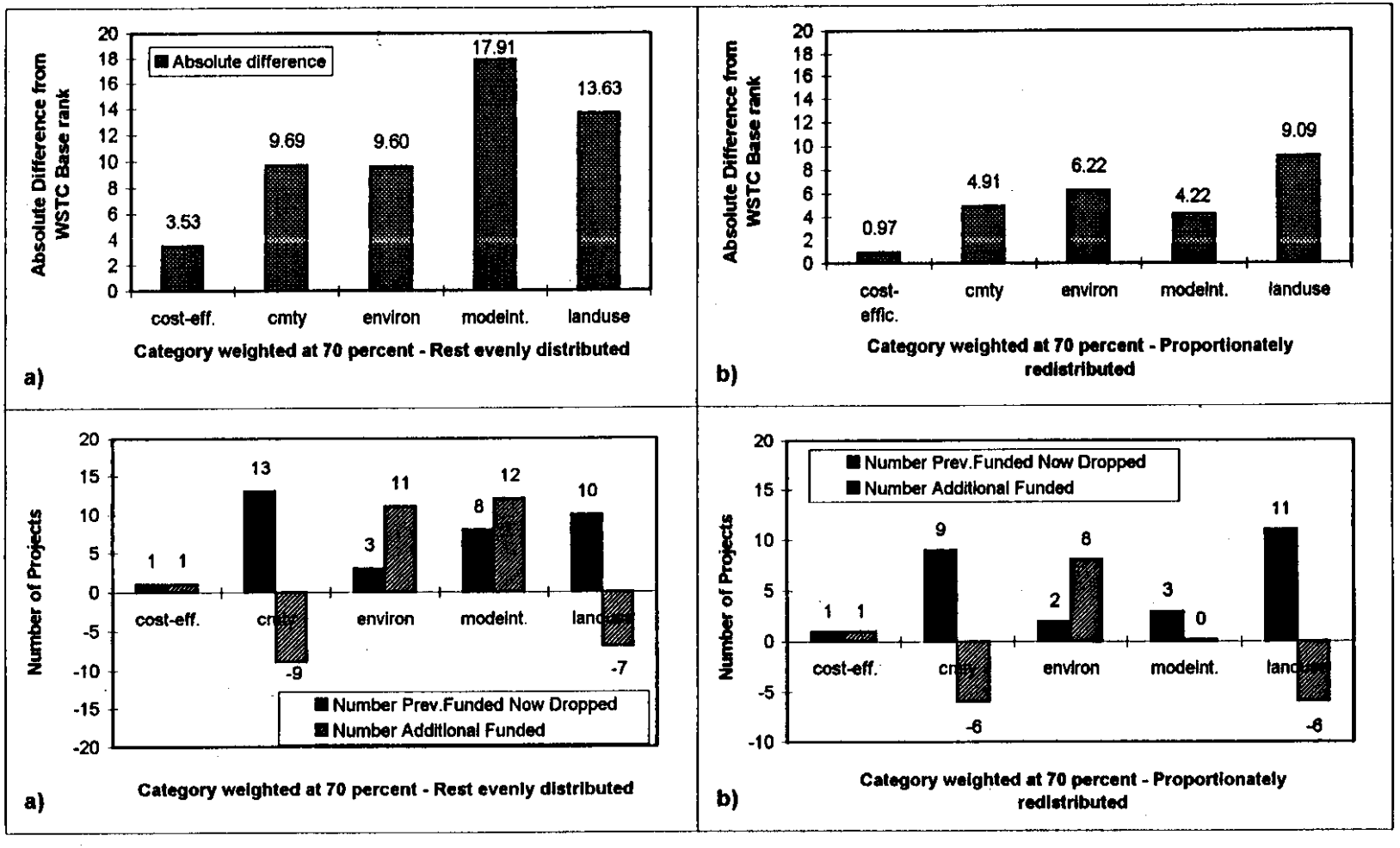


Figure 20. Weight Simulation #2 Results

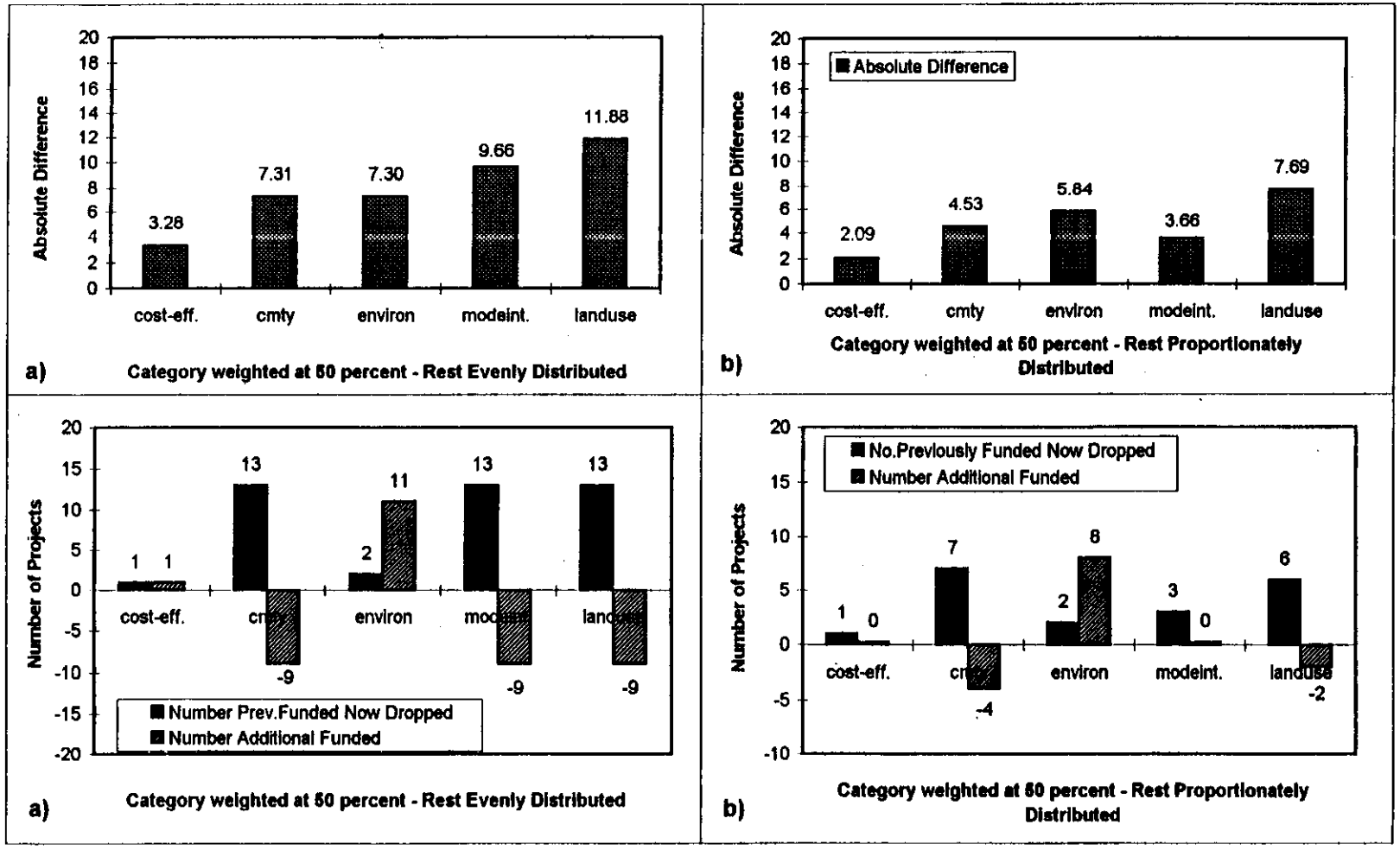


Figure 21. Weight Simulation #3 Results

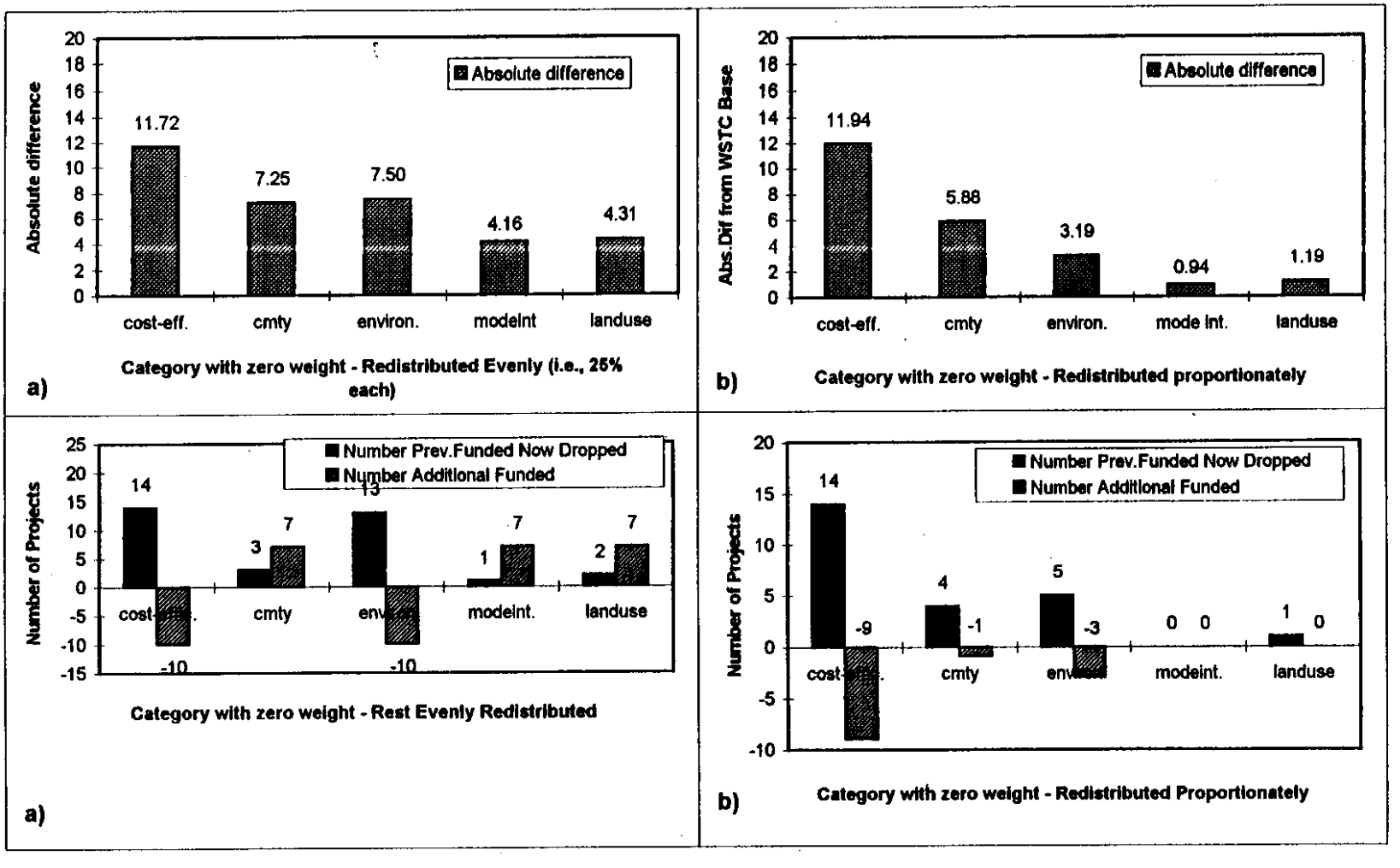


Figure 22. Weight simulation #4 Results

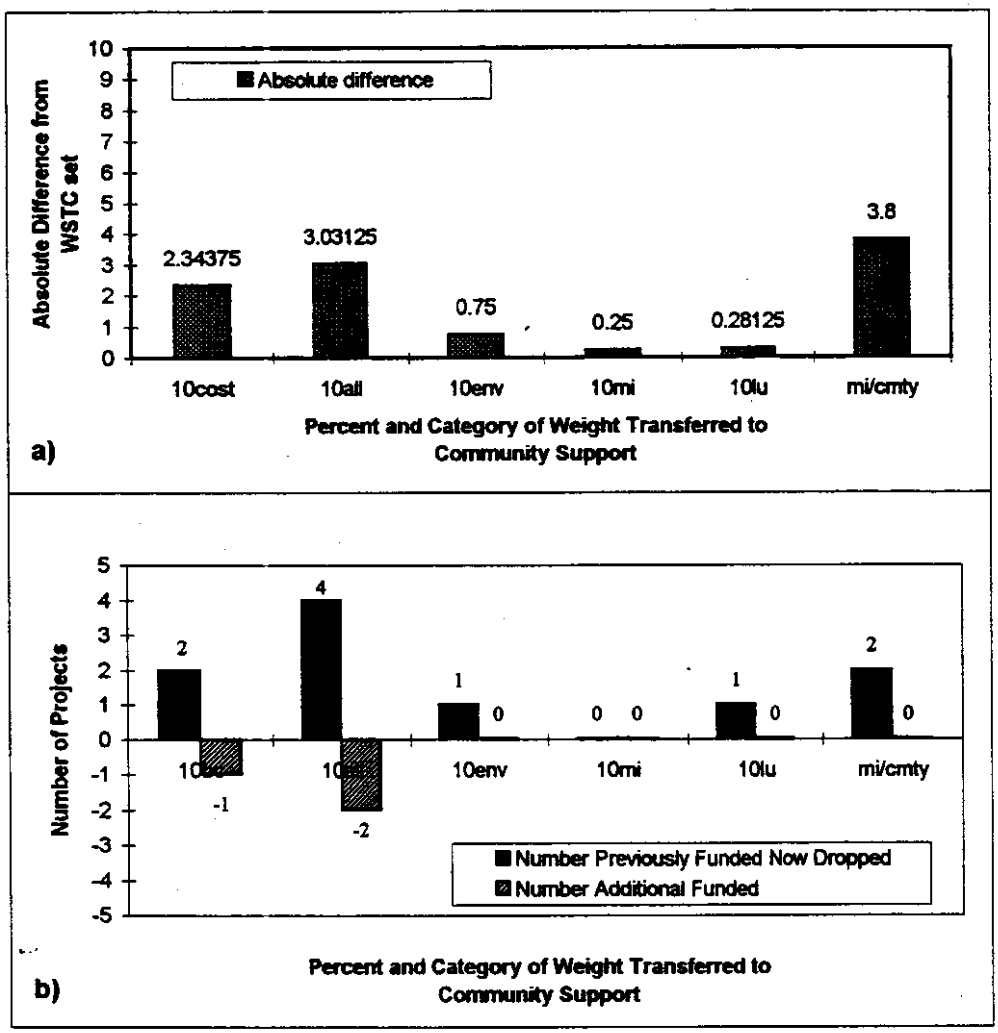


Figure 23. Weight Simulation #5 Results

categories did not cause much change in the funded set of projects when they carryied less than 3 percent of the weight, as in the original WSTC application. Simulation #3b (Figure 21) reflected the same effects to a somewhat lesser degree.

Not surprisingly, simulation #4 (Figure 22) showed that dropping a category altogether generally caused rank order deviations, dependent on the original magnitude of weight. Thus, eliminating either the mode integration or land use categories would cause the least difference from the existing WSTC base rank. Note, however, that while both of these two categories produced especially small absolute deviations (i.e., approximately equal to 1.0) and at most one difference in the top, "funded" portion of the project set, the three environmental categories appeared to be much more sensitive to changes in weight even though altogether they carried only 1 percent more of the total weight (see Table 2). Last, simulation #5 (Figure 23) was designed to examine the effect of increasing the weight of the most error-sensitive category (i.e., community support). Because community support was also the second-most heavily weighted category, simulation #5 further examined the effect of switching its weight with that of the third-most heavily weighted category (i.e., mode integration). Interestingly, the project rank order was robust to changes in the community support weight up to 50 percent. At least this result held if the proportions were approximately maintained by transferring only 10 percent of each other category's weight (see "10all" in Figure 23), or as in the mode integration-community support categorical weight trade (i.e., "mi/cmty" in Figure 23).

Clearly, it is very important that decision makers be very certain of at least the hierarchy of category weights. Given that certainty, the proportionate redistributions and simulation #1b showed that cost efficiency was comparatively robust (i.e., with absolute deviations of ≤ 3.5 with only one shift out of the funded set, Figure 19) to transfers of up to 15 percent its original weight. Another interesting conclusion is that the community support and land-use criteria seemed to consistently favor more expensive projects than did

cost efficiency criteria (e.g., at a category weight of 50 percent seven projects were dropped and four fewer projects were funded with the same budget, simulation #3b, Figure 21). On the other hand, environmental criteria tended to favor lower cost projects than did cost efficiency measures (e.g., at a category weight of 50 percent two projects were dropped while eight additional projects were funded instead, simulation #3b, Figure 21).

6.3 INFERRED SIMULATION INTERACTIONS

Comparing the weight simulation results to those of the category error simulations was important for contextualizing these various sensitivities. It also assisted in characterizing the meaning of absolute difference in rank order. So even though the experiment was not designed to explicitly test such interactions, several characteristics were inferred.

First, the absolute differences due to errors as high as 35 percent in cost efficiency (i.e., with a mean of 3.0, Figure I-1) are approximately the same magnitude as the absolute differences caused by incrementally removing and redistributing weight from cost-efficiency to the other four categories (i.e., weight simulation #1b, Figure 19) and likewise, from each other category to community support (i.e., weight simulation #5, Figure 23). This was not surprising because, at 65 percent of the total weight, cost efficiency was expected to have the greatest influence on project rank order. However, at 35 percent these error sensitivities were not the highest deviations produced in this study.

Project rank order, as shown in section 6.1, was actually most sensitive to errors in estimating community support. Thus, a second and contrary characteristic is that the range of absolute differences produced by simulating errors in community support is most closely associated with the range observed by alternately assigning each category 50 percent of the total weight (i.e., weight simulation #3b, Figure 21). In other words, its sensitivity is associated with a scenario that tests an altogether different weight hierarchy among

WSDOT's five categories. The magnitude of differences observed in community support with this kind of weight distribution ranged from 4.5 to 8.1, with a mean absolute difference at 35 percent error equal to 6.28 (Figure I-4).

A third characteristic is that all the error sensitivities tested for the environmental categories, mode integration, and land use are lower in magnitude than those caused by all but the smallest modifications to the original WSTC distribution of category weight. The absolute differences found in these categories were all less than 2.0. In other words, up to 35 percent error, the category independent sensitivity was lower than that observed in 38 of the 46 unique weight scenarios modelled in this study.

Finally, one goal of this research was to evaluate whether there might be a minimum acceptable error level beyond which the rank order becomes unstable. Because none of the error sensitivities revealed by this study were close to random (i.e., the magnitude of absolute difference in rank order that corresponds to random project selection, Table 7), the term "acceptable" can only be defined subjectively, or by simultaneously examining the weight sensitivity levels. As discussed in section 6.2, weight simulations with absolute differences of ≤ 3.5 can be considered comparatively robust. If we were to apply this as an "acceptable" limit of rank order difference, the resulting recommendation would be to accept scoring errors up to

- ~ 15 percent in community support
- ~ 40 percent in cost-efficiency estimates
- potentially well over 35 percent in environmental, mode integration, and land-use categories.

6.4 INTERPRETATION ISSUES

First, it is important to highlight a bias introduced by one of the Visual Basic subroutines used to carry out the simulations. Before moving out of the random number

generation loop in the "VaryErrorChange" macro, the "CheckZero" subroutine stepped through each original score and added 0.5 to every zero value. This was necessary to ensure that every project score received some level of multiplicative error; zero values would otherwise have remained unchanged. Therefore, the changes in rank were slightly exaggerated in every category except cost efficiency. The subroutine was unnecessary in the cost efficiency category because benefit-cost ratios are never equal to zero. Furthermore, adding 0.5 to ratios originally near to 1.0 could significantly change the interpretation of efficiency because of the intrinsic meaning of the ratio (i.e., a B/C originally equal to 0.7 would become equal to 1.2 and then appear to possess more benefits than costs). However, the different subroutine for adding errors to cost-efficiency scores did not appear to accentuate the magnitude of absolute deviations enough to alter the descending order of sensitivity category-wise (i.e., enough to switch the MAD of the top two categories so as to fall in line with descending category weight). The effect of this subroutine exaggeration on the two "number of projects" measures was indeterminate. However, the consequences for interpreting the results overall are thought to be minimal.

Second, only one budget level was used in these error simulations. As previously discussed in section 4.3 the allocation magnitude can affect rank order sensitivity enough to suggest completely different conclusions (e.g., Miller et al. 1987). Although the selected budget scenario modelled did correspond to the actual allocation approved by the WSTC in 1995, in no way does it constitute a standard. Thus, before WSDOT considers any modifications to its process, it is highly recommended that several other budget scenarios be similarly modelled.

Despite these two interpretation issues, the fact remains that community support was the most sensitive category at this budget level. One potential cause of this unexpected result was the large variety in score range and shape of the criteria score distributions, as described in section 4.2. It seems that adding error to categories with relatively normal

score distributions may cause a greater shuffle in project rank order than when error is added to a highly a-normal distribution. This would make sense because in a highly leptokurtic distribution (such as exists for the noise category) the majority of project scores are very far apart from the positive or negative-ideal drawn out of the extreme tails of the distribution. In this type of scenario, even large percent errors would not affect the scores in the tails but would be likely to greatly shuffle the majority group of project scores. The converse is also true. That is, when the scores are normally distributed or when the score range is small, the positive- or negative-ideals are more likely to be defined by different projects than in the base case. On this basis, it is not surprising then that community support (the most normally distributed sets of scores) was the most category most sensitive to error.

CHAPTER SEVEN: PRIORITIZATION METHOD COMPARISONS

This chapter describes the method designed to compare three separate but overlapping sets of project prioritization results: (1) Puget Sound Regional Council's STP and CMAQ regional rank, (2) WSDOT's systems planning rank as applied in the Puget Sound region, and (3) WSDOT's mobility program rank. Chapter 2 describes the first two methods, and the third, referred to throughout this report, constitutes the case study. The figures in this chapter are merely summaries of fact. Section 7.2 briefly discusses the implications for regionally coordinated decision making.

7.1 RANK CORRELATION METHOD

The main element guiding these comparisons was that the project sets were not equal in size, nor were they evaluated by the same criteria or ranked with the same algorithms. Only a subset of projects from each prioritization were found to have been ranked by one or both of the other two methods as well. The objective was to describe the correlation in ordinal rank among the subsets. Non-parametric tests for significance of association were used to compare the projects' ranks. Spearman's (r_s) and Kendall's (τ) rank correlation coefficients were the two sample statistics.

Spearman's coefficient gives greater weight to largely disparate paired ranks, whereas Kendall's coefficient weights each difference in rank equally. If there is uncertainty about the reliability of close ranks, then Spearman's is probably a better measure, and vice versa. However, in testing the coefficients for significance, the normal approximation for τ, is considered to be more accurate than for r_s even though the difference is small with more than ten observations (Sokal and Rohlf 1995). Both rank correlation measures are reported here and range from +1 to -1, either of which indicates a

perfect linear relationship between the ranks of the two variables; zero is a perfectly random value. The formulae are as follows:

Kendall's:

$$\tau = \frac{N}{n(n-1)} = \frac{4\sum_{1}^{n} C_i - n(n-1)}{n(n-1)}$$ by the conventional method.

Spearman's:

$$r_s = 1 - \frac{6\sum_{1}^{n} (R_i - R_j)^2}{n(n^2-1)}$$ for paired variables.

where n is the number of observations, C_i is a count of the number of higher ranks following any given rank, and R is the ordinal rank of a project as prioritized by method i or j.

In keeping with the focus of this case study, WSDOT's mobility project list was used as the basis for comparison. The PSRC and systems planning project lists were cross-referenced against the WSDOT mobility project list; project descriptions and cost estimates were used to identify corresponding projects. In some cases, the adjoining projects were staged differently on the separate lists. When two or more project scopes were summarily equivalent to that of another, more aggregated project, they were both compared to its ordinal rank as though a tie. Where such equivalence could be debated or the descriptions were indeterminate, the projects were removed from the corresponding subsets. A few WSDOT projects that lacked additive technical and policy systems planning scores were also eliminated from the comparison. In this way, the number of projects in common was be a bit underestimated across the three sets, but error was minimized.

This chapter analyzes the WSDOT systems planning method applied to projects in the four-county Puget Sound planning area. Because this area includes part of two separate WSDOT regions and urban as well as rural areas of these counties, the different program

boundaries had to be taken into account. Therefore, one set of comparisons was made between the systems planning rank and the statewide urban mobility rank, while a second set compared the systems planning rank to a regional mobility rank. This regionally sorted set, consisting of urban *and* rural mobility improvement projects within the four-county region, was re-prioritized by TOPSIS-6. Thus, the statewide urban mobility program shared 46 projects in common with the systems planning list, while the newly defined regional mobility project set had 51 projects in common with systems planning. Eleven mobility projects were also submitted as STP or CMAQ proposals in the Puget Sound. Two of these eleven projects were located in rural areas. So, to avoid an excessively small sample size, PSRC's prioritization was compared only to the regionally adjusted WSDOT mobility prioritization.

7.2 RESULTS AND INTERPRETATION

Table 8 summarizes the paired results; mean absolute differences are included for purpose of comparison with chapter 6. Interestingly, most pairs showed highly random rank correlations and none were significantly correlated.[8] As expected, the mean absolute differences were smaller in magnitude than the random value for sets of 64 projects (i.e., 20.67) and did not vary much. Note that both characteristics limit the usefulness of a mean absolute difference (MAD) as a measure for small project sets (e.g., with the PSRC subset of eleven projects).

Of the large samples, only the regionally prioritized set of mobility projects (i.e., Puget Sound Region Mobility) approached a generally accepted significance level chance

[8] McFarland and Memmott's (1987) research provides additional context for these across-method rank correlation results. They found significant positive correlations between each pair of the prioritization methods they tested: a sufficiency rating, a priority formula incorporating sufficiency ratings, and a benefit-cost analysis technique. Nearly 2000 added-capacity projects of the Texas state DOT were examined.

Table 8. Rank Correlation Statistics by Prioritization Method

Prioritization Method	Systems Plan			PSRC	
	Combined	Policy	Technical	Screening	Technical
STATEWIDE URBAN MOBILITY				n/a	n/a
Number of Projects	46	46	46		
Mean Absolute Difference	15.24	15.02	15.7		
Kendall's τ	0.0460	0.0710	-0.0538		
Significance (p)*	0.656	0.499	0.602		
	(random)	*(random)*	*(random)*		
Spearman's r_s	0.0795	0.0825	-0.0563		
Significance (p)*	0.599	0.586	0.710		
	(random)	*(random)*	*(random)*		
PUGET SOUND REGION MOBILITY					
Number of Projects	51	51	51	11	7
Mean Absolute Difference	15.54	15.73	16.43	2.18	2.43
Kendall's τ	0.1269	0.1136	0.0158	0.4114	0.000
Significance (p)*	0.193	0.253	0.871	0.083	1.00
	(0.80 level)		*(random)*	*(0.90 level)*	*(random)*
Spearman's r_s	0.1914	0.1477	0.0254	0.5413	-0.0180
Significance (p)*	0.179	0.301	0.860	0.085	0.969
	(0.80 level		*(random)*	*(0.90 level)*	*(random)*

* Correlations are determined to be "random" if significance level is $\leq$ 0.50; usually accept H_0 at $\leq$ 0.95.

across any paired comparison, where 0.95 is the most broadly accepted level of significance. Even in these cases, there was an approximately 10 to 20 percent chance that two random distributions would positively correlate this well. Otherwise, overwhelmingly random relationships existed for every combination between the systems planning and mobility improvement methods. In fact, the best correlation overall existed across agencies, as the PSRC regional project evaluation screening scores and WSDOT's mobility rank order were significant at the 0.90 level. Figure 24 illustrates this relationship, and Figure 25 is a scattergram of the PSRC technical scores and WSDOT's regional mobility rank. A comparison of the two clearly emphasizes the need for a larger sample size precisely because the two do not appear to be, by visual inspection, very different, although the

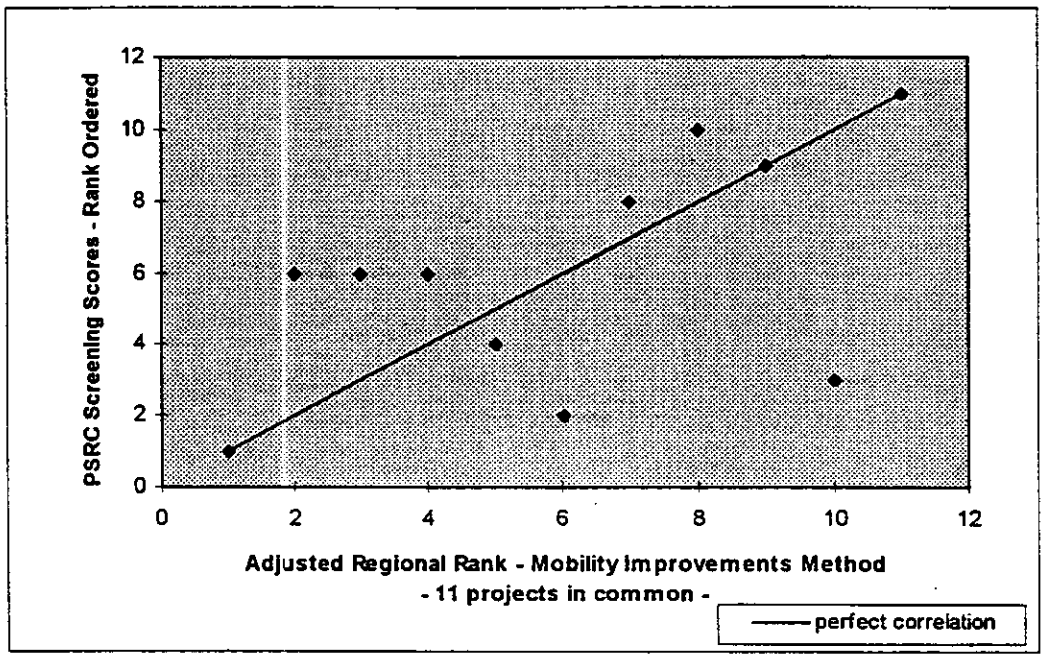


Figure 24. PSRC Screening Scores vs. Mobility Improvement Method

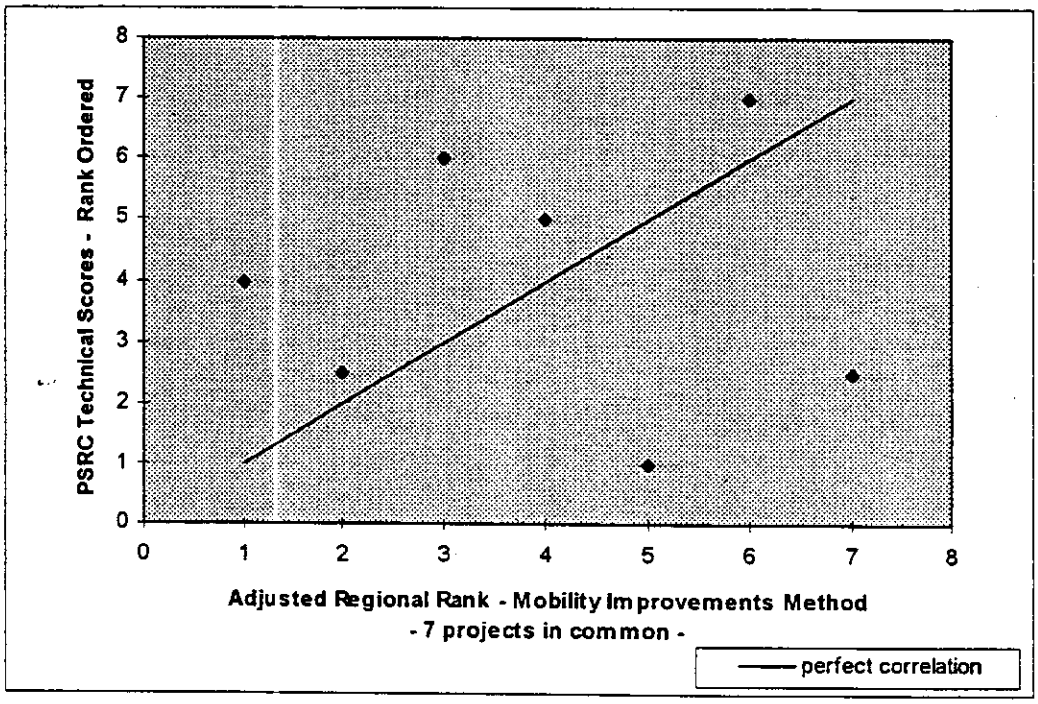


Figure 25. PSRC Technical Scores vs. Mobility Improvement Method

scattergram (i.e., the projects in Figure 25) conversely depicts a perfectly random correlation. Still, these initial results were rather surprising since the PSRC may have many good reasons to be using the STP and CMAQ funds to implement quite different regional priorities than would WSDOT with projects in the mobility program. However, it seems reasonable to expect greater correlations in rank between two sequential methods in the same agency (i.e., between WSDOT's mobility and systems planning evaluation methods).

Project Type Preferences

Figures 26, 27, and 28 illustrate other interesting qualitative differences among the WSDOT prioritization methods. According to long-range plans, every project in the regional mobility subset was identifed as an urban core, urban fringe, or rural area project. On this basis, the scattergrams were analyzed by quadrant to reveal methodological preferences for certain types of projects (Table 9). The trends were strong and obvious.

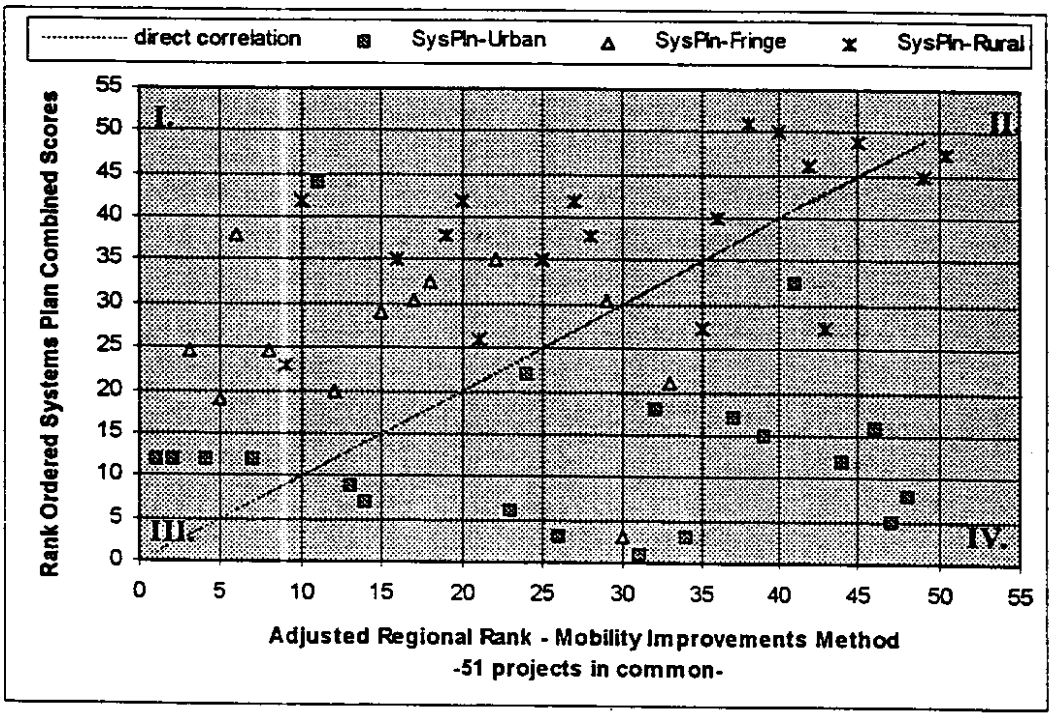


Figure 26. Systems Plan Combined Scoring vs. Mobility Improvements Method

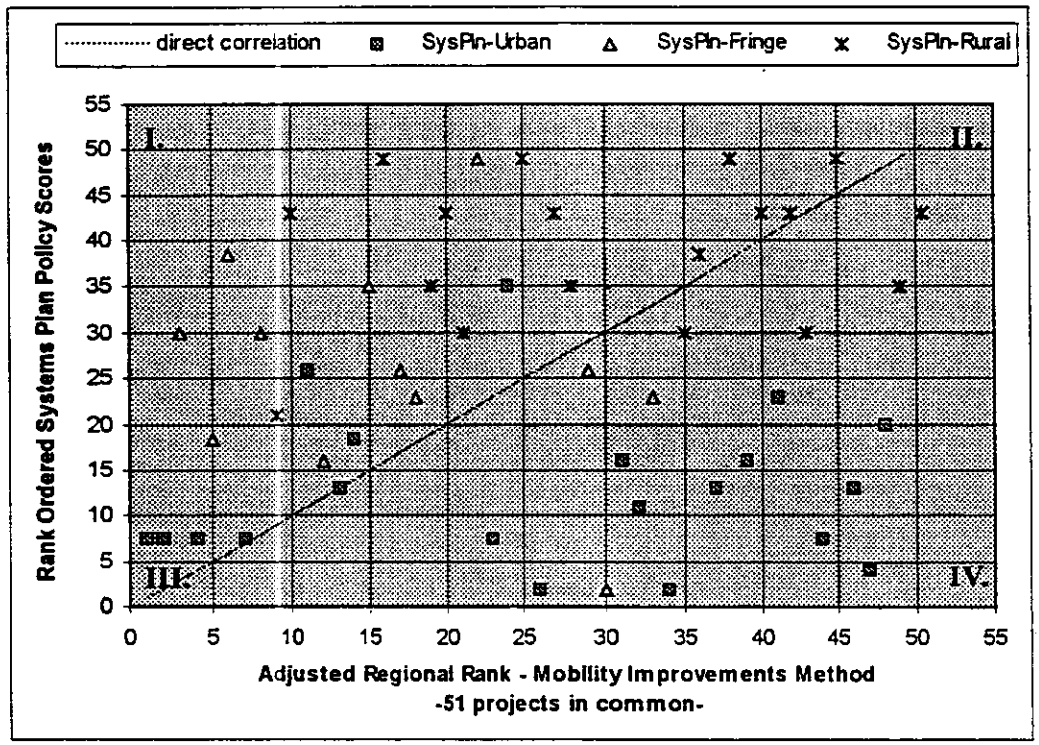


Figure 27. Systems Plan Policy Score vs. Mobility Improvements Method

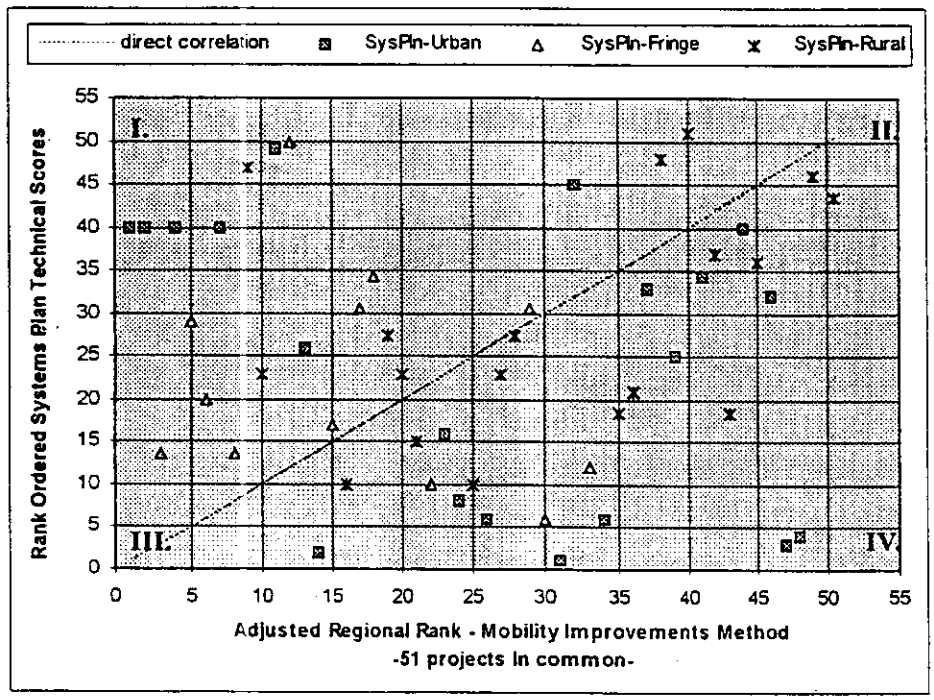


Figure 28. Systems Plan Technical Score vs. Mobility Improvements Method

Table 9. Quadrant Analysis of Scattergrams

WSDOT Prioritization Method	Number of Projects†			Ratio (High to Low)
	High	Intersecting with median line	Low	
*Mobility Improvements Method**				
Quadrant numbers	I, III		II, IV	
Urban core	9	-	11	0.82
Urban fringe	9	-	3	3.0
Rural	6	1	11	0.55
*Systems Planning Method***				
Quadrant numbers	III, IV		I, II	
Combined Scores:				
Urban core	18	-	2	9.0
Urban fringe	6	-	6	1.0
Rural	1	-	17	0.06
Policy Scores:				
Urban core	18	-	2	9.0
Urban fringe	5	-	7	0.71
Rural	1	-	17	0.06
Technical Scores:				
Urban core	8	1	11	0.73
Urban fringe	7	-	5	1.4
Rural	9	-	9	1.0

† Proportionately, the compared set includes 40% urban, 24% urban fringe, and 36% rural projects.

* Based on prioritization by TOPSIS-6 of 51 projects in the Puget Sound four-county region set.

** Method described in section 2.1.

First, the mobility prioritization method clearly favored projects in the urban fringe. Nine of 13 urban fringe projects consistently lay in quadrants I and III, without changing when the statewide urban project set was evaluated. Urban core and rural projects were more evenly distributed across the dividing line. Meanwhile, urban fringe projects were equally distributed between high and low quandrants when rank ordered by the systems planning combined scores; this rank order balance only shifted by one project between policy and technical scores. Second, urban *core* projects were strongly favored by the systems planning policy and combined scoring processes, whereas rural projects were strongly disfavored, and urban fringe projects were evenly distributed (Figures 27 and 28).

Third, as might be expected, the technical scoring process more evenly distributed each type of project across high and low quandrants. Together with the aforementioned methodological trends, it is interesting to consider the fact that the least random rank correlation of this pair existed between the regional mobility improvements prioritization and the systems planning *combined* scores.

Internal Rank Correlations

As previously mentioned, and for reasons discussed by Barnes (1996) WSDOT's mobility prioritization method is noticeably sensitive to project set variations. Table 10 records the scoring or project set correlations internal to each method. Note that although significant, the statewide and regional mobility project rankings were not perfectly linear. It is also interesting that the rank order correlations between the policy and combined systems planning scores were nearly twice as great as than between the technical and combined scores. Obviously, WSDOT systems planners have captured two very different types of project characteristics with these additive criteria. However, because the systems plan ranking criteria were given equal weights (i.e., both the policy and technical criteria were normalized and then multiplied by 0.5, as described in section 2.1) this result also indicates that the present methods of normalizing each set of score ranges are not sufficiently equivalent.

The relatively low significance levels between the two stages of PSRC's regional project prioritization were somewhat more unusual. Usually, screening criteria are intended to measure the same project characteristics as the ultimate evaluation criteria. Although screening criteria are expected to be less accurate, these results suggest a completely unreliable rank correlation with the second stage of scoring. This is not a very desirable trait in any prioritization method. Note that the small sample size analyzed in this study does limit the validity of this conclusion, though it also strongly supports further research

to reveal the extent of internal correlation among the complete set of successfully screened STP and CMAQ projects (i.e., with 45 rather than 7 projects).

Table 10. Internal Correlation of Prioritization Methods

Score (or Project Set) Comparison	Rank Correlation*				
	Number of Projects	Kendall's τ	Significance	Spearman's r_s	Significance
Mobility Improvements					
Statewide Urban vs. Puget Sound Region Project Set (i.e., TOPSIS-6 method)	46	0.9845	0.000 *(0.99 level)*	0.9981	0.000 *(0.99 level)*
*Systems Plan Scores***					
Combined vs. Technical	46	0.3056	0.003	0.4248	0.003
Combined vs. Policy	46	0.7312	0.000 *(0.99 level)*	0.8918	0.000 *(0.99 level)*
Policy vs. Technical	46	0.0212	0.841 *(random)*	0.0662	0.662 *(random)*
PSRC Scores					
Screening vs. Technical	7	0.5500	0.091 *(0.90 level)*	0.6273	0.132 *(0.85 level)*

* Correlations are determined to be "random" if significance level is $\leq$ 0.50, and are almost linear if level = 0.99.

** The same conclusions are drawn with slightly higher significance levels when comparison is based on the 51 project set (i.e., the set corresponding to the regional mobility improvements sort).

General Comments

It is important to recognize that the WSDOT systems planning method guides regional funding allocations and preceeds the mobility improvements prioritization in WSDOT's biennial budget development process. One consequence of insignificant rank correlations between these two methods is that regional needs could be overlooked or, alternatively, over-emphasized. If department policy goals are intended to be the same at every step of the budget process, then these results also raise the question of which prioritization better reflects WSDOT policy. This is an issue that would require executive review and, therefore, is one that cannot be resolved by this project. However, three methodological differences are clear.

First, 15 percent less weight was assigned to congestion-related traffic analysis criteria (i.e., volume to capacity ratios) in the systems planning technique than was given to the similar criteria in the mobility method (i.e., the project benefit-cost analysis of the cost-efficiency category). Second, the systems planning policy criteria do not account for the degree of environmental impact. Third, the systems planning method does not involve any form of cost-effectiveness or efficiency analysis. Much of the observed rank order differences between these two WSDOT evaluation methods could be attributed to the weight hierarchy difference and the exclusion of project cost analysis at the systems planning stage.

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

This project used the WSDOT mobility improvement project programming method as a case study of one flexible framework for assessing projects related to all highway modes. Rank order sensitivity to estimate errors and to various categorical weight distributions was investigated. Furthermore, direct comparisons were made between WSDOT priority programming, a WSDOT systems planning, and a Puget Sound Regional Council project prioritization method. The goals of this study were to inform the policy-making debate over assigning subjective category weights and selecting pertinent categories of criteria, and to investigate the range of acceptable error in project performance predictions. In so doing, the reliability and adequacy of the WSDOT ranking methodology was also assessed.

Overall, WSDOT policies have become more focused on multimodal and intermodal decision-making, which demands multiple objective trade-offs. The mobility prioritization methodology does constitute a flexible, inclusive framework for assessing all highway-related projects, including some non-SOV modes and strategies. As applied in the 1995-1997 biennium, the TOPSIS-6 ranking algorithm determines the optimal priority order for funding projects on the basis of cost efficiency, degree of community support, environmental impacts, mode integration, and land use plan consistency. Cost efficiency is most heavily weighted criterion and is estimated on the basis of improving people and goods movement rather than emphasizing additional vehicle capacity. Chapter four illustrated how project benefit-cost ratios prove to be sufficient means of capturing cost-efficiencies for this program, of discriminating independent projects from one another, and also for ensuring a cost-effective program.

Methodologically, TOPSIS, the mobility improvements technique, meets several well recognized priority assessment needs. According to Simon et al. (1988) the mobility

programming method succeeds in evaluating a full range of disparate criteria, highway construction project types, and costs, and in externally determining criteria weights on the basis of policy objectives. Note, however, that Simon et al. also suggested that priority assessment techniques should, in general

1. Avoid pre-determined bounds for objective variables - which is an aspect of the 1995-1997 method that was eliminated by Barnes (1996) in order to improve rank reliability.
2. Avoid double-counting - which does exist to some degree in the WSDOT criteria (e.g., financial contributions from other agencies were subtracted from the project cost before benefit cost analysis in 1995-1997, while projects were also awarded higher community support scores on the basis of the magnitude of the same local contributions).
3. Be applicable to both problem and solution assessment - which would be very costly with large data sets and the WSDOT method (e.g., systems planning evaluation methods differ from programming methods).
4. Arrange variables in a hierarchical structure that would accomodate highly complex projects by using extensive evaluation criteria but simultaneously shift to simpler but similar criteria for more minor project proposals—which would require new research to design and test.
5. Be fairly uniform in methodology among different local authorities in order to more similarly prioritize highway projects—which has certainly not been achieved in the Puget Sound region, as shown in chapter 7.

In keeping with the difficulties of multiple objective decision-making, however, note that attempting to implement some of these remaining recommendations would cause unsolvable conflicts in WSDOT's case (e.g., the unbounded criteria of no.1 and the work of Barnes 1996).

In terms of the selected criteria, only the rank correlation results of chapter 7 suggest a need for re-examining certain categories. In particular, the land-use category may need re-examination because two WSDOT methods were found to prioritize a dissimilar distribution of projects by locale: that is, the mobility improvements method favors projects in the urban fringe, while the systems planning evaluation methods prefer urban core projects. Therefore, rank correlation results suggest that it may be advisable to improve the mobility criteria's representation of Washington's growth management and urban core connectivity policies or to revisit the hierarchy of criteria category weights.

Note, however, that the sensitivity analyses of this study should be considered before changing *any* criteria. These analyses were conducted to better understand how the four non-monetary criteria influence the final rank order and what range of rank variations are caused by changes to the categorical weight hierarchy and scores. In all, the WSDOT method was found to be fairly robust to score variations but highly sensitive to the distribution of weight and, as shown by Barnes (1996), project mix. On this last point, it is notable that the rank order differences due to changes in the project mix were much smaller in magnitude than what would be expected from a methodological change such as score standardization (Alexander and Beimborn 1987, Barnes 1996). However, this study assumed that the ranking method was pre-determined and therefore tested only aspects of implementation, including criteria selection, estimate errors, categorical weight distribution, and rank correlation with other programming methods.

7.1 SUMMARY OF SENSITIVITY ANALYSIS

The sensitivity simulations were designed to be, as a general approach, useful in evaluating other types of prioritization methods. In WSDOT's case, this means that the sensitivity testing framework of this study can be directly applied to TOPSIS-8, the recently revised ranking algorithm. The analysis objectives were to inform the policy-

making debate over applying weight to each criteria category, selecting pertinent categories of criteria, and how much accuracy is required in estimating project impacts.

Error simulations entail (a) applying random error to the input variables, (b) prioritizing the modified project set, (c) calculating objective measures of rank order difference, (d) iterating the process several times, and (e) applying significance tests. Similarly, the weight simulation framework begins with (a) changing the distribution of weight among each criteria category as desired, (b) prioritizing the modified project set, and (c) calculating objective measures of rank order difference. It is not necessary to iterate the weight simulations nor appropriate to apply significance tests unless the weight scenarios are randomized. Neither type of simulation accounts for potential interaction effects. Macro programs were developed to facilitate the analyses; Visual Basic macro language and Microsoft Excel version 5.0 were utilized.

Errors as high as 70 percent were incrementally applied to the existing project scores. Five alternative weight distributions were modelled on the 1995-1997 WSTC base case. Three objective measures of difference were used in this study: (1) mean absolute difference in rank, (2) the number of projects dropped out of a pre-determined top portion of the rank, and (3) the number of additional projects that could be funded with the corresponding budget allocation.

The most comprehensive conclusions drawn from the category independent results are the following:

- Community support is the category most sensitive to input error (i.e., shows the greatest rank order deviations).
- Cost efficiency is the second most sensitive category.
- There is no significant difference between 2.5 and 5 percent error in any category; associated rank order deviations are noticeable only for the cost-efficiency and community support categories.

- None of the error sensitivites revealed by this study are close to random.

Thus, it was shown that the mobility improvements prioritization method is quite robust to errors in predicting future volumes and estimating individual criteria scores. The sensitivity to scoring error is, in fact, much lower than that modelled in the weight simulations. It does, however, remain to be seen whether there might be significant interactions between simultaneous errors occurring in two or more criteria categories, and whether the same results would be obtained for simulations that used the newly modified ranking algorithm, TOPSIS-8.

The most important conclusion regarding sensitivity to categorical weight distribution is that decision makers should be very certain of, at least, the hierarchy of category weights. It is clear that weight distribution is very influential and should be used to reflect agency policy. Other interesting conclusions from the weight simulations are as follows:

- Rank order differences, as indicated by all three measures of difference, are close to random when 70 percent of the weight is assigned to community support, mode integration, or land use, with the rest evenly distributed (i.e., simulation #2a). [In fact, the sensitivity to such a large shift in weight is substantially more pronounced than error sensitivites caused by either 20 percent errors in community support or 50 percent error in cost efficiency estimates.]
- Dropping a category altogether generally causes rank order deviations, dependent on the original magnitude of weight.
- Either the environmental categories are an exception to the former, or 8 percent is a threshold value for applying meaningful category weights.
- Project rank order is robust to changing the community support category weight by 50 percent of the original WSTC value (i.e., 14 percent).

- Likewise, project rank order is robust to proportionate transfers of up to 10 percent of the original WSTC cost-efficiency weight (i.e., up to 6.5 percent transferred to other categories. Note: cost efficiency carries the largest original weight).
- Community support and land-use criteria seem to consistently favor more expensive projects than do the cost-efficiency criteria, while the environmental criteria tend to favor lower cost projects instead.

Even though this experiment was not designed to explicitly test interactions between the error and weight simulations, several characteristics were still inferred. Any simulation with an absolute difference of ≤ 3.5 is considered comparatively robust (in an aggregate way). Thus, if this value is applied as an "acceptable" limit of rank order difference, the resulting recommendation would be to accept scoring errors of up to:

- ~ 15 percent in community support
- ~ 40 percent in cost-efficiency estimates
- potentially well over 35 percent in environmental, mode integration, and land-use categories.

7.2 NEEDS FOR FURTHER STUDY

The WSDOT mobility improvements methodology is designed to inform program managers and department executives of the interrelationships of five specific criteria categories. Methodologically, it can be used to increase knowledge of investment trade-offs and does represent a significant step toward the ability to evaluate and rank multimodal projects. However, and as always, there are many opportunities for further study. Two of the most important recommendations are to

1. investigate error and weight sensitivity at several other budget levels (because only one level equal to $150 million was studied in this project)

2. apply the same simulation framework to the TOPSIS-8 ranking algorithm.

In fact, it is highly recommended that these two sensitivity analysis extensions be investigated before WSDOT considers any further modifications to the WSDOT mobility prioritization process.

Other interesting areas for further study include the following:

- testing for interaction effects across categories or between weight distribution and error (e.g., by utilizing a 2^k factorial design)
- developing error probabilities for certain categories of criteria (e.g., by comparing the effect of reasonable ranges of inputs such as discount rate, volume predictions, etc., on the resulting benefit-cost ratios; environmental mitigation costs vs. actual costs incurred with past projects)
- simulating variable error levels (e.g., by applying a bootstrapping design and probability distributions once available)
- developing and applying more measures of rank order differences (e.g., maximum change in rank, or rank correlation - which was not used to analyze error and weight *sensitivity* in this study, although as an aggregate measure it may be an interesting addition to future sensitivity analyses)
- improving the criteria (e.g., monetarily quantifying more project impacts, developing equivalent cost-efficiency techniques for alternative mode projects)
- improving the macro programs by incorporating each module into one global, windows-driven program
- designing additional project mix sensitivity tests (e.g., by bootstrapping through input data)

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A SENSITIVITY ANALYSIS AND IMPLEMENTATION REVIEW OF THE MOBILITY IMPROVEMENTS PRIORITIZATION METHOD

WA-RD 428.2

Appendices
May 1997

Washington State Department of Transportation

Washington State Transportation Commission
Planning and Programming Service Center
in cooperation with the U.S. Department of Transportation
Federal Highway Administration

APPENDIX A. PROJECT DESCRIPTION SHEETS, CRITERIA WORKSHEETS, AND SCORING GUIDELINES

PROPOSED MOBILITY IMPROVEMENT PROJECT DESCRIPTION

DISTRICT:_____
LOCAL JURISDICTION(S):_____
_____

SR:_____
PROJECT TITLE:_____
SR MILEPOST:_____ to SR MILEPOST_____
LENGTH:_____ (miles)

The purpose of the following descriptions is to identify the existing geometric characteristics of the project area, to detail the proposed improvements, and to describe the proposed future facility.

In each case, ***descriptions must address the following conditions:*** number, width, and type of lanes; shoulder, sidewalk, and bike lane width/existence; median width and type; interchange/intersection specifications; midpoint of expansion; safety measures (e.g. signalization, lighting, etc.); functional class; design speed; alignment changes; and right-of-way needs.
A ***map must be attached*** that highlights the project area and describes the section-township-range coordinates, distance from the nearest intersection, and names of roadways in the vicinity. Where the project proposal entails a new roadway/alignment or major intersection improvements, attach a secondary map &/or cross section at a larger scale.

Description of Existing Facility:

Description of Proposed Improvements and Future Facility:

Ranking relative to other proposed district project submittals?_____ of _____.

MOBILITY PRIORITIZATION CRITERIA

- **COST EFFICIENCY- Benefit-Cost Analysis for Safe Movement of People and Goods**

- **COMMUNITY SUPPORT**

- **ENVIRONMENT**
  - **Wetland Assessment**
  - **Water Quality and Permitting**
  - **Noise Assessment**

- **MODAL INTEGRATION**

- **LAND USE**

COST EFFICIENCY WORKSHEET -

Benefit-Cost Analysis for the safe movement of people and goods

The purpose of this worksheet is to summarize project costs and benefits. Detailed calculations should be included for each project and attached on a separate page. Benefits and costs should be expressed as present values using the following parameters:

Discount Rate (i) = 0.04
Study Period (n) = 20 years
(may vary on some projects, yet MUST be consistent with the time period used to calculate Project Benefits in any case. See accompanying outlines as detailed below.)

Project Cost Estimate: **199_ $'s**

Construction _____ (C)
(Sum ALL relevant line items including: environmental mitigation, and right-of-way; and excepting the following:)

Environmental Retrofit _____ (E_R)
(costs incurred due to a pre-existing condition, e.g. noise barriers, water quality treatment, and fish barrier removal. Some may be exempt.)

Preliminary Engineering _____ (S_P)

Annual Operating and Maintenance _____
(based on historical rates in similar area with proposed geometrics, except the following: Snow and Ice Removal, Structures & Ferries, Rest Area Management, and Public Damage Repair) (OpM_A)

Calculate the Present Value of Project Costs (PV_C):

$$PV_C = (C) + (E_R) + (S_P) + \left\{ OpM_A \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] \right\}$$

Total Est. Costs (PV_C) = _____

Project Benefit Estimate:

Present Value of User Benefits _____
(includes both Travel Time Savings & User Operating Savings. Calculate as outlined in accompanying "User Benefits Worksheets")

Present Value of Safety Benefits _____
(Calculate as outlined in accompanying "Safety Benefits Worksheets")

Total Est. Benefits (PV_B) = _____

Calculate the BENEFIT-COST RATIO of Proposed Project:

$B/C = (PV_B)/(PV_C)$ = _____

COMMUNITY SUPPORT WORKSHEET

The purpose of this worksheet is to assess the community support and potential impact from the proposed project. For each question, check the appropriate answer and log score in the blank to the right.

Question		Score
1. Is local, regional, or TIB financial participation anticipated? **If yes,** identify and indicate scale by percentage of total project costs: < 10% _____ 10-25% _____ > 25% _____	___Yes No=3 If Yes, < 10% =2 10-25% =1 > 25% =0	_____
2. a. Have any local governments endorsed this project? (Identify): _____ _____ _____	Yes=0 No=3	_____
b. Have any local organizations endorsed this project? (Identify): _____ _____ _____	Yes=0 No=1	_____
3. a. Have any local governments indicated opposition? (Indicate scale): _____ _____ _____	___Yes No=0 If Yes, minimal=1 moderate=2 significant=3	_____ _____
b. Have any private groups or individuals indicated opposition? (Indicate scale): _____ _____ _____		_____ _____
4. Will the project divide identifiable neighborhoods, school or business service areas?	Yes=1 No=0	_____
5. Will this project displace homes, cultivated farmlands, or businesses? **If yes**, indicate scale of displacement: No. Homes/Farms/Businesses: Estimated Acreage: < 6 _____ _____ 6-20 _____ _____ > 20 _____ _____	___Yes No=0 If Yes, < 6 = 1 6-20 = 2 > 20 = 3	_____
a. Has an evaluation of the potential opposition of the displaced been conducted?	___Yes ___No	
TOTAL SCORE:		_____

WETLAND WORKSHEET:

The purpose of this worksheet is to assess the potential impact from the proposed project. For each question, check the appropriate answer or enter the appropriate acreage, and log score in the blank to the right.

Question			Score
1. Are there any wetlands within 300' from the edge of the present roadway?	____Yes No=0		_____
If yes, identify the Class and required buffer for each wetland. Note the total acerage that may be affected as a result of the proposed project below:			
Category 1	____No. of acres	(x6)=	_____
Category 2 or Category 3			
Forested	____No. of acres	(x3)=	_____
Scrub-Shrub	____No. of acres	(x2)=	_____
Emergent	____No.of acres	(x1.5)=	_____
Category 4	____No.of acres	(x1.25)=	_____
All Buffers	____No.of acres	(x1)=	_____
		TOTAL SCORE : (if yes, minimum=0.5, if no, score=0.0)	_____

WATER QUALITY AND PERMITTING WORKSHEET:

The purpose of this worksheet is to assess the potential watershed impact and permitting requirements associated with the proposed project. For each question, check the appropriate answer or enter the appropriate acreage, and log score in the blank to the right. *If a required permit has already been obtained for the expected duration of the need, enter 0 pts and the date issued in the corresponding blank to the right.*

Question		Score
1. Will the project be located within 2000 feet of any body of water?		
If yes, then address the following:	____Yes No=0	_____
What will the total impervious surface area be upon completion of the proposed project (within 2000' of any water body)?	< 6 acres =1 6-20 acres =2 > 20 acres =3	_____
Will the project require hydraulic permits (HPA's)?	Yes=4 No=0	_____
Is there a known fish passage problem?	Yes=1 No=0	_____
Will the project require COE Section 10, 404, or Coast Guard Section 9 permit?	Yes=5 No=0	_____
Will the project require Shoreline Development permits?	Yes=4 No=0	_____
Is the project located within a Shoreline of Statewide Significance?	Yes=1 No=0	_____
Will any water quality permits be required (ie., NPEDS, Short Term Modification of Water Quality Standards)?	Yes=4 No=0	_____
Is the project a new roadway?	Yes=1 No=0	_____
2. Have any adjacent areas been identified as sensitive/critical by one or more governing juridictions? (Identify:)_____	Yes=5 No=0	_____
3. Is the project located within a regulatory floodway?	Yes=4 No=0	_____
4. Will the project increase impervious surface area within an EPA designated sole source aquifer area? (Identify:)_____	Yes=2 No=0	_____
5. Will this project require the purchase of additional right-of-way, or use of existing right-of-way?	___Yes No=0	_____
If yes, is the project located within:		
Forest Lands as defined by Dept. of Natural Resources?	Yes=4 No=0	_____
U.S. Forest Service National Forest jurisdiction?	Yes=1 No=0	_____
Other jurisdiction/resource lands of regional significance? (Identify:)_____	Yes=2 No=0	_____
	SUBTOTAL:	_____
If permitting agencies have been contacted, are there any foreseeable conflicts or disagreements?	___Yes ___No ___ Unknown or not applicable	if no, divide subtotal by 2.
	TOTAL SCORE:	_____

NOISE WORKSHEET:

The purpose of this worksheet is to assess the potential noise impact and associated costs due to the proposed project. For each question, check the appropriate answer or enter the appropriate number of residences, and log score in the blank to the right.

Question **Score**

1. Have existing noise impacts been identified along the proposed project distance? ___Yes ___No

   If yes, include the cost of feasible and reasonable mitigation measures in the project cost estimate, or cite determination otherwise:_____

2. Is this project a new <u>or</u> existing alignment? ____New ____Existing

   If new, evaluate the number of receptors within **400'** of the edge of the proposed roadway. Go to question #4.

   If existing, go to question #3.

3. Does the proposed project include widening of an existing roadway? ___Yes ___No

   If yes, evaluate the number of receptors within **200'** of the edge of the proposed roadway. Go to question #4.
   If no, go to question #5, enter 0 in the blank to the right.

4. Refer to the chart below, and compute the project score as follows: Divide the number of lanes that will be added/constructed by 2. Multiply the result by the number of receptors in each distance category and by the appropriate risk factor (for New *<u>or</u>* Existing alignment per question #2) for each receptor category as indicated below.

No. of lanes added or constructed / 2	Receptor Category	Number of Receptors	Noise level risk factor (r.f.): NEW	EXISTING	SUBTOTAL = (No. lanes/2) * (No. receptors) * (r.f.)
	< 100'		4	2	
	101-200'		2	1	
	201-400'		1		

5. Sum the results (Subtotals) for each category and enter the total project score in the blank to the right. **TOTAL SCORE:** _____

MODE INTEGRATION WORKSHEET

The purpose of this worksheet is to assess the level of modal integration supported by the proposed project. For each question, check the appropriate answers and log score in the blank to the right.

Question		Score
1. Does the proposed project increase mobility using existing capacity (e.g., access control, TDM/TSM, GP=>HOV conversion, frontage road improvement)?	Yes=0 No=1	_____
2. Does the project improve or facilitate linkage for movement of goods through port or terminal facilities (i.e., multimodal land-based, rail/trucking; waterborne; airborne)?	Yes=0 No=1	_____
3. Is the project, or does the project include, a designated HOV transfer area (e.g., park and ride lots, sheltered turnouts, flyer stop)?	Yes=0 No=1	_____
4. Does the proposed project improve integration between existing HOV facilities and connecting arterials (e.g., improved on or off ramp transitions, improvements to HOV termini)?	Yes=0 No=2	_____
5. Does the proposed project link or extend to existing HOV lanes?	Yes=0 No=2	_____
6. Is the project, or does it include, facilities designed to encourage use of bicycles with other modes or encourage bicycle use (e.g., bike carriers on buses, loop detectors or lane designations at intersections, storage facilities at park and rides)?	Yes=0 No=1	_____
7. Does the project link or extend existing or planned bikeways?	Yes=0 No=1	_____
8. Does the proposed project link or extend existing or planned pedestrian facilities, &/or include additional pedestrian amenities?	Yes=0 No=1	_____

TOTAL SCORE: _____

LAND USE WORKSHEET:

The purpose of this worksheet is to assess the current land use and local planning/transportation policies, plans, and implementation measures of the governing jurisdictions concerned with the proposed project area. For each question, check the appropriate answer or enter the appropriate response, and log score in the blank to the right.

Question		Score
1. Is the project included in the Comprehensive and/or Transportation Plan of any of the following? (If so, identify by name):		
Regional Transp. Planning Org.	:_____	
Other regional planning agency	:_____	
County &/or City government	:_____	
	:_____	
Other local interests/agencies	:_____	
2. Do all the local governments having an interest in the project include it in their plans as identified above?	Yes=5 No=0	_____
If no, has any action been taken by each of the appropriate planning agencies to approve the project?	Yes=5 No=0	_____
Indicate the action by what agency(cies):_____		
3. Has the *"Land Use Policy and Implementation"* file for local governments been updated in each jurisdiction that this project passes through?	Yes= 5 No=0	_____
4. Is the project on a roadway that directly links two or more designated growth centers?	Yes= 3 No=0	_____
5. Is the project located on an established or planned transit line/route?	Yes= 1 No=0	_____
	TOTAL SCORE:	_____

SCORING GUIDELINES

November 15, 1993

COMMUNITY SUPPORT:

Scoring:

- #3. Score the scale of opposition referenced by common extremes: minimal=1 to 2 individuals or a group without substantial support; significant=mobilized opposition substantial enough to seriously threaten the success of the project.
- #5. Score only the scale of displacement by number of homes/farms/businesses displaced. Acerage estimation is additional information in the scoping process.
- #5a. No score is assigned. The question serves as a procedural checklist for completing the project cost estimate.
- Total Score = sum each score entered in the column to right.

Definitions:

- "Divide identifiable neighborhoods, schools, business service areas"- Subject to local plans/existing conditions this may become an affirmative response in the case of substantial widening projects, access restrictions, or barrier separated facilities. Refer to historical local response and community plans where available.

WETLANDS:

This worksheet is intended to prompt a paper inventory of wetland resources for each project area. The values are based on the body of federal, state, and local regulations related to wetland preservation. Most notably, concurrent with WSDOT [*Environmental* 1993:3-2-1A] and other state agency procedures, the "Washington State Four-tier Rating System, September 1, 1990" is used as the worksheet framework and the replacement ratios for compensatory mititgation outlined in *The Model Wetlands Protection Ordinance*, Washington State Department of Ecology are applied. The required band of analysis (300') is also based on the body of literature and adopted ordinances which establish wetland buffers ranging from 25-300' statewide. These buffers are also subject to a 1:1 replacement ratio in RCW 36.70A mandated local regulations statewide, as reflected on the worksheet.

Refer to the *District Resource List* for local inventory information and see the enclosed outline of the "Washington State Four-tier Rating System, September 1, 1990".

Scoring:

- Evaluate the acerage of the footprint of proposed construction encroachment into an inventoried wetland area &/or the associated buffers only.
- When the equivalent Four-tier Category of a wetland is unknown, use the "Category 2 Forested" replacement ratio.
- Total Score = sum each score entered in the column to right.

- If there are ANY wetlands that may be affected as defined above, the minimum Total Score=0.5 acres regardless of the area of encroachment. If there are NO wetlands or buffer areas affected as defined above, the Total Score=0.0 acres.

Definitions:

- "wetlands"- lands that are either permanently or seasonally "inundated by surface or ground water with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction." (Presidential Executive Order 11990). [*Environmental* 1993:3-2-1A]

WATER QUALITY AND PERMITTING:

Scoring:

- Refer to the WSDOT Environmental Procedures Manual 6.0-6.9, March 1990 to evaluate permit requirements for the proposed project. (*Environmental* 1993)
- Total Score = subtotal of each score entered in the column to right subject to the final operation as noted on the worksheet.

Definitions:

- "body of water"- All inter/intrastate waters within the ordinary high water line such as lakes, rivers, streams (including intermittent streams), mudflates, sand-flats, wetlands, sloughs, prairie pot-holes, wet meadows, playa llakes, or natural ponds, including all waters which are subject to the ebb and flow of the tide (ending where the rise and fall of the water surface can no longer be pratically measured in a predictable rhythm due to masking by hydrologic, wind, or other effects).
- "total impervious surface area"- The total surface area of the roadway upon completion of the proposed project (i.e., width including the improvements * length of the roadway segment within 2000' of any water body).
- "Hydraulic Project"- Construction or other work that will use, divert, obstruct, or change the natural flow or bed of any river or stream, or that will utilize any of the salt or fresh waters of the state, or materials from the stream beds (WAC 220-110-020(16)).
- "fish passage problem"- Any migration barrier condition that exists when adult &/or juvenile fish are either delayed or denied passage beyond a point in a stream system or marine shallow water habitats during the normal course of their migration for spawning or rearing purposes. If fish are delayed from reaching suitable spawning areas, mass spawning or spawning in unsuitable substrate can occur, resulting in a decrease in survival. [WDF/WDW/DOT MOU (GC9058), & WDF/DOT State Interagency Agreement for Fish Passage Inventory & Barrier Removal (GC9392).]
- "Shoreline of Statewide Significance"- water areas of the state, including reservoirs, and their associated wetlands, including lands within 200 feet of the high-water mark

including associated marshes, bogs, swamps, floodways, riverdeltas, and flood plains for which there is a special interest in preserving the natural characteristics and in encouraging and increasing public access to enjoy the physical and aesthetic qualities of the natural shoreline with the overall best interest of the state and people generally being considered. The restriction for development is greater because the master plan must meet the requirements of RCW 90.58.020 (see RCW 90.58.030 for list).

- "new roadway"- project construction along a new alignment.
- "Sensitive/Critical"- designation subject to definition by the local governing authorities under SEPA, GMA, or zoning code implementation.
- "governing jurisdiction"- The public agency, political unit, or apparatus with administrative powers to command, determine, judge, or otherwise enforce the laws, public policy and affairs within the proposed project area.
- "regulatory floodway"- the area regulated by federal, State or local requirements to provide for the discharge of the base flood (the flood which has a one percent chance of being equalled or exceeded in any given year, a.k.a 100-year floodplain) so the cumulative increase in water surface elevation is no more than a designated amount (not to exceed one foot). The "Zone A" designation on the *Flood Insurance Rate Maps* by the Federal Emergency Management Agency, indicates the 100-year floodplain, or minimum level to be used by a community in its floodplain management regulations. (44 CFR Ch.I 9.4)
- "sole source aquifer area"- area designated by the EPA as the sole or principal source of drinking water for a given aquifer service area; that is, an aquifer which is needed to supply 50% or more of the drinking water for that area and for which there are no reasonably available alternative sources should the aquifer become contaminated. (Section 1424(e) of Safe Drinking Water Act, 1974)
- "Forest Land"- all land that is capable of supporting a merchantable stand of timber (a stand of trees that will yield logs &/or fiber suitable in size and quality for the production of lumber, plywood, pulp, or other forest products and of sufficient value at least to cover all the cost of harvest and transportation to available markets) and is not being actively used for a use which is incompatible with timber growing. (RCW 76.09.020, WAC 222)
- "Other jurisdictions/resource lands of regional significance"- areas including but not limited to: tribal governments, reservation lands, regulatory commissions (e.g., Columbia River Gorge Commission), significant/endangered wildlife corridors, prime/unique farmlands, archaeological/historical sites, National Park lands, other recreation land, and wild and scenic rivers that have been identified in the planning process as outlined in the Environmental Procedures Manual 3.0-3.12, March 1990. (*Environmental* 1993).

NOISE:

The intent of this worksheet is that it be carried out in-house using aerial photographs of the right-of-way and the table provided on the worksheet.

Scoring:

- Determine whether there are existing noise impacts over 67dBA level that would require mitigation where feasible and reasonable (see definition below). Cost of mitigation measures MUST be included in the cost estimate EXCEPT where mitigation has been previously determined 'unfeasible' or 'unreasonable' by WSDOT procedures. This determination must be referenced on the worksheet in the space provided and is the only justifiable reason for not including these potential costs in the estimate.
- If the proposed project is on a *new alignment* evaluate the number of receptors within 400' of the edge of the existing roadway.
- If the proposed project will **widen** the roadway along the *existing alignment*, evaluate the number of receptors within 200' of the edge of the existing roadway.
- Working with aerial photographs of the area, group the number of receptors with respect to distance from the edge of proposed roadway as categorized on the worksheet chart. If new, <100', 101-200', 201-400'; if existing, <100', 101-200' ONLY).
- Using the Noise Level Risk Factors in question #4, compute the subtotals as follows: Divide the number of lanes that will be added/constructed by 2. *This result will be the same for each Receptor Category.* Multiply the result by the number of receptors in each distance category and by the appropriate risk factor. Apply only *one* risk factor to each Receptor Category from either the new *or* existing alignment column in the worksheet chart.
- Add the Subtotals in the right-hand column of the worksheet chart and log the Total Score in the blank provided.

Definitions:

- "exisiting noise impacts"- Noise priority sites as established by WSDOT Directive D 22-22, November 2, 1987. Guidelines are detailed for conducting a noise inventory for existing state highways. The priority listing was developed based on an inventory of noise sensitive developments which existed, or for which a building permit had been approved, prior to May 14, 1976 and is current as of August 19, 1986 in Appendix A. As new sites must be investigated, because of citizen complaints or public officials' concerns, the procedures in this Directive will be used to prioritize the new sites. More comprehensive or up-dated inventories may have been conducted by individual districts, check with environmental noise specialists. (*Environmental* 1993:3.1, pub.March 1990)
- "feasible mitigation"- Noise mitigation that has no overwhelmingly significant physical constraints to construction and will provide significant noise abatement for

some of the impacted receptors. Refer to WSDOT Headquarters Environmental division for specific parameters.

- "reasonable mitigation"- Noise mitigation that will cost $\leq$ $10,500/residence, not withstanding scenic views, desireablity, and other consideration. Refer to WSDOT Headquarters Environmental division.

MODE INTEGRATION:

Scoring:

- Total Score = Sum of each score entered in the the column to the right.

Definitions:

- "improve or facilitate linkage for movement of goods through port or terminal facilities"- The proposed project must facilitate the movement of goods along a roadway with high truck traffic (for roadway classifications by truck percentage, Refer to "Task B: Freight and Goods Transportation System; Cost Responsibility Study-Phase I", Final Report for the St of WA Legislative Transportation Commission, January 1993.) and be within a ten mile radius from the terminal facility.
- "increased mobility"- used here to indicate conditions of greater movement of people and/or goods along the main roadway than presently supported by the facility.
- "bikeway"- Includes all four bikeway classes described by WSDOT Design Manual Standards.

LAND USE:

Scoring:

- Total Score = Sum of each score entered in the the column to the right.

Definitions:

- "local governments having an interest"- Those counties/cities where the proposed project a
- "*Land Use Policy and Implementation* file"- reference to a DOT District specific library of up-to-date documents, long-range transportation policies, and implementation measures for each city or county government encompassed by the District planning area. Each file must contain the following elements to enter a score of 5 points: *Land Use Checklist*, Comprehensive Plan, Transportation Plan, Zoning Code, Road/Design Standards, Critical Areas/Sensitive Areas Code/Ordinance, and other supporting inter-local, regional, &city/county-wide policy documents.
- *"Land Use Checklist"*- Form used to facilitate distillation of the governing jurisdiction's codes and policies. Intended for use as a procedural checklist, only categorical completion of this form (yes/no) is scored. See blank form attached.

- "designated growth center"- An area designated by regional or local planning agencies to receive a major share of the regional employment growth in the future.

LAND USE CHECKLIST

Indicate the specific zoning code/ordinances, comprehensive plan, transportation plan, road/design standards, or other adopted policy documents that implement each policy described below:

Policy	Citations:
a. Requires sidewalks as part of site planning.	
b. Requires/Encourages integrated bikeways or bicycle systems/facilities.	
c. Requires transit coordination for major residential, commercial, or retail development projects. (e.g., Bus turnouts, Sheltered passenger waiting facilities, etc.).	
d. Allows trade-offs between parking requirements and TDM measures.	
e. Requires/Encourages Clustering of major buildings	
f. Requires/Encourages physical orientation of major buildings to facilitate transit use.	
g. Requires Large-scale developments to integrate preferential lane treatment in their site design.	
h. Promotes measures to minimize impacts from development of adjacent land on roadway capacity (e.g., requiring combined driveways where possible, rear access, one-way drives, etc.).	
i. Other exceptional policies as appropriate:	

APPENDIX B. MATHEMATICAL SUMMARY OF TOPSIS

MATHEMATICAL SUMMARY OF TOPSIS[1]

One of the most frequently used methods for prioritizing elements (i.e., projects) with disparate units is called technique for order preference by similarity to ideal solution (TOPSIS), which was developed by Hwang and Yoon based on the concept of Euclidean distance. The algorithm uses one project thát has the weighted minimum Euclidean distance as the ideal solution and assumes that each criterion has a monotonically increasing (or decreasing) utility. The "ideal project" is composed of all of the best criteria values, and the "negative-ideal project" has all of the worst criteria values. The method compares the Euclidean distance of each criterion to both the ideal and the negative-ideal solutions simultaneously by taking the relative closeness to this ideal solution, thus, the priority of each project is obtained.

Figure B-1 shows an example of the Euclidean distances to the ideal and negative-ideal solutions in two dimensional space. A^* is the ideal project, A^- is the negative-ideal project. In the figure, project A_1 has shorter distances both to the ideal project A^* and to the negative-ideal project A^-, than the other project A_2. To justify the selection of projects, TOPSIS compares the relative closeness to the ideal solution by considering the two distances at the same time.

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[1] Hwang, Ching-Lai and Yoon, Kwangsun. (1981). *Lecture Notes in Economics and Mathematical Systems*. Springer-Verlag Berlin Heidelberg New York.
Note: Contents of this appendix were also previously published by Niemeier et al. (1995).

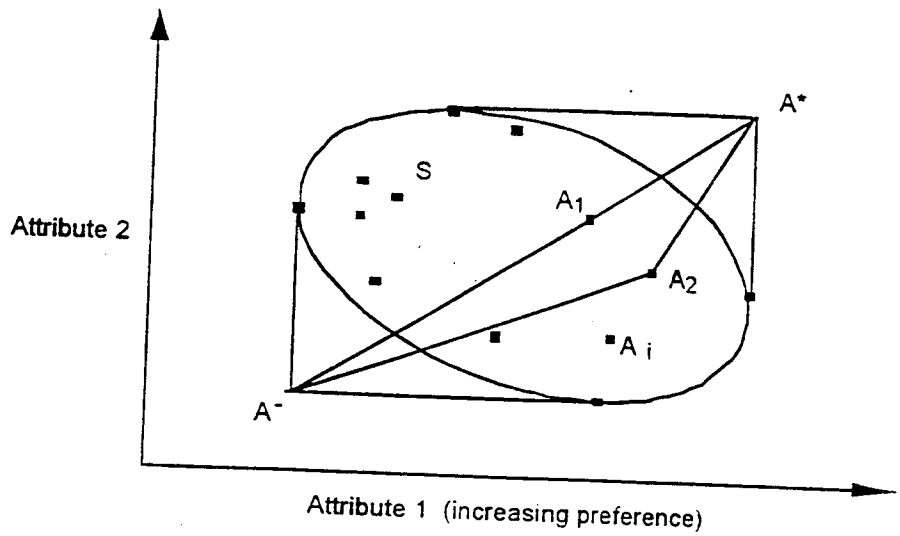


Figure B-1. Euclidean Distance to the Ideal and Negative-ideal Solutions in Two Dimensional Space

ANNOTATED ALGORITHM

The TOPSIS method evaluates m projects through n criteria, which make up the following decision matrix:

$$
D = \begin{array}{c} \\ X_1 \\ X_2 \\ \vdots \\ X_i \\ \vdots \\ X_m \end{array}
\begin{array}{c}
\begin{array}{cccccc} B_1 & B_2 & & B_j & & B_n \end{array} \\
\begin{bmatrix}
D_{11} & D_{12} & \cdots\cdots & D_{1j} & \cdots\cdots & D_{1n} \\
D_{21} & D_{22} & \cdots\cdots & D_{2j} & \cdots\cdots & D_{2n} \\
\vdots & \vdots & & \vdots & & \vdots \\
D_{i1} & D_{i2} & \cdots\cdots & D_{ij} & \cdots\cdots & D_{in} \\
\vdots & \vdots & & \vdots & & \vdots \\
D_{m1} & D_{m2} & \cdots\cdots & D_{mj} & \cdots\cdots & D_{mn}
\end{bmatrix}
\end{array}
$$

where X_i = the ith project considered,

B_j = the jth criteria considered in the decision, and

D_{ij} = the numerical outcome of the ith project with respect to jth criteria.

Next, TOPSIS uses a set of weights obtained from decision makers to describe the importance of each criterion. It assumes the larger the attribute outcomes, the greater the benefit criteria and the less preferable the cost criteria. It consists of the following steps:

Step 1 Construct the normalized decision matrix (R). This process transforms the various criteria dimensions into non-dimensional criteria, which allows comparison across the different criteria. An element r_{ij} of the normalized decision matrix R can be calculated as:

$$r_{ij} = \frac{D_{ij}}{\sqrt{\sum_{i=1}^{m} D_{ij}^2}} \tag{B.1}$$

Step 2 Construct the weighted normalized decision matrix (V). A set of weights W = (W_1, W_2, ...W_j, ...W_m) are accommodated into the decision matrix. The weights should sum to one, that is $\sum_{j=1}^{n} W$. The updated weighted matrix can be calculated by multiplying each column by its associated weight:

$$v_{ij} = r_{ij} * W_j \tag{B.2}$$

Step 3 Determine ideal and negative-ideal solutions: Let the ideal solution A^* and the negative A^- be defined as:

$$A^* = \{ (\max_i v_{ij} \mid \in J), (\min_i v_{ij} \mid j \in J') \mid i = 1,2, ...,m) \}$$

$$= \{ v_1^*, v_2^*, ...v_i^*, ...v_n^* \} \tag{B.3}$$

$$A^- = \{ (\min_i v_{ij} \mid \in jJ), (\max_i v_{ij} \mid j \in J') \mid i = 1,2, ...,m) \}$$

$$= \{ v_1^-, v_2^-, ...v_i^-, ...v_n^- \} \tag{B.4}$$

where $J = \{ j = 1,2, \ldots\ldots, n \mid j$ associated with benefit criteria$\}$
$J' = \{ j = 1,2, \ldots\ldots, n \mid j$ associated with benefit criteria$\}$.

Step 4 Calculate the separation measure. The separation between each project can be measured by the n-dimensional Euclidean distance. The distance of each project from the ideal one is then given by

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \qquad i = 1, 2, \ldots\ldots, m \qquad \text{(B.5)}$$

Similarly, the distance from the negative-ideal one is given by

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \qquad i = 1, 2, \ldots\ldots, m \qquad \text{(B.6)}$$

Step 5 Calculate the relative closeness to the ideal solution. The relative closeness of A_i with respect to A^* is the priority of each project, which is defined as:

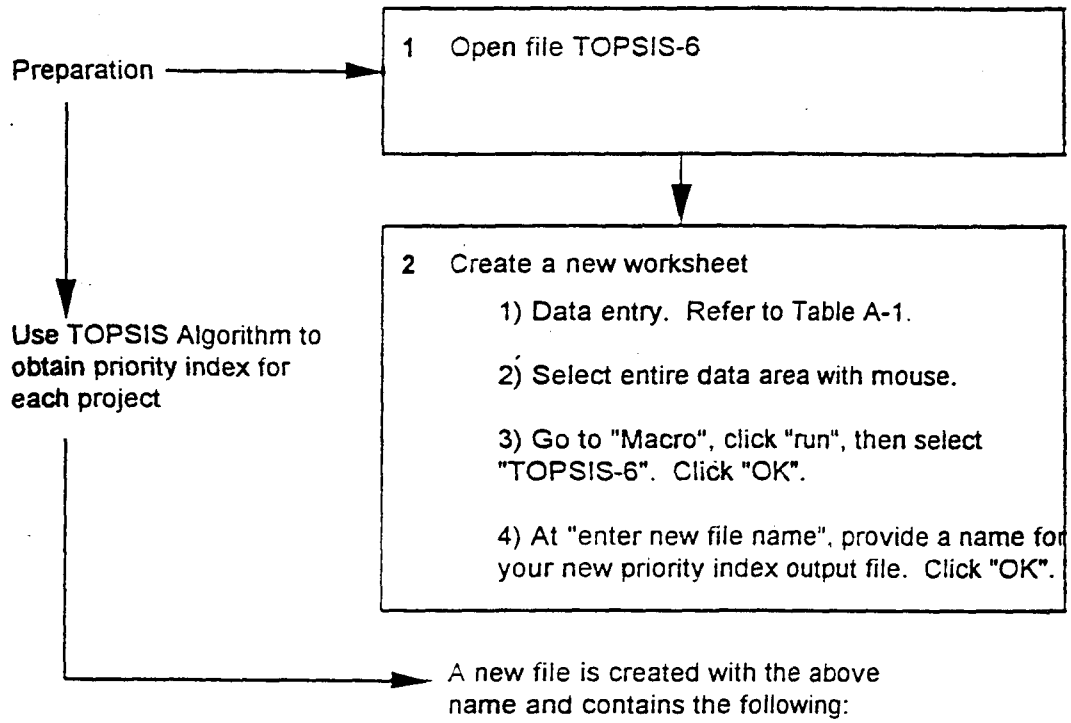
$$p_i^* = S_i^- / (S_i^* + S_i^-), \quad 0 < p_i^* < 1, \quad i = 1, 2, \ldots\ldots, m \qquad \text{(B.7)}$$

Step 6 Rank the priority order. A set of projects can now be priority ranked according to the descending order of p_i^*.

APPENDIX C. TOPSIS-6 ILLUSTRATION AND ANNOTATED CODE

PROGRAM INSTRUCTIONS
(Refer to Figure C-1 and Table C-1)

Step 1	Open TOPSIS-6 macro file from the directory.
Step 2	Open the data file containing projects and evaluation criteria values. This data file must be formatted as shown in Table A-1. Column 1 is used for the project identification (project identification can be any alpha-numeric combination). Columns 2 through 2+y are reserved for the evaluation criteria, where y=x-1 and x=Project Cost Column. Row 2 of the data sheet must include a weight for each evaluation criteria. The sum of the weights must equal 1.00. Row 3 is used to denote whether the criteria should be maximized or minimized. A "1" is used when high values are favored over low values, e.g., B/C and Land Use scores. A "0" is used when low values are favored over high values, e.g., environmental impact criteria.
Step 3	Highlight (select) the entire data set area exactly with the mouse.
Step 4	Go to "Macro" on the main menu and select TOPSIS-6. The program will display interim calculations to the right of the selected worksheet area. Be sure that you have saved the input worksheet prior to running the program. At the prompt, enter the name of a new file to which the output should be written. At the second prompt in the new worksheet, enter the program budget as indicated. Use the same units as were input for project costs previously. TOPSIS-6 will figure the project list that can be funded given the budget scenario in exact rank order and display the remaining funds in the third column, row five. When the program is complete, a window will display a notice as an indicator. Enter "OK".
Step 5	After the macro has completed execution, close the input data file and the TOPSIS-6 macro file; do NOT save any changes. Next, save the output file including changes and proceed to view the project priority indices in rank order. In order to format the output file, it must be saved under a different name before customizing the document.



Priority Index	Project I.D.	Project Cost	Budget	Project I.D.	Project Cost
0.893	1-01	28,000	75,000	1-01	28,000
0.767	1-02	18,500	Remaining	1-02	18,500
0.725	1-03	24,200	4,300	1-03	24,200
0.642	1-04	32,100			
0.509	1-05	5,480			
...	...	...			

Figure C-1. Application Procedure

Table C-1. Data Input Format

Project	B/C	Commun-ity Support	Wetlands	Water Quality	Noise	Modal Integrat-ion	Land Use
Weight	0.65	0.14	0.026	0.026	0.026	0.07	0.06
Max/Min	1	0	3.0	0	0	0	1
1-01	11.31	2	0.5	21	36	4	12
1-02	10.2	5	8	10	20	5	15
...	...	...	...	...	...	...	...

TOPSIS - 6 ANNOTATED CODE

A1. Topsis (t)

Start of the macro

A2. =SET.NAME("range",SELECTION())

Give the highlighted data area a name as "range"

A3. =ROWS(range)

Return the number of rows in "range"

A4. =COLUMNS(range)

Return the number of columns in "range"

A5. =SET.NAME("temp",OFFSET(range,0,A4+1)

Return a reference of the same size and shape as "range", with its upper-left corner shifted horizontally by the number of column of "range" (A4) plus 1. And give this shifted reference a name as "temp"

A6. =SET.NAME("workspace",INDEX(temp,4,2):INDEX(temp,A3,A4-1))

Give the area from row4-col2 in "temp" to rowA3-colA4 in "temp" a name as "workspace"

A7. =SET.NAME("origin",INDEX(range,4,2):INDEX(range,A3,A4-1))

Give the area from row4-col3 in "range" to row A3-colA4-1 in "range" a name as "origin"

A8. =SET.NAME("weight",INDEX(range,2,2):INDEX(range,2,A4-1))

Give the area from row2-col2 in "range" to row2-colA4-1 in "range" a name as "weight"

A9. =SET.NAME("logic",INDEX(range,3,2):INDEX(RANGE,3,A4-1))

Give the area from row3-col2 in "range" to row3-colA4-1 in "range" a name as logic

A10. =SET.NAME("sum1",INDEX(workspace,1,1):INDEX(workspace,1,A4-2))

Give the area from row1-col1 in "workspace" to row1=colA4-2 in "workspace" a name as "sum1"

A11. =SET.NAME("sum",OFFSET(sum1,A3-2,0))

Return a reference of the same size and shape as "sum1", with its upper-left corner shifted vertically by the number of A3 minus 2. And give this shifted reference a name as "sum"

A12. =SET.NAME("positive",OFFSET(sum,1,0))

Return a reference of the same size and shape as "sum", with its upper-left corner shifted vertically by one row. And give this shifted reference a name as "positive"

A13. =SET.NAME("negative",OFFSET(positive ,1,0))

Return a reference of the same size and shape as "positive", with its upper-left corner shifted by one row. And give this shifted reference a name as "negative"

A14. =SET.VALUE(A22,1)

Start outer loop. Initialize the counter at cell A22 to 1

A15. =SET.VALUE(A17,0)

Intialize the value of A17 to 0

A16. =SET.VALUE(A18,1)

Start inner loop. Intialize the counter at cell A18 to 1

A17. =A17+INDEX(origin,A18,A22)^2

Calculate the sum of squares of each cell in the first column of "origin", and repeat for all the columns

A18. =A18+1

Increment the inner loop counter A18

A19. =IF(A18<(A3-2),GOTO(A17))

The inner loop ends when all the rows in each column of "origin" are reached

A20. =SELECT(INDEX(sum,1,A22))

Select the cell of row1-colA22 in "sum"

A21. =FORMULA(A17)

Write the result of A17 to the above selected cell

A22. =A22 + 1

Increment the outer loop counter A22

A23. =IF(A22<A4-1,GOTO(A15))

The outer loop terminates when all the columns in "origin" are reached

A24. =SET.NAME("ido",INDEX(range,4,1):INDEX(range,A3,1))

Give the area from row4-col1 to row A3-col1 in "range" a name as "ido"

A25. =SET.NAME("costo",INDEX(range,4,A4):INDEX(range,A3,A4))

Give the area from row4-colA4 to row A3-colA4 in "range" a name as "costo"

A26. =SET.NAME("dummy",INDEX(workspace,1,1):INDEX(workspace, A3-3,1))

Give the area from row1-col1 to rowA3-3-col1 in "workspace" a name as "dummy"

A27. =SET.NAME("sep",OFFSET(dummy,0,A4))

Return a reference of the same size and shape as "dummy", with its upper-left corner shifted horizontally by the number of A4. And give this shifted reference a name as "sep"

A28. =SET.NAME("sepn",OFFSET(dummy,0,A4+1))

Return a reference of the same size and shape as "dummy", with its upper-left corner shifted horizontally by the number of A4 plus 1. And give this shifted reference a name as sepn"

A29. =SET.NAME("ci",OFFSET(dummy,0,A4+2))

Return a reference of the same size and shape as "dummy", with its upper-left corner shifted horizontally by the number of A4 plus 2. And give this shifted reference a name as "ci"

A30. =SET.NAME("id",OFFSET(ci,0,1))

Return a reference of the same size and shape as "ci", with its upper-left corner shifted horizontally by one row. And give this shifted reference a name as "id"

A31. =SET.NAME("cost",OFFSET(ci,0,2))

Return a reference of the same size and shape as "ci", with its upper-left corner shifted horizontally by two rows. And give this shifted reference a name as "cost"

A32. =SET.VALUE(A51,1)

Start outer loop. Initialize the counter at cell A51 to 1

A33. =SET.VALUE(A37,1)

Start inner loop. Initialize the counter at cell A37 to 1

A34. =SELECT(INDEX(workspace,A37,A51))

Select the cell of row A37-colA51 in "workspace"

A35. =INDEX(origin,A37,A51)/SQRT(INDEX(sum,1,A51))*INDEX(weight,1,A51)

Construct the weighted normalized matrix. (see Steps 1&2 of TOPSIS)

A36. =FORMULA(A35)

Write the result of A35 to the above selected cell

A37. =A37 + 1

Increment the inner loop counter A37

A38. =IF(A37<A3-2,GOTO(A34))

Repeat the above calculations until all the rows in "workspace" are reached. End of Steps 1&2 of TOPSIS

A39. =MAX(INDEX(workspace,1,A51):INDEX(workspace,A3-3,A51))

Return the largest number in the list from row1-colA51to row A3-3-colA51 in "workspace"

A40. =MIN(INDEX(workspace,1,A51):INDEX(workspace,A3-3,A51))

Return the smallest number in the list from row1-colA51 to row A3-3-colA51 in "workspace"

A41. =IF(INDEX(logic,1,A51)=0,GOTO(A47))

If the value of cell row1-colA51 in "logic" is 0, gotoA47. This corresponds to the case of minimization in TOPSIS Step 3. When its value is 1, goto next step A42. This corresponds to the case of maximization in TOPSIS Step 3

A42. =SELECT(INDEX(positive,1,A51))

Select the cell of row1-colA51 in "positive"

A43. =FORMULA(A39)

Write the value of A39 to the above selected cell

A44. =SELECT(INDEX(negative,1,A51))

Select the cell of row1-colA51 in "negative"

A45. =FORMULA(A40)

Write the value of A40 to the above selected cell

A46. =GOTO(A51)

End of maximization case

A47. =SELECT(INDEX(positive,1,A51))

Select the cell of row 1-colA51 in "positive"

A48. =FORMULA(A40)

Write the value of A40 to the above selected cell

A49. =SELECT(INDEX(negative,1,A51))

Select the cell of row1-colA51 in "negative"

A50. =FORMULA(A39)

Write the value of A39 to the above selected cell. End of minimization case

A51. =A51+1

Increment the outer loop counter of A51

A52. =IF(A51<A4-1,GOTO(A33))

End of Step 3 of TOPSIS

A53. =SET.VALUE(A84,1)

Start of outer loop, initialize the counter A84 to 1

A54. =SET.VALUE(A63,0)

Initialize A63 to 0

A55. =SET.VALUE(A65,0)

Initialize A65 to 0

A56. =SET.VALUE(A68,0)

Initialize A68 to 0

A57. =SET.VALUE (A70,0)

Initialize A70 to 0

A58. =SET.VALUE(A71,0)

Start of inner loop, initialize the counter A59 to 0

A59. =SET.VALUE(A74,0)

Intitialize A74 to 0

A60. =SET.VALUE(A75,0)

Initialize A75 to 0

A61. IF((AND(INDEX(positive,1,A71)>0,INDEX(workspace,A84,A71)>0)),goto A65)

Determines whether the workspace value and ideal criteria value share the same sign

A62. IF((AND(INDEX(workspace,A84,A71)<0,INDEX(positive,1,A71<0)), goto A65

Same as A61

A63. =A63 + (INDEX(workspace,A84,A71)+(0-INDEX(positive,1,A71)))^2

Calculates the separation measure, Step 4 of TOPSIS, when criteria values of the workspace & ideal share the same sign

A64. =goto A66

Skips the alternate case calculation (see A65).

A65. =A65 + INDEX(workspace,A84,A71)-INDEX(positive,1,A71))^2

Calculates the separation measure, Step 4 of TOPSIS, when criteria value of the workspace is negative and the ideal criteria value is positive.

A66. =IF((AND(INDEX(workspace,A84,A71)>0,INDEX(negative,1,A71)>0)), goto A70)

Determines whether the workspace value and negative-ideal criteria value share the same sign.

A67. =IF((AND(INDEX(workspace,A84,A71)<0,INDEX(negative,1,A71)<0)), goto A70

Determines whether the workspace value and negative-ideal criteria value share the same sign.

A68. =A68 + ((INDEX(workspace,A84,A71) - INDEX(0-INDEX(negative,1,A71)))^2

Calculates the separation measure, Step 4 of TOPSIS, when criteria values of the workspace and negative-ideal share the same sign

A69. =goto A71

Skips the alternate case calculation(A70).

A70. =A70+(INDEX(workspace,A84,A71)-INDEX(negative,1,A71))^2

Calculate the separation measure, Step 4 of TOPSIS, when value in workspace is positive and the negative-ideal criteria value is negative.

A71. =A71 + 1

Increment counter of inner loop A71

A72. =IF(A72<A4-1,GOTO(A61))

Inner loop terminates when all the columns in row A84 of "workspace" are reached

A73. =SELECT(INDEX(sep,A84,1))

Select row A84-col1 of "sep"

A74. =A63 + A65

Sum all possible separation measures to the ideal

A75. =A68 + A70

Sum all possible separation measures to the negative-ideal

A76. =SQRT(A74)

Take the square root of the result in A74. This is the separation to ideal-solution for each project

A77. =FORMULA(A76)

Write the above result in the selected cell (See A61)

A78. =SELECT(INDEX(sepn,A84,1))

Select row A84-col1 of "sepn"

A79. =SQRT(A75)

Take the square root of the result in A75. This is the separation to negative-ideal solution for each project.

A80. =FORMULA(A79)

Write the above result in the selected cell (See A64)

A81. =SELECT(INDEX(ci,A84,1))

Select row A84-col1 of "ci"

A82. =INDEX(sepn,A84,1)/(INDEX(sepn,A84,1)+INDEX(sep,A84,1))

Calculate relative closeness, i.e., priority index. This is Step 5 of TOPSIS

A83. =FORMULA(A82)

Write the above result to the selected cell (see A81)

A84. =A84+ 1

Increment the outer loop counter A84

A85. =IF(A84<(A3-2),GOTO(A54))

The outer loop terminates when all the rows in "workspace" are reached

A86. =SELECT(ido)

Select "ido", which contains the ID numbers of all the projects

A87. =COPY()

Copy the selected region, i.e., "ido"

A88. =SELECT(id)

Select "id"

A89. =PASTE()

Paste the selected data, i.e., the ID numbers, to "id"

A90. =SELECT(costo)

Select "costco", which contains the cost of all the projects

A91. =COPY()

Copy the selected region

A92. =SELECT(cost)

Select "cost"

A93. =PASTE()

Paste the copied content, i.e., the costs, to "cost"

A94. =SELECT(INDEX(workspace,1,1):INDEX(negative,1,A4-2))

Select the area from the first cell in "workspace" to the last cell in "negative"

A95. =EDIT.DELETE()

Delete the selected area. Notice: steps A94 and A95 clear all the intermediate results on the worksheet

A96. =SELECT(INDEX(sep,1,1):INDEX(sepn,A3-3,1))

Select the area from row1-col1 in "sep" to rowA3-3-col1 in "sepn", which contains the final results of Topsis. We are going to write these results in a new file (see the following a few steps)

A97. =EDIT.DELETE()

Delete the selected area

A98. =INPUT("Enter a new file name (non-existing):",2)

Display a dialog box into which the user can enter information in text, i.e., the filename in which the user wants to store the final results

A99. =FOPEN(A98,3)

Create the file named by the user in A98, with read/write access

A100. =FCLOSE(A99)

Close the file specified in A99

A101. =SELECT(INDEX(ci,1,1):INDEX(cost,A3-3,1))

Select the area from row1-col1 in "ci" to rowA3-3-col1 in "cost"

A102. =SORT(1,,2)

Sort priority indices by rows in descending order. This is Step 6 of TOPSIS

A103. =CUT()

Cut the selected area, i.e., the sorted results

A104. =OPEN(A98)

Open the file created in step A98 as a window

A105. =SELECT("r[1]c")

Select the first row and column "r[1]c"

A106. =PASTE()

Paste the cut content (i.e., the sorted results) in the new file

A107. =SET.NAME("b_range",SELECTION())

Give the selected area a name as "b_range"

A108. =ROWS(b_range)

Return the number of rows in "b_range"

A109. =COLUMNS(b_range)

Return the number of columns in "b_range"

A110. =SELECT("r[-1]c")

Select (an inserted) row above the sorted results in the new file, "r[-1]c"

A111. =FORMULA("Priority Index")

Write the heading "Priority Index" in the first above selected cell

A112. =SELECT("rc[1]")

Select the first cell in the next column over (to the right), "rc[1]"

A113. =FORMULA("Rank Order")

Write the heading "Rank Order" in the above selected cell

A114. =SELECT("rc[1]")

Select the first cell in the next column over (to the right), "rc[1]"

A115. =FORMULA("Project cost")

Write the heading "Project cost" in the above selected cell

A116. =SELECT("rc[1]")

Select the first cell in the next column over, "rc[1]"

A117. =FORMULA("Total Budget")

Write the heading "Total Budget" in the above selected cell

A118. =SELECT("r[2]c")

Select the cell two rows beneath the previous cell (in the fourth column), "r[2]c"

A119. =FORMULA("Remainings")

Write the heading "Remainings" in the above selected cell

A120. =SELECT("r[-2]c[1]")

Select two rows above and the next cell over (top row, fifth column), "r[-2]c[1]"

A121. =FORMULA("Funded Proj's")

Write the heading "Funded Proj's" in the above selected cell

A122. =SELECT("r[1]c[-1]")

Select the cell one row beneath and one column to the left of the previous (second row, fourth column), "r[1]c[-1]"

A123. =INPUT("Enter the total budget (unit should be consistent with the raw data!)",1)

Display a dialog box for user to enter information as text; i.e., the total available budget

A124. =FORMULA(A123)

Write the value A123 to the above selected cell (under "Total Budget") in new file

A125. =IF(A123>=INDEX(b_range,1,3),GOTO(A128))

Determine whether the top priority project is funded under the input budget scenario. Begins the outer loop if there is enough funding.

A126. =ALERT("No projects can be funded under this ranking order! Please check your total budget.")

Display a dialog box notifying user that the total budget entered will not cover the project cost of the top ranked item

A127. =RETURN()

Stop the macro

A128. =SET.VALUE(A131,0)

Start inner loop. Initializes the counter at cell A131 to zero.

A129. =SET.VALUE(A130,0)

Start outer loop. Initializes the counter at cell A130 to zero

A130. =A130+1

Increment the outer loop counter A130

A131. =A131+INDEX(b_range,A130,3)

Calculate the accumulated project cost in descending priority order

A132. =IF(A131>A123,GOTO(A139))

Determine if accumulated project cost exceeds the total budget input

A133. =IF(A130=A108,ALERT("all projects can be funded!"),GOTO(A138))

Determine if the project is from the last row in "b_range"

A134. =SELECT("r[2]c")

Select cell two rows beneath previous cell in new file under "Remainings" (fourth row, fourth column), "r[2]c"

A135. =A123-SUM(INDEX(b_range,1,3):INDEX(b_range,A108,3))

Calculate the remaining budget if any.

A136. =FORMULA(A135)

Write the value of A135 to the above selected cell

A137. =RETURN()

Increment the inner loop

A138. =GOTO(A130)

End of outer loop

A139. =A123-(A131-INDEX(b_range,A130,3))

Calculate remaining budget; i.e., subtracts partially funded project from accumulated project costs of A131

A140. =SELECT("r[2]c")

Select cell two rows beneath previous cell in new file under heading "Remainings" (fourth row, fourth column), "r[2]c"

A141. =FORMULA(A139)

Write the value A139 to above selected cell

A142. =SELECT(INDEX(b_range,1,2):INDEX(b_range,A130-1,2))

Select the cells of row1-col2 in "b_range" through row A130-1 (outer loop counter)-col2

A143. =COPY()

Copy selected cells

A144. =SELECT("rc[3]")

Select cell three columns over previous selection, "rc[3]"; i.e., under heading "Funded Proj's"

A145. =PASTE()

Paste copied cells from above in selected cells; i.e., paste names of projects funded by total budget input under the heading "Funded Proj's"

A146. =ALERT("This is the end!",3)

Display dialog box notifying user that the algorithm is finished

A147. =RETURN()

Stop the macro.

APPENDIX D. SUMMARY OF DELPHI ANALYSIS FOR WEIGHT SETTING

SUMMARY OF DELPHI ANALYSIS FOR WEIGHT SETTING

September, 1993
University of Washington Campus

Introductory Discussion:

- Presentation of ranking methodology and categories of evaluation criteria.
- Presentation of the Delphi Analysis framework and session proceedings.

ROUND 1 RESULTS:

	NPV	CMTY	ENV	MODE	L/U
Mean	51	17	12	11	9
Standard Deviation	18	11	7	3	5

Major Discussion Points:

- Concern that Community Support is not adequately represented
- Concern that project costs will eliminate certain high cost projects

ROUND 2 RESULTS:

	NPV	CMTY	ENV	MODE	L/U
Mean	53	17	11	10	9
Std Dev.	11	10	6	4	5

Major Discussion Points:

- That NPV represents a large number of policy goals and is not being given adequate emphasis
- Next round -resolved to give each sub-goal under NPV its own weight and sum total for NPV full weight.

ROUND 3 RESULTS:

	NPV	CMTY	ENV	MODE	L/U
Mean	65	14	8	7	6
Std Dev.	8	7	3	1	1

Major Discussion Points:

- The criteria objectives need to be repackaged to make it explicit that NPV carries a fair number of policy goals with it.
- These results shall be the committee recommendation to full WSTC for adoption.

APPENDIX E. PRIORITIZED MOBILITY PROJECTS - 1995-1997 BIENNIUM

MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

RURAL

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost
1	0.9593	D- 3, SR 101, Chicken Coop Road EB Passing / Truck Climbing Lane	55.54	4	0.5	15	0	10	11	503,109
2	0.6294	D- 3, SR 101, Dawley Rd. to Blyn Hwy., Truck Climbing Lane	34.96	4	1.4	21	5	9	11	1,096,800
3	0.5479	D- 3, SR 101, Gardiner Cemetery Road to MP 277.6	30.36	4	1	10	5	9	10	1,355,750
4	0.4573	D-5, SR 90, Elk Heights Vic WBND TCL	25.23	4	1.5	2	0	9	14	5,270,516
5	0.4114	D- 3, SR 101, Blyn Eastbound Passing Lane	22.69	5	0.5	11	0	10	11	595,400
6	0.3980	D- 5, SR 970, Teanaway River to Virden	21.91	5	0.5	0	0	9	13	1,950,000
7	0.2990	D- 3, SR 5, Maytown I/C to 93rd I/C	15.89	1	0.5	6	0	9	13	6,662,500
8	0.2459	D- 5, SR 90, Highline Canal vicinity to Elk Heights I/C vic.	13.04	4	1.5	2	0	9	14	6,889,155
9	0.1757	D- 5, SR 90, Rygrass Summit to Columbia River Bridges	8.77	4	0.5	1	0	9	9	8,012,319
10	0.1529	D-1, SR 20, Fredonia to SR 5 - Widening	6.87	2	0.5	9.0	49	9	11	35,995,000
11	0.1173	D-5, SR 90, Ryegrass Summit Vic EBND TCL	4.69	4	0.5	1	0	9	9	1,592,464
12	0.1162	D- 6, SR 90, Harvard Road I/C	3.72	2	0	4	2	7	14	14,500,000
13	0.1147	D-5, SR 12, Airport Rd Interchange Modification	3.05	1	0.5	1	16	5	11	797,000
14	0.1082	D- 5, SR 24, Vernita Hill Vicinity	3.49	3	0.5	1	0	9	10	850,000
15	0.1071	D-1, SR 539, Lynden Park & Ride Lot	0.55	0	0.5	1.5	24	5	14	1,271,000
16	0.1032	D- 3, SR 101, Mt. Walker N.B. Passing / Truck Climbing Lane	3.49	4	0.5	10	0	9	10	372,879
17	0.1011	D-1, SR 539, Horton Rd to Laurel Rd (Stage 1) - Widening	3.73	4	2.8	8.5	326	9	14	20,565,000
18	0.1011	D- 3, SR 104, Kingston Traffic Circulation Imp.	3.19	4	0.5	26	15	5	14	6,377,000
19	0.1006	D- 3, SR 101, Blyn Westbound Passing Lane	3.60	5	0.5	11	0	10	11	644,600
20	0.0996	D-1, SR 539, Laurel Rd to Tenmile Rd (Stage 2) - Widening	1.98	2	0.5	10.0	98	9	14	4,516,000
21	0.0990	D- 3, SR 104, SR 19 - West WB Passing / Truck Climbing Lane	3.08	4	0.8	14	0	10	11	912,000
22	0.0964	D- 3, SR 109, NB Truck Climbing Lane, MP 4.5	2.76	4	0.5	10	0	8	11	1,868,900

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Figure E-1. Rural Prioritization

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MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

RURAL

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost
23	0.0952	D-1, SR 2, Sultan City Limits - TWLTL Lane	1.16	2	0.5	0.5	25	10	6	338,000
24	0.0945	D- 3, SR 109, SB Truck Climbing Lane (EB), MP 4.5	2.54	4	0.5	11	0	8	11	1,391,801
25	0.0910	D-2, SR 26, SR 243 I/C TO MP 5.5 VIC	1.35	3	0.5	14	0	10	10	1,516,640
26	0.0907	D- 3, SR 101, Northbound Passing Lane	2.10	4	0.5	15	0	10	11	599,400
27	0.0891	D- 3, SR 3, Belfair Vicinity	2.70	6	0.5	10	0	7	14	1,069,260
28	0.0890	D-1, SR 2, Index vicinity	0.83	3	2.5	27	3	9	14	3,382,000
29	0.0880	D-1, SR 5, Blaine - NB Pace Lane Extension	0.78	3	0.5	0.5	25	10	5	2,366,000
30	0.0877	D- 6, SR 195, Plaza to Spangle	0.36	3	1.3	0	5	8	8	17,450,000
31	0.0876	D- 5, SR 12, Waitsburg By-pass	1.20	3	13.5	24	6	8	13	5,401,792
32	0.0875	D- 3, SR 101, Southbound Passing Lane	1.61	4	0.5	15	0	10	11	623,540
33	0.0865	D- 6, SR 904, Cheney to SR 90	1.27	3	9.8	19	67	8	9	9,915,350
34	0.0846	D- 6, SR 195, Rosalia to Plaza	0.27	3	7.9	25	4	8	8	24,307,500
35	0.0845	D- 2, SR 215, Omak vicinity	0.33	4	0	1	0	6	13	1,150,000
36	0.0844	D- 3, SR 109, SB Passing Lane, MP 14.5 to 15.0	0.89	4	0.5	9	0	9	11	290,900
37	0.0843	D- 3, SR 109, NB Passing Lane, MP 14.5 to 15.0	0.87	4	0.5	9	0	9	11	299,800
38	0.0842	D- 5, SR 12, Old Naches Road Interchange	0.94	4	2.5	5.5	0	9	11	12,920,000
39	0.0841	D- 3, SR 109, SB Passing Lane, MP 14.0 to 15.0	0.90	4	0.6	14	0	9	11	587,900
40	0.0839	D- 3, SR 101, Shore Road to Joslin Road	3.90	8	24	16	408	9	14	17,331,550
41	0.0834	D- 3, SR 109, NB Passing Lane, MP14.0 to 15.0	0.71	4	0.6	14	0	9	11	765,110
42	0.0824	D-1, SR 2, SR 2 to SR 522 Monroe Bypass	1.11	4	2.2	12.0	116	7	11	28,534,000
43	0.0821	D- 6, SR 395, Hamilton Road to Montgomery Road	1.10	4	1.5	25	71	8	8	12,078,200
44	0.0816	D- 5, SR 12, SR 124 Interchange	0.21	4	13.25	8	0	3	14	8,000,000
45	0.0814	D- 4, SR 6, Pluvius Vicinity Realignment	0.30	4	0.625	7	0	7	0	1,176,000
46	0.0798	D- 4, SR 6, Rock Creek Bridge Replacement & Realignment	0.12	4	2.35	23	0	7	0	2,067,000
47	0.0789	D- 4, SR 4, Svensons Curve Realignment	0.34	4	4.625	24	12	10	0	1,561,000
48	0.0782	D- 5, SR 12, SR 124 to Boise Cascade	0.49	4	35	9.5	32	3	14	17,300,000
49	0.0772	D- 4, SR 503, Lewisville Park vicinity Climbing Lanes	1.03	5	2	22	4	10	1	2,879,000
50	0.0771	D- 6, SR 395, MP 172 to Hamilton Road	0.98	5	2.5	24	36	8	8	9,508,800

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Figure E-1. Rural Prioritization (continued)

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MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

RURAL

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost
51	0.0765	D-1, SR 5, SR 5, 9, 539 and 543 SC&DI	1.25	6	0.5	0.5	0	8	5	2,386,000
52	0.0763	D-1, SR 530, SR 5 to Old SR 99 Wye Connection - Widening	0.43	5	1.0	11.0	7	10	5	1,062,000
53	0.0759	D- 5, SR 12, SR 410 to Naches	0.38	4	43.5	15.5	15	8	13	16,208,740
54	0.0750	D-1, SR 539, Tenmile Rd to Int'l Boundary: Fishtrap Creek to W Main St (Stage 1) - Widening	1.87	5	2.8	12.5	537	9	14	18,053,000
55	0.0747	D- 6, SR 270, Johnson Rd. to Idaho State Line	0.71	5	10.6	24	10	7	9	12,502,525
56	0.0747	D- 3, SR 12, Passing lanes MP 32.00 to MP 33.83	0.39	6	0.5	15	0	10	14	1,047,864
57	0.0742	D- 5, SR 22, I-82 to SR 97	0.26	5	6.5	30	96	8	14	34,000,000
58	0.0737	D- 4, SR 101, Smith Creek Road vicinity Climbing Lane	0.51	5	8.875	24	0	9	5	5,655,000
59	0.0732	D- 3, SR 101, Carlsborg/Hooker Roads I/C	1.73	10	0.5	15	0	7	14	6,049,480
60	0.0721	D1, SR 522, Snohomish Riv Br to SR 2 (Stage 3) - Widening	0.23	5	0.8	13.0	227	10	10	38,498,000
61	0.0693	D- 3, SR 101, SR 101/SR 107 I/C	0.27	7	0.5	14	0	8	9	777,230
62	0.0660	D- 4, SR 97, Brooks Park to Summit Climbing Lane	0.52	8	0.5	8.5	3.5	9	0	3,789,000
63	0.0610	D- 5, SR 90, Hyak to Stampede Road I/C	0.76	7	30.25	13.5	10	9	4	26,838,000
64	0.0526	D-1, SR 96, Seattle Hill Rd to SR 9 - Widening & Realignment	0.25	6	4.0	11.5	1318	8	11	15,960,000

Figure E-1. Rural Prioritization (continued)

MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

URBAN

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost (dollars)
		EXCEPTIONS:								
1	-	D-1, SR 99, Vic. 60th Ave to SR 525 (Stage 2) - Widening	291.79	1	0.6	10.5	388	4	14	1,014,000
2	-	D-1, SR 99, King/Snohomish CL to Vic. 60th Ave (Stage 1) - Widening	232.58	1	0.5	10.5	304	4	14	1,217,000
3	-	D- 5, SR 240, Edison Street I/C	86.32	1	0.5	12	28	4	14	3,253,200
4	0.9437	D- 3, SR 161, SR 161 / SR 167 Eastbound Ramp	66.50	5	0.5	12	0	8	14	505,336
5	0.9336	D- 3, SR 510, Martin Way to Pacific Avenue SE	63.83	5	0.5	4	102	3	14	7,706,016
6	0.7139	D- 3, SR 16, Gig Harbor I/C	47.32	0	0.5	6	0	8	14	1,360,000
7	0.6820	D- 3, SR 510, SR 5 to Martin Way	45.46	5	0.5	4	0	6	14	2,801,803
8	0.6536	D- 6, SR 2, SR 2/SR 206/Market St. Intersection	43.40	3	0	2	34	8	8	626,730
9	0.5925	D-1, SR 99, 35th Ave. W (Lake Rd.) to SR 525 - NB Right Turn Lane	39.56	7	0.5	0.5	20	10	14	168,000
10	0.4634	D- 4, SR 501, Mill Plain Extension	30.55	4	0.5	1.5	180	6	11	500,000
11	0.3958	D- 3, SR 305, SR 3 to Bond Road	25.86	3	4.5	15	6	7	14	3,441,469
12	0.3694	D- 3, SR 161, 204th St. E to 176 St E	24.06	3	0.5	8	112	9	11	2,948,500
13	0.3634	D- 3, SR 16, SR 5 to Wollochet TSM	23.59	3	0.5	5	0	6	14	4,052,000
14	0.3048	D-1, SR 99, Airport Rd: I/S HOV Priority	19.19	0	4.5	7.0	103	10	14	200,000
15	0.2955	D-6, SR 90, University Rd I/C	18.87	3	0	2	61	6	9	13,000,000
16	0.2840	D- 3, SR 161, 36th to Jovita	18.36	6	0.5	13	141	9	14	4,695,530
17	0.2536	D- 3, SR 101, Mottman Road I/C	15.53	1	0.5	6	0	5	14	3,540,589
18	0.2525	D-6, SR 90, Pines Rd I/C Modification	15.66	2	0	2	0	9	8	460,000
19	0.2460	D- 3, SR 410, Linden Drive I/C	15.20	2	0.5	21	13.5	8	14	4,157,504
20	0.2372	D- 3, SR 510, SR 5 O-xing	14.67	3	0.5	4	0	6	11	9,104,160
21	0.2248	D- 3, SR 410, 214th Avenue E to 234th	13.30	0	0.5	13	213	10	11	3,608,693
22	0.2161	D-1, SR 527, SR 522/Main St Intersection Improvements	12.99	2	0.5	10.0	36	9	11	1,056,000
23	0.1990	D- 5, SR 224, SR 240 Interchange	11.90	4	0.5	1	3	3	14	10,180,799
24	0.1967	D- 3, SR 3, SR 3/SR 303 I/C (Waaga Way)	11.23	1	0.5	12	0	10	14	4,215,120

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Figure E-2. Urban Prioritization

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MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

URBAN

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost (dollars)
25	0.1866	D-1, SR 522, Lake City Way Multi-Modal Project - SR 5 to SR 405 - HOV Priority	11.53	7	0.5	15.0	287	5	9	6,409,000
26	0.1833	D-1, SR 5, Northbound Downtown Rechannelization	11.13	7	0.5	0.0	0	8	9	2,090,000
27	0.1538	D- 6, SR 2, North Spokane/Division St. -Stage 2	8.43	4	0	2	123	4	14	2,925,000
28	0.1502	D-1, SR 9, SR 522 to Clearview (Stage 2): 228th to SR 524/212th-Widening	7.70	2	1.3	11.5	38	10	11	4,792,000
29	0.1481	D-1, SR 527, 164th St SE to 132nd St SE - Widening	7.99	3	0.7	17.0	345	5	11	14,573,000
30	0.1471	D-1, SR 524, 24th to SR 527 - Widening	8.72	5	10.5	22.0	704	9	11	6,839,000
31	0.1452	D-1, SR 900, Duvall Ave SE to SR 90 (Stage 1): Tibbets Creek to SR 90 - Widening	9.34	5	95.0	27.0	680	6	11	5,467,000
32	0.1405	D-1, SR 161, Jovita Blvd to SR 18 (Stage 2): Milton Way to S 360th/Milton Rd S-Widening	7.94	5	6.5	17.0	290	8	11	10,232,000
33	0.1362	D- 5, SR 82, I-82 / Yakima Ave.	5.21	0	2	6	19	5	14	2,800,000
34	0.1330	D- 3, SR 161, 234th to 204th	7.19	6	0.5	14	63	9	11	7,565,730
35	0.1309	D-1, SR 542, Orleans to Britton (Stage 1): Orleans St to Hannegan Rd - Widening	5.47	1	2.0	9.5	128	8	11	4,210,000
36	0.1308	D-1, SR 5, Boeing Access Rd I/C - Flyover Structure	5.19	1	0.5	6.0	0	8	14	3,260,000
37	0.1254	D- 3, SR 410, 234th to Hinkleman Ext. Road	5.95	3	2	13	213	10	11	5,800,941
38	0.1224	D1, SR 522, SR 9 to Paradise Lk Rd (Stage 1) - New I/C & Widening	6.31	6	2.5	8.0	62	10	10	29,488,000
39	0.1178	D- 5, SR 240, Stevens Drive to SR 182	4.58	3	0.5	0	0	4	14	15,800,000
40	0.1176	D- 6, SR 90, Sprague Ave. to Argonne Rd. -Stage 2 (Broadway Ave to Argonne Rd)	4.96	3	0	7	162	9	14	15,138,675
41	0.1167	D-1, SR 9, SR 522 to Clearview (Stage 1B): SR 522 to 228th-Widening	4.26	2	0.5	11.0	17	10	11	8,077,000
42	0.1149	D- 6, SR 90, Sprague Ave. to Argonne Rd. -Stage 1 (I/C)	4.58	3	0	7	102	9	14	37,765,775

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Figure E-2. Urban Prioritization (continued)

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MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

URBAN

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost (dollars)
43	0.1115	D-1, SR 525, SR 99 to SR 526 - Widening & HOV Lanes	3.62	1	4.2	17.0	474	10	11	17,998,000
44	0.1104	D-1, SR 520, NE 40th St I/C & C-D Lanes	0.48	0	0.5	0.0	1	8	14	13,281,000
45	0.1088	D-3, SR 3, SR 3/SR 305 Interchange - Stage 2	0.21	0	0.5	6	0	9	11	1,248,000
46	0.1049	D-5, SR 395, Lewis / Sylvester Street I/C	0.31	1	0	4	0	4	14	5,860,000
47	0.1040	D-1, SR 5, 196th St SW (SR 524) I/C	3.24	4	0.5	3.5	46	1	14	17,589,000
48	0.1039	D-1, SR 20, Avon Ave to SR 9 - Channelization & Access Control	2.54	2	1.3	5.0	192	6	13	1,399,000
49	0.1017	D-4, SR 5, Burnt Bridge through 78th Street	3.55	4	0.5	14	135	6	14	45,813,311
50	0.1009	D-1, SR 9, SR 522 to Clearview (Stage 3): SR 524/212th to 176th-Widening	2.17	2	0.5	12.5	153	10	11	13,578,000
51	0.1007	D-6, SR 2, North Spokane/Division St -Stage 3	3.18	4	0	2	123	5	14	8,046,000
52	0.0998	D-4, SR 205, 4th Plain Road Southbound on-ramp	1.41	2	0.5	1	13	9	6	1,435,000
53	0.0995	D-1, SR 5, SR 526 to Marysville - HOV Lanes	2.72	4	0.5	1.0	14	4	14	130,130,000
54	0.0993	D-3, SR 20, Port Townsend Vicinity Truck Climbing Lane	3.53	5	0.5	11	0	7	11	864,529
55	0.0985	D-3, SR 105, Southbound Truck Climbing Lane	2.89	4	0.5	10	0	9	14	383,936
56	0.0978	D-3, SR 20, Port Townsend TWLT Lane	2.78	4	0.5	1	0	9	10	362,265
57	0.0978	D-1, SR 20 SPUR, Commercial Ave./ 12th to San Juan / Victoria Ferry Terminal - Widening	0.29	2	0.5	2.5	0	8	13	2,106,000
58	0.0975	D-3, SR 410, Hinkleman Ext. Road to Park Avenue	2.63	3	0.6	13	213	9	11	3,478,555
59	0.0974	D-1, SR 542, Orleans to Britton (Stage 2): Hannegan Rd to Britton Rd	0.63	1	5.0	9.5	430	8	11	12,209,000
60	0.0967	D-2, SR 17, Pioneer Way to Stratford Road	0.70	2	1.6	24	52	6	13	4,850,000
61	0.0966	D-1, SR 5, Marysville P&R Lot	1.62	3	1.0	10.0	0	4	11	6,503,000
62	0.0965	D-5, SR 24, SR 82 to Keys Road, MP 0.0-0.98	2.63	4	0.5	14.5	21	5	11	10,967,191
63	0.0964	D-4, SR 5, Salmon Creek to SR 205	2.37	4	0.5	16	32	3	14	21,541,000
64	0.0952	D-1, SR 527, 132nd St SE to 112th St SE - Widening	2.53	3	1.4	11.5	387	7	11	13,295,000

Figure E-2. Urban Prioritization (continued)

MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

URBAN

Rank Order	Priority Index	Project	B/C 0.65 1	Cmty Sup. 0.14 0	Wetlands 0.0267 0	Water Q. 0.0267 0	Noise 0.0266 0	Mode Int. 0.07 0	L/U 0.06 1	WSDOT Project Cost (dollars)
65	0.0944	D- 5, SR 240, SR 182 to Columbia Center I/C	2.73	4	10.5	15.5	41	5	14	21,000,000
66	0.0939	D- 3, SR 105, Northbound Truck Climbing Lane	2.13	4	0.5	10	0	9	14	455,750
67	0.0938	D-1, SR 9, Lake Stevens Park & Ride Lot	0.73	2	11.5	5.5	90	7	11	5,750,000
68	0.0931	D- 4, SR 205, 18th Street Interchange	1.98	4	0.5	2.5	95	6	14	17,686,000
69	0.0919	D- 2, SR 20, MP 277.61 to Bigham Flats	0.27	3	0	11	0	8	13	3,988,000
70	0.0919	D- 3, SR 101, Cloquallam Rd. Undercrossing I/C	0.22	3	0.5	11	0	7	13	5,161,800
71	0.0914	D- 3, SR 510, Bingo Hall Vicinity, TWLT Lane	2.23	5	0.5	4	0	9	14	500,300
72	0.0913	D-1, SR 5, NE 175th St to NE 205th St - Auxiliary Lane	3.01	7	0.5	10.0	18	8	14	4,031,000
73	0.0913	D-1, SR 20, Goldie Rd to Ault Field Rd - TWLT Lane & Access Control	0.16	3	0.5	2.0	14	9	9	5,657,000
74	0.0904	D- 3, SR 510, 93rd to SR 507, TWLT Lane	2.87	8	0.5	4	0	10	14	2,345,346
75	0.0897	D- 3, SR 304, Bremerton Ferry Terminal to Vic Gorst	2.19	5	0.5	19	84	5	14	25,309,000
76	0.0895	D-1, SR 5, 41st Street SE to SR 2 - Northbound Auxilary Lane	0.79	4	0.5	0.5	5	8	14	16,035,000
77	0.0891	D- 5, SR 395, Hillsboro Street I/C	0.57	4	0.5	0	0	8	14	9,577,157
78	0.0891	D- 2, SR 2, Easy Street	0.38	4	0	1	0	4	9	3,400,000
79	0.0887	D- 6, SR 290, Mission Ave. to Argonne Rd.	1.18	4	0	8	98	8	14	8,241,551
80	0.0878	D- 5, SR 82/823, Selah Connection	1.02	4	2.2	12.5	47.5	5	10	27,500,000
81	0.0870	D- 4, SR 14, Brady Road Interchange (SE 192nd)	1.07	3	16.25	30	6	9	9	10,899,500
82	0.0868	D-1, SR 18, Weyerhouser Wy to SR 167 Truck Climbing Shld Lane	2.31	6	5.0	5.0	16	10	13	3,574,000
83	0.0866	D1, SR 522, Paradise Lk Rd to Snohomish River (Stage 2) - New I/C & Widening	3.01	5	23.1	7.5	78	10	10	29,155,000
84	0.0866	D-1, SR 509, SR 518 I/C Modification	1.44	5	0.5	5.0	3	9	11	15,085,000
85	0.0854	D- 4, SR 14, SR 14/SR 500 Interchange	0.74	4	3.5	17	3	8	6	8,138,550
86	0.0853	D-1, SR 5, 172nd St I/C Modifications	2.14	7	0.5	0.0	56	8	11	8,606,000
87	0.0851	D-1, SR 202, E Lk Sammamish Pkwy to Sahalee Wy (Stage 1 & 2) - Additional Lanes	3.14	6	3.5	21.0	537	7	11	30,456,000
88	0.0844	D- 4, SR 500, Ward Road to NE 162nd Avenue	1.38	6	0.5	2.5	7	6	11	2,974,390

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Figure E-2. Urban Prioritization (continued)

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MOBILITY IMPROVEMENT PROGRAM (I1) 95-97 BIENNIUM STATEWIDE RANKING

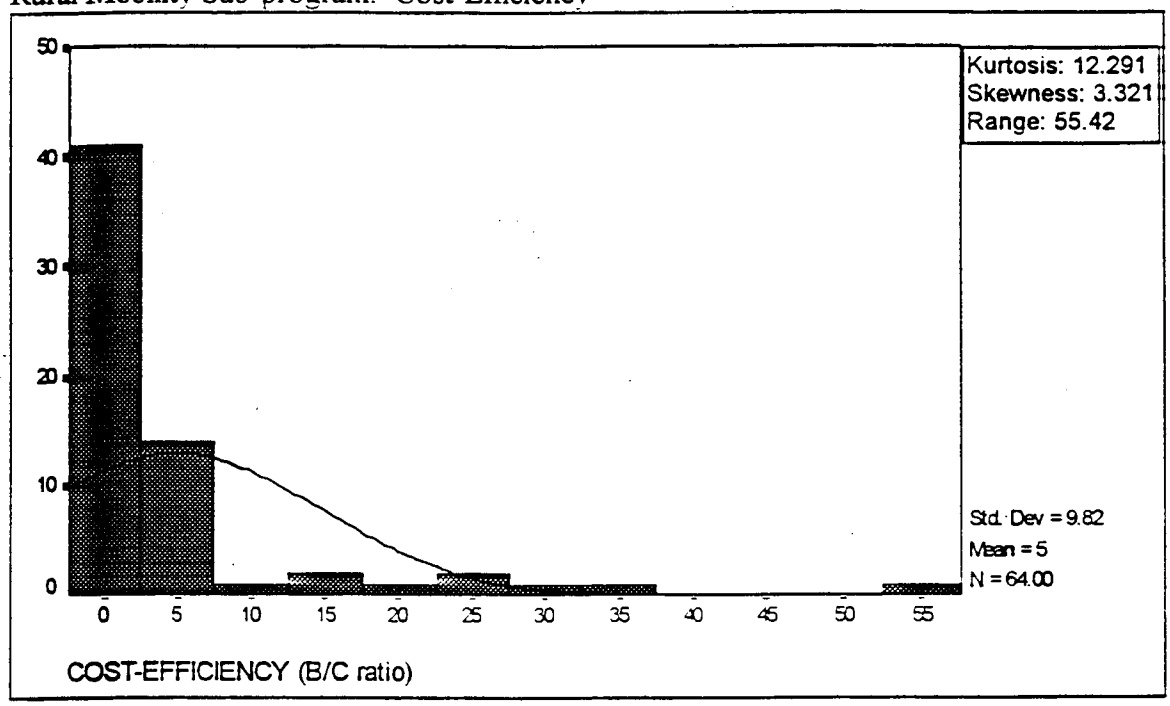
URBAN

Rank Order	Priority Index	Project	B/C	Cmty Sup.	Wetlands	Water Q.	Noise	Mode Int.	L/U	WSDOT Project Cost (dollars)
			0.65	0.14	0.0267	0.0267	0.0266	0.07	0.06	
			1	0	0	0	0	0	1	
89	0.0838	D- 6, SR 395, Hastings Road to MP 172, -Stage 2	0.82	5	0	15.5	28	8	13	11,142,272
90	0.0838	D- 3, SR 3, Gorst RR Bridge to SR 304	1.74	5	1.82	29	280	5	14	28,554,240
91	0.0832	D1, SR 90, Sunset I/C Modifications	2.75	5	31.0	21.0	26	10	14	5,876,000
92	0.0831	D- 3, SR 101, Aberdeen/Hoquiam Stage 1	0.22	5	0.5	25	8	6	14	36,220,000
93	0.0827	D-1, SR 5, SR 161 to SR 18 Interchange Modification	0.36	5	0.5	23.0	2	10	14	30,684,000
94	0.0796	D- 4, SR 502, Dollars Corner to Battle Ground	0.70	5	4.63	21	100	9	11	10,553,000
95	0.0789	D- 5, SR 397, Finley Road to East 10th Avenue	0.69	7	0.5	0	10	9	3	3,630,000
96	0.0783	D-1, SR 99, Aurora Br (Geo.Wash Mem Br 99/560) Widening	0.01	7	0.5	15.0	0	7	14	18,722,000
97	0.0753	D-1, SR 169, SR 516 to 196th Ave (Stage 1): 225th SE vic to 220th Pl/Witte Rd - Widening	1.95	8	3.5	25.0	401	7	11	7,914,000
98	0.0746	D- 3, SR 16, Tacoma Narrows Bridge	0.24	8	0.5	26	160	7	14	421,200,000
99	0.0745	D-1, SR 509, South Access Rd Extension	2.16	8	7.3	21.0	1008	3	14	196,030,000
100	0.0710	D- 3, SR 167, SR 5 to SR 161 (Stage 2 construction of new SR 161 alnmt.)	0.24	8	11.5	23	88	9	14	46,186,400
101	0.0709	D- 4, SR 5, Rush Road vicinity to Thurston County Line	2.52	4	121.65	29	33	8	13	121,868,000
102	0.0626	D- 3, SR 167, SR 509 to SR 5 - Stage 1	0.03	8	18.45	27	387	9	14	109,584,000
103	0.0604	D-1, SR 516, Wax Rd to SR 169 (Stages 1 & 2) - Widening	1.19	8	18.9	18.0	824	10	11	19,778,000

Figure E-2. Urban Prioritization (continued)

APPENDIX F. CATEGORY SCORE HISTOGRAMS

Rural Mobility Sub-program: Cost-Efficiency



Rural Mobility Sub-program: Community support

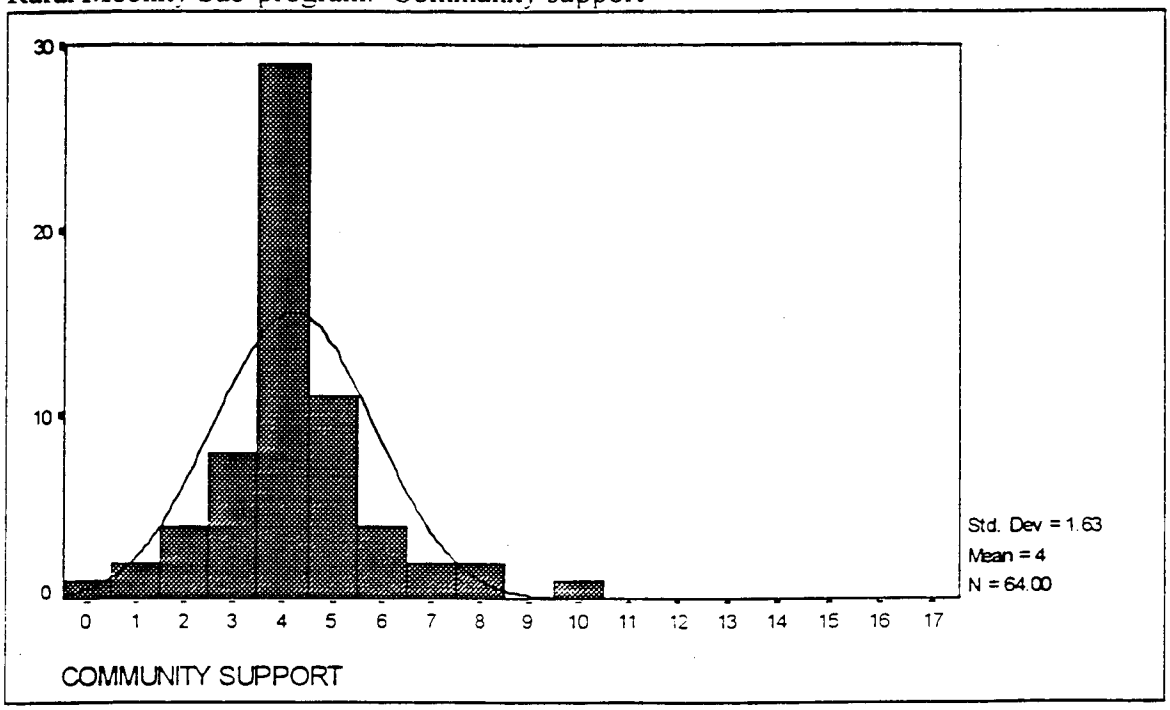
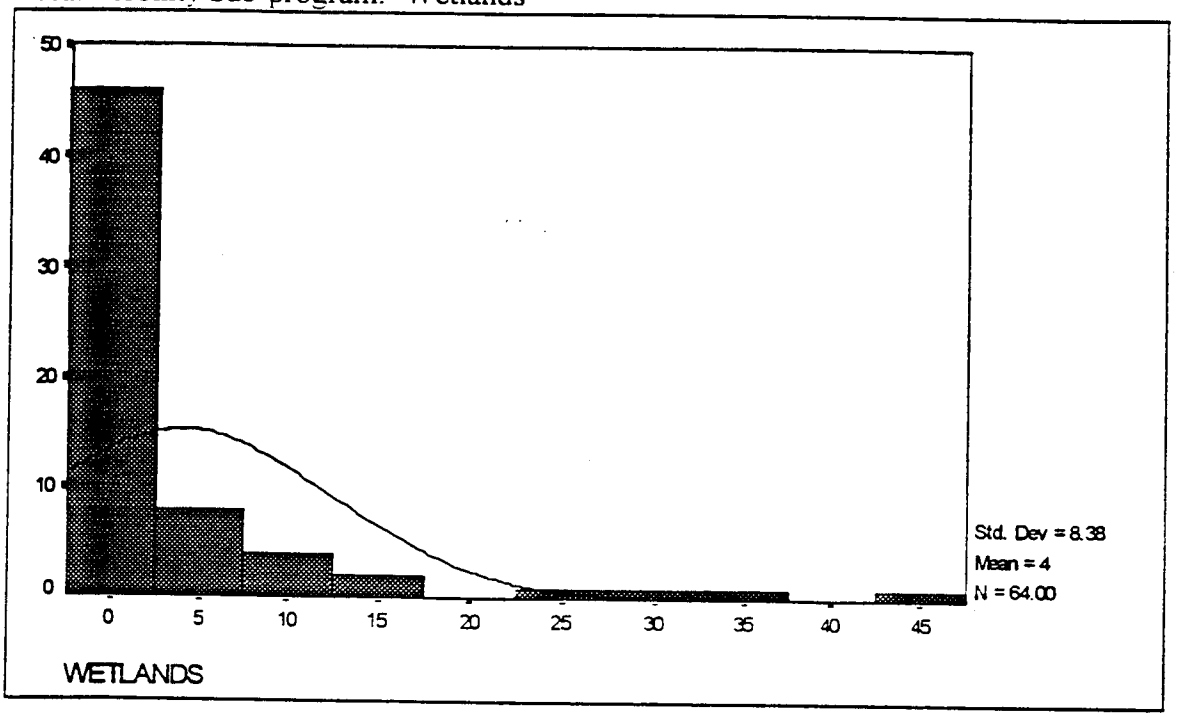


Figure F-1. Rural Mobility Sub-Program Histograms

Rural Mobility Sub-program: Wetlands



Rural Mobility Sub-program: Water quality

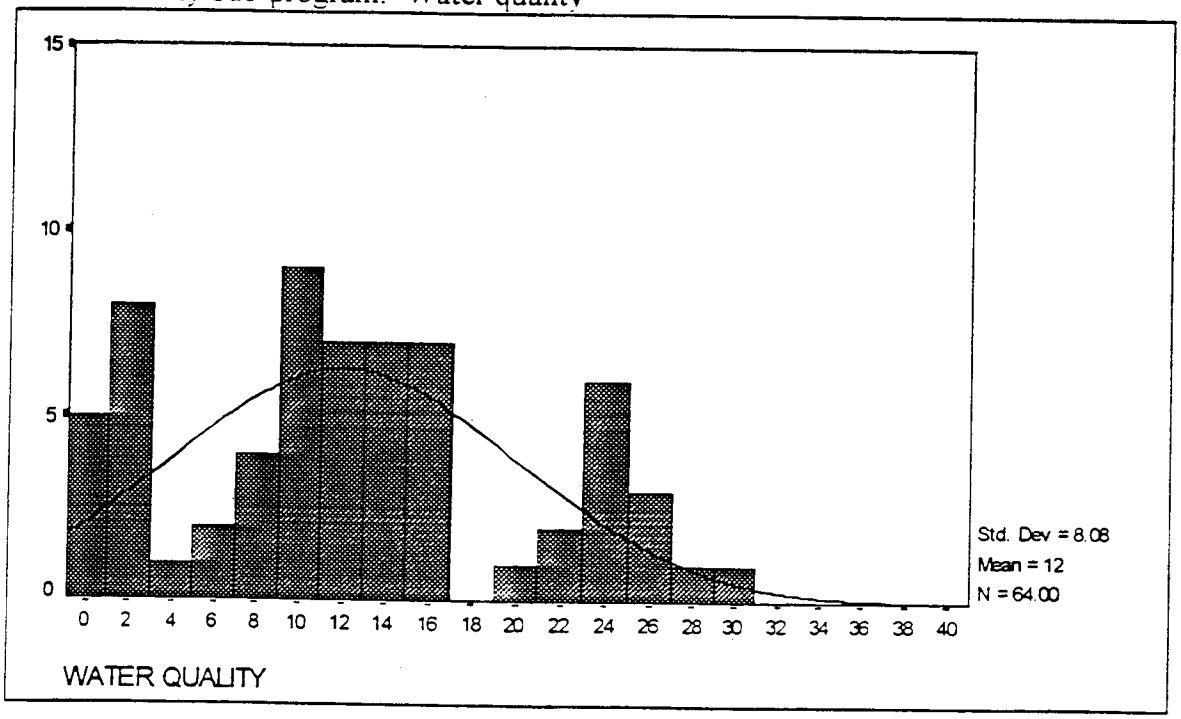
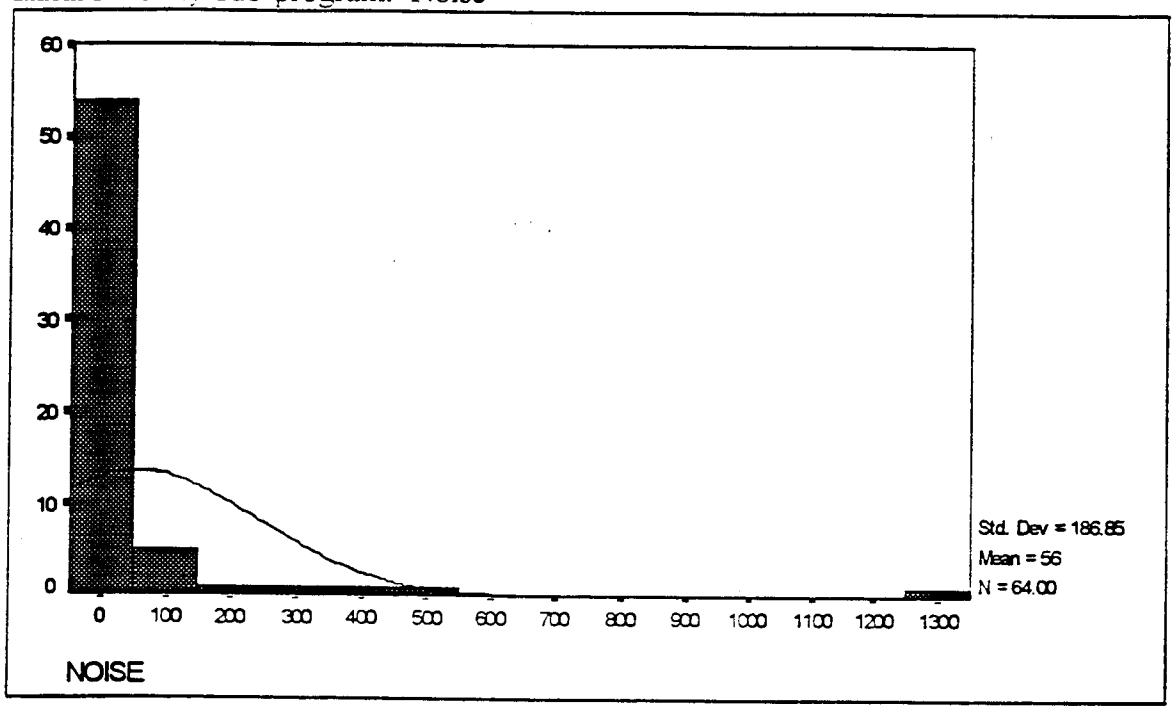


Figure F-1. *Rural Mobility Sub-Program Histograms (continued)*

Rural Mobility Sub-program: Noise



Rural Mobility Sub-program: Noise category - truncated

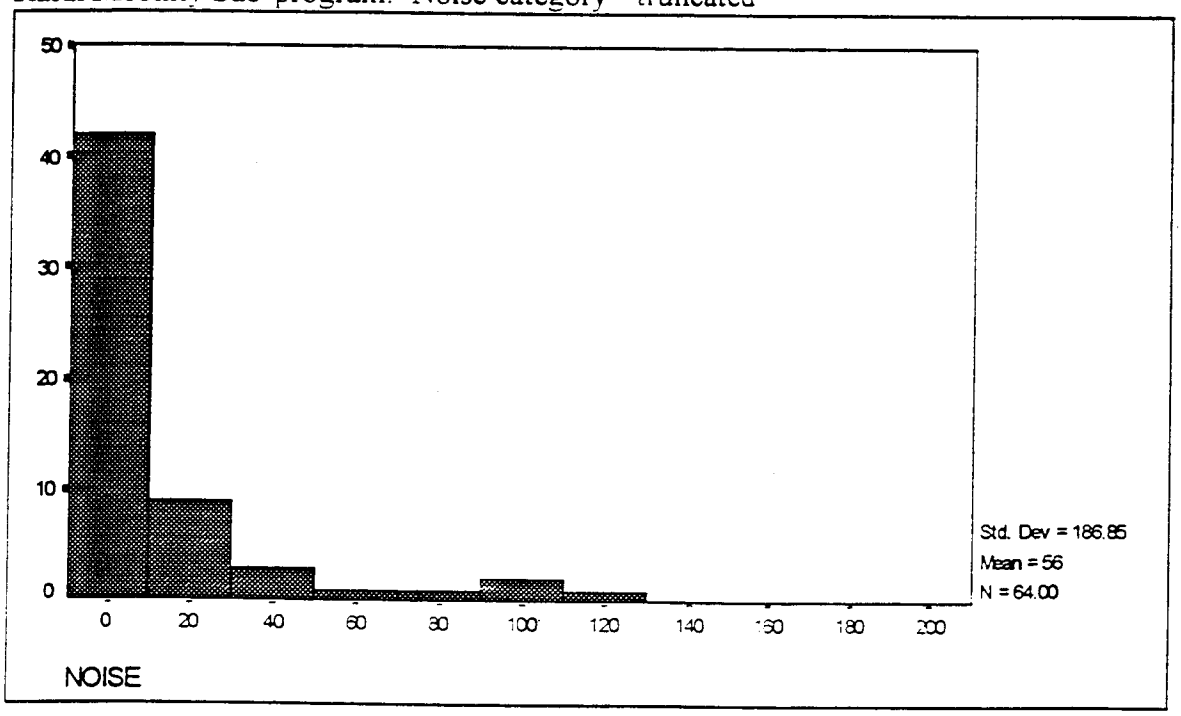
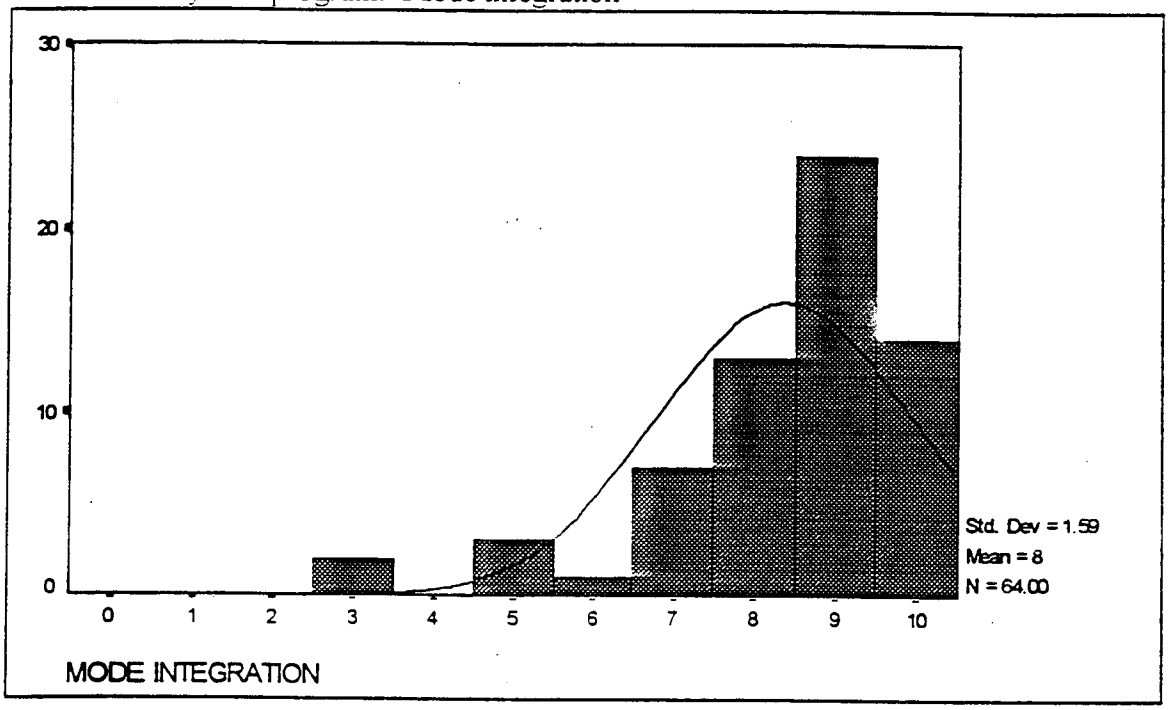


Figure F-1. *Rural Mobility Sub-Program Histograms (continued)*

Rural Mobility Sub-program: Mode integration



Rural Mobility Sub-program: Land use

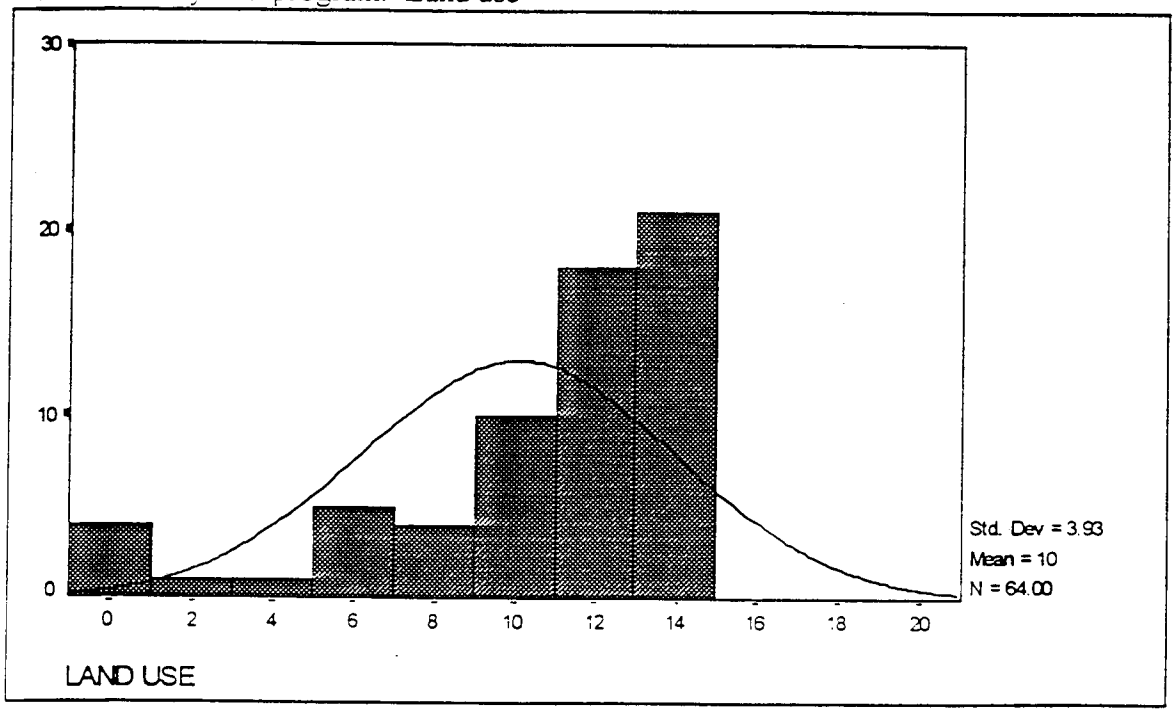
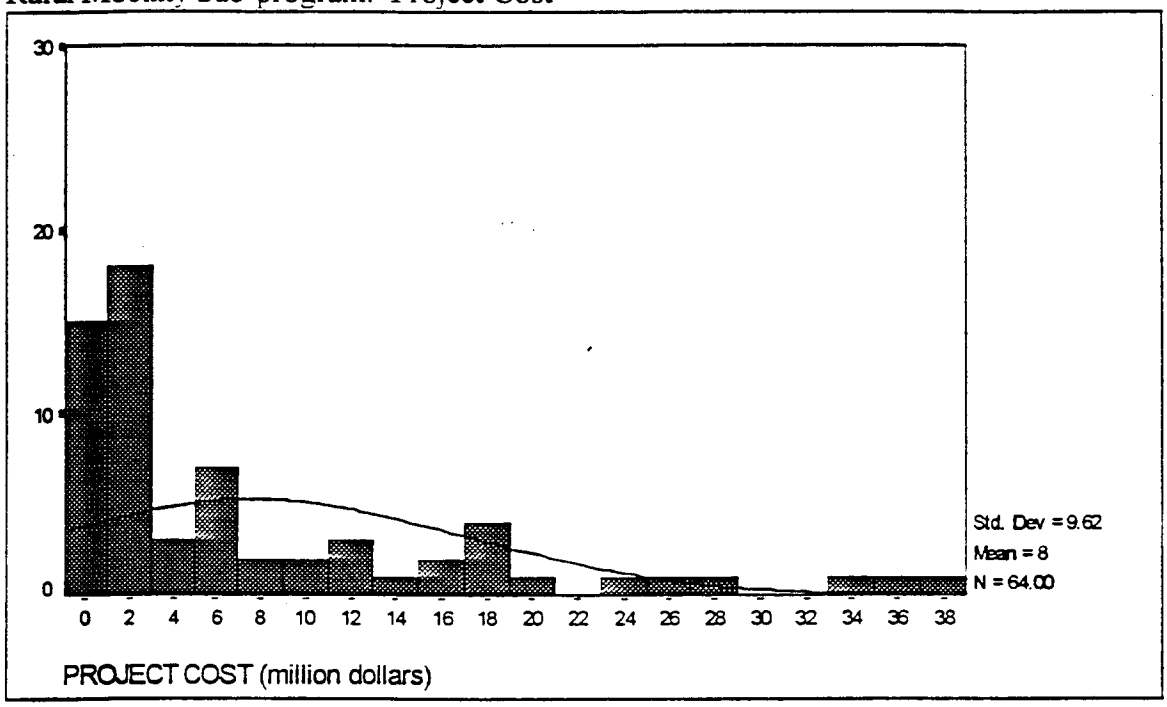


Figure F-1. Rural Mobility Sub-Program Histograms (continued)

Rural Mobility Sub-program: Project Cost



Rural Mobility Sub-program: Project Net present value

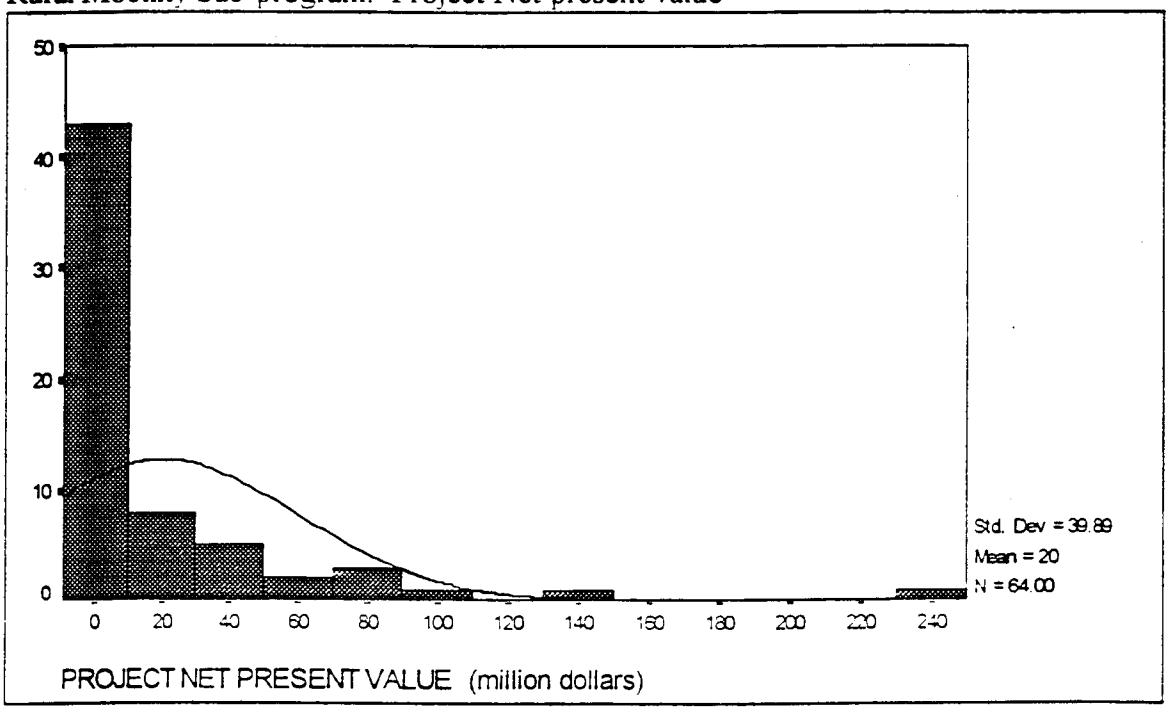
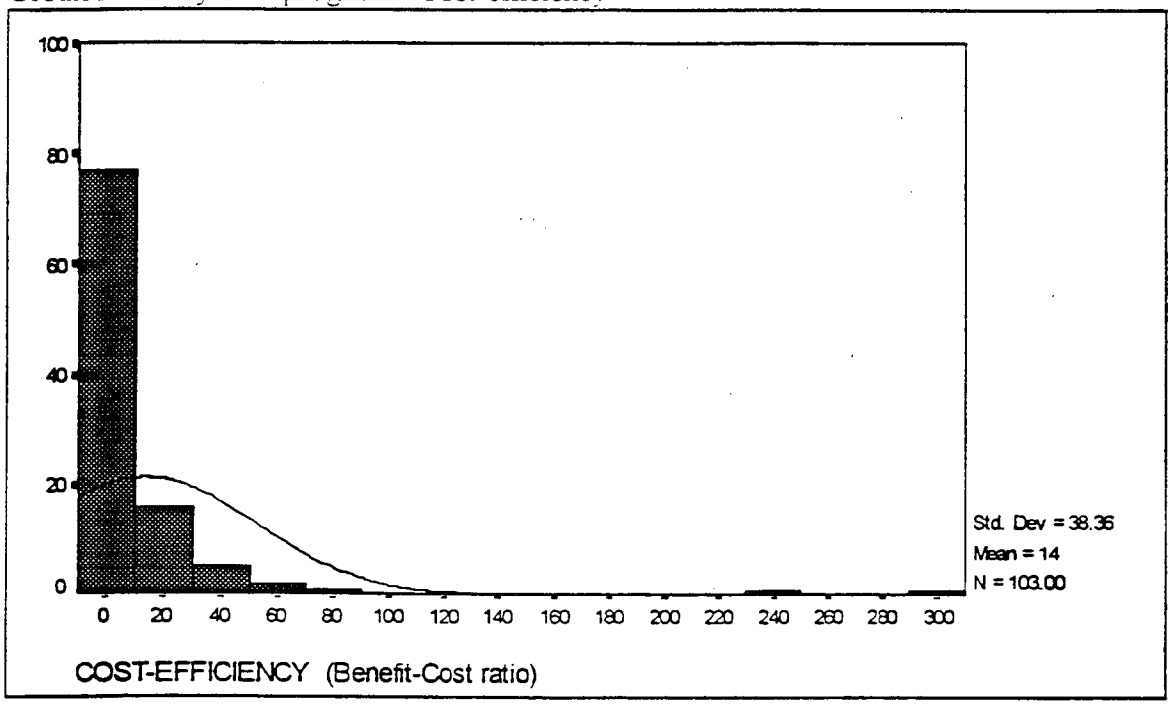


Figure F-1. Rural Mobility Sub-Program Histograms (continued)

Urban Mobility Sub-program: Cost-efficiency



Urban Mobility Sub-program: Cost-efficiency - Truncated

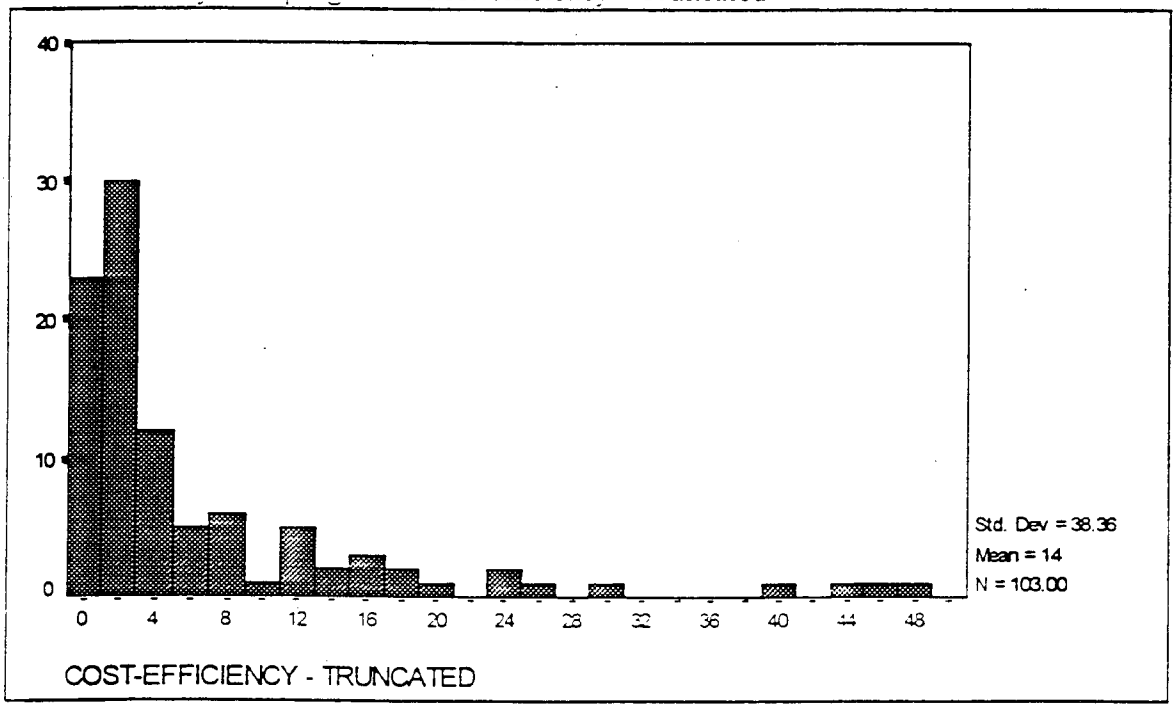
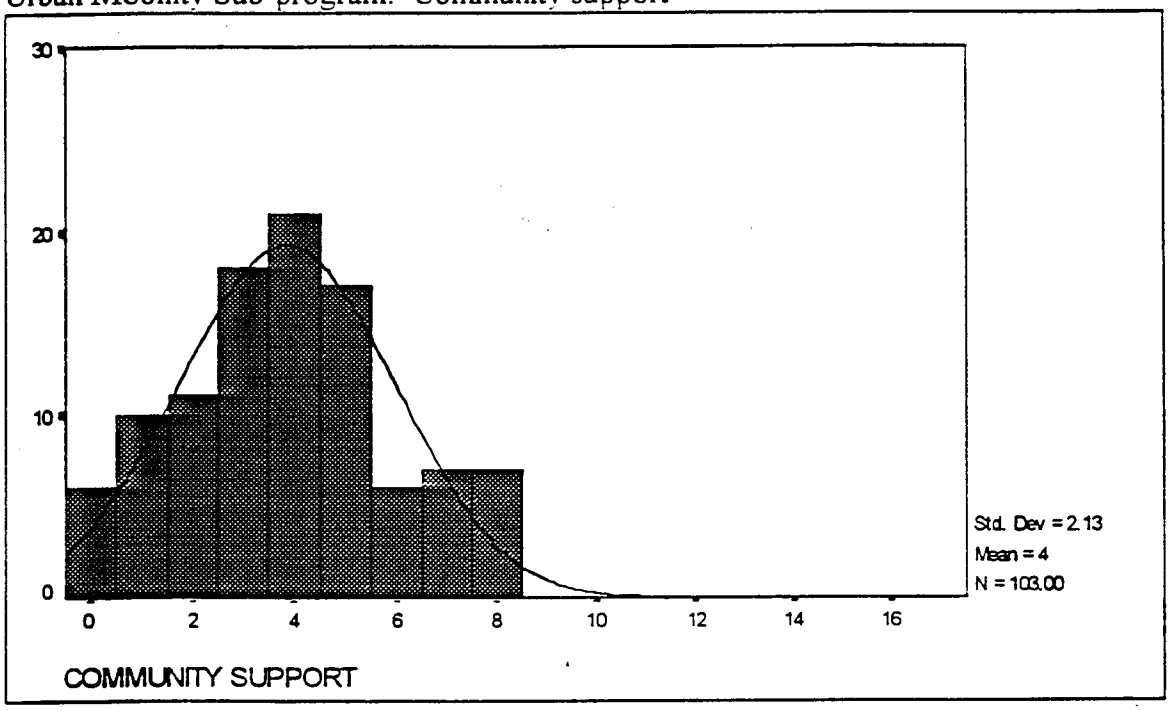


Figure F-2. Urban Mobility Sub-Program Histograms

Urban Mobility Sub-program: Community support



Urban Mobility Sub-program: Wetlands

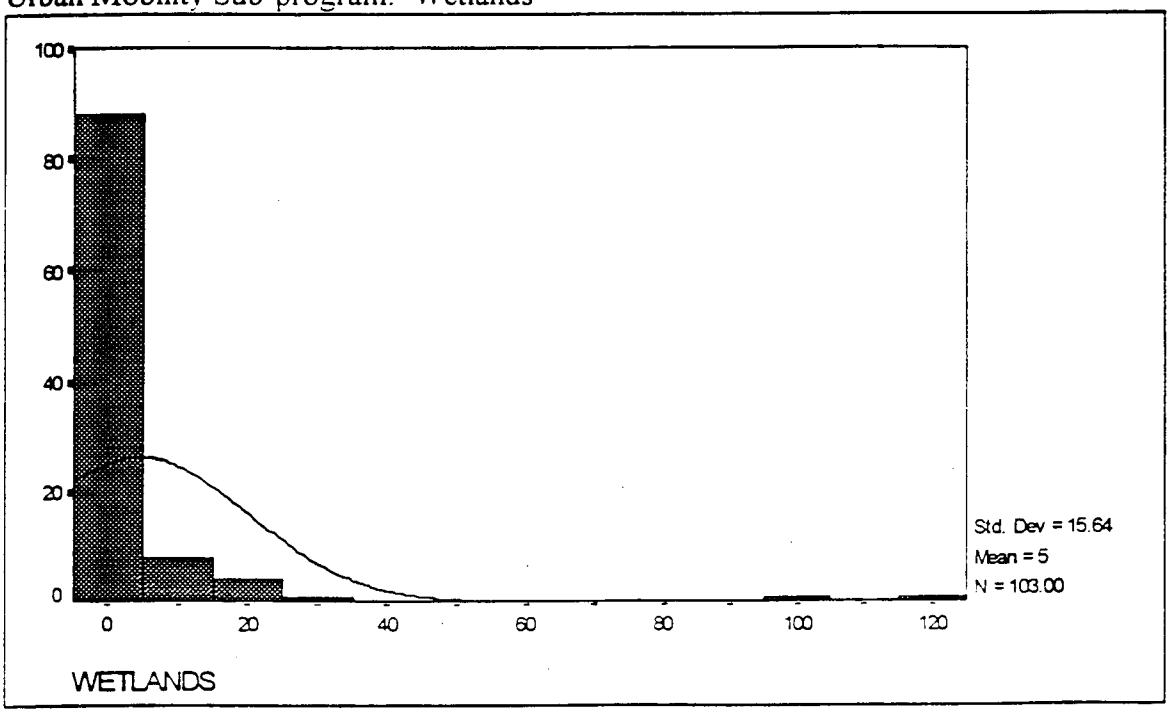
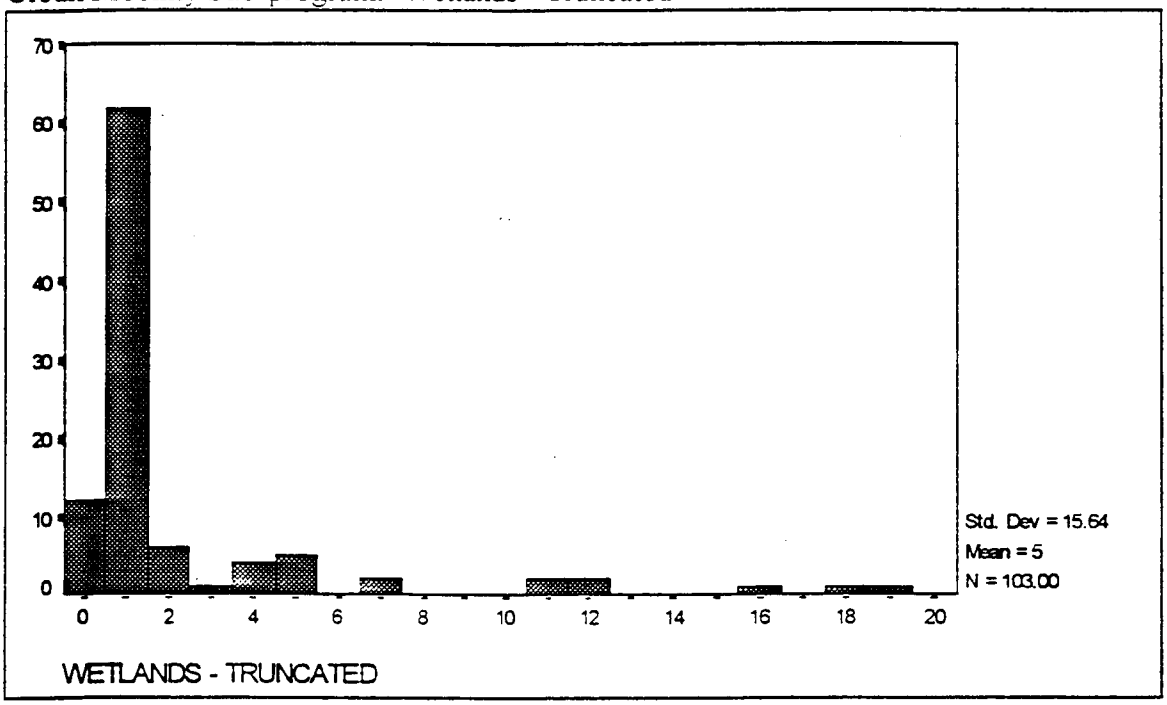


Figure F-2. Urban Mobility Sub-Program Histograms (continued)

Urban Mobility Sub-program: Wetlands - Truncated



Urban Mobility Sub-program: Water quality

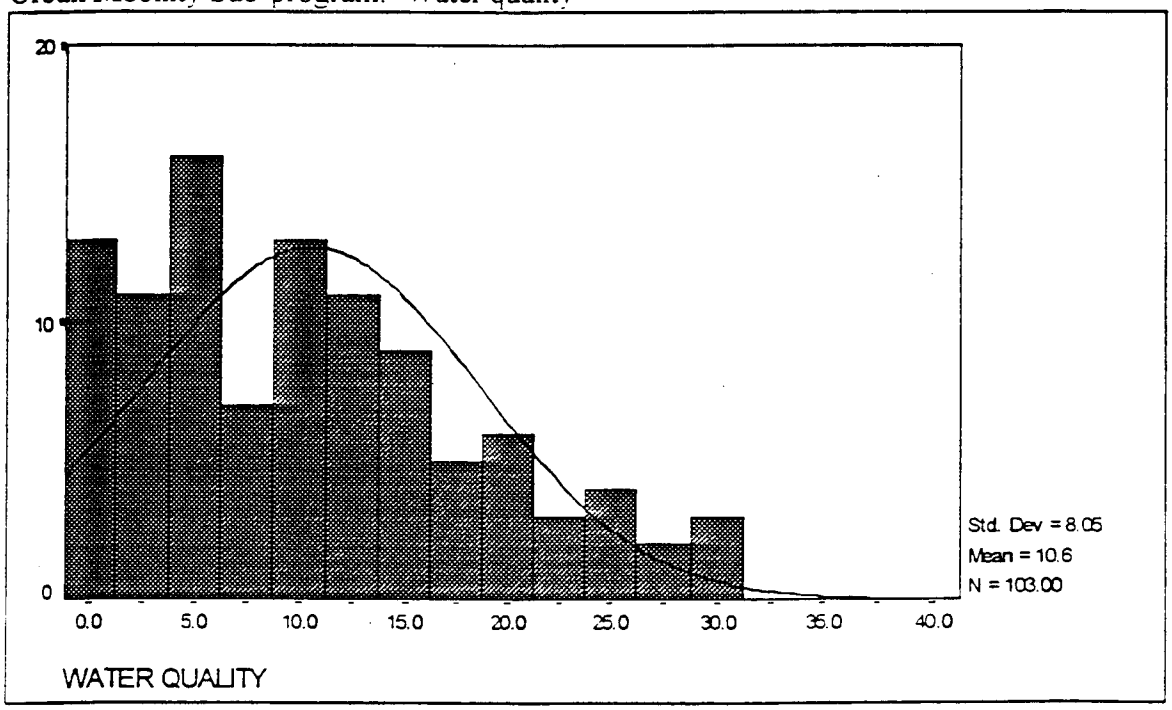
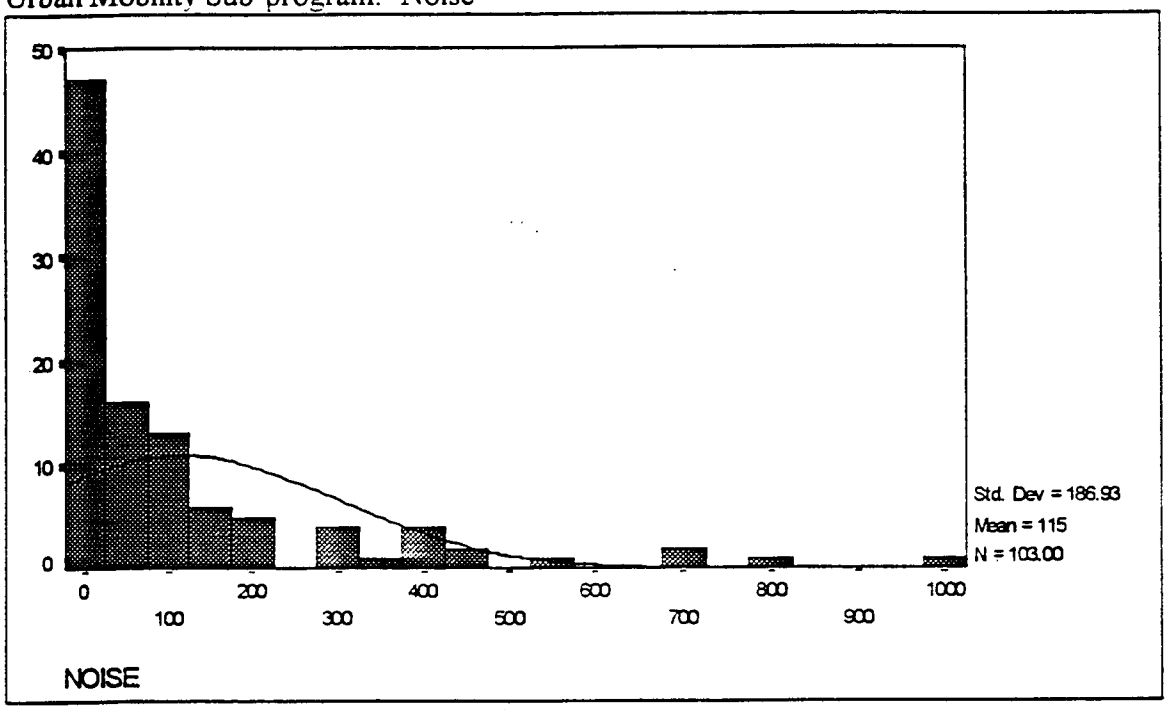


Figure F-2. Urban Mobility Sub-Program Histograms (continued)

Urban Mobility Sub-program: Noise



Urban Mobility Sub-program: Noise - Truncated

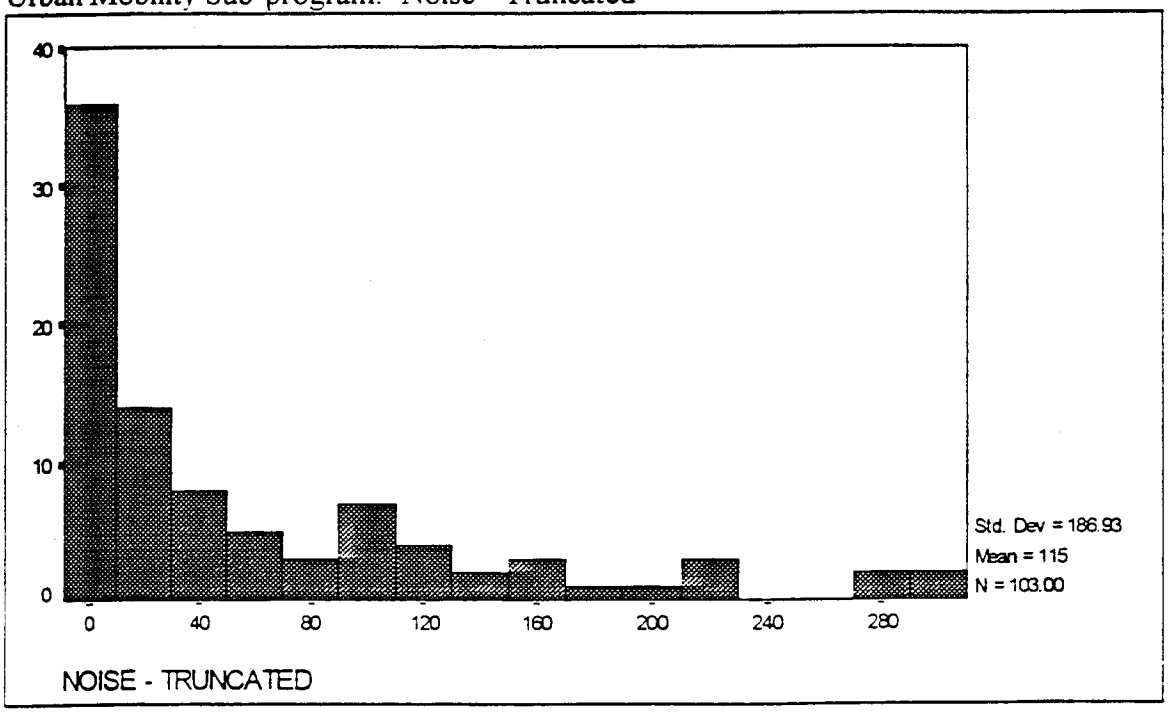
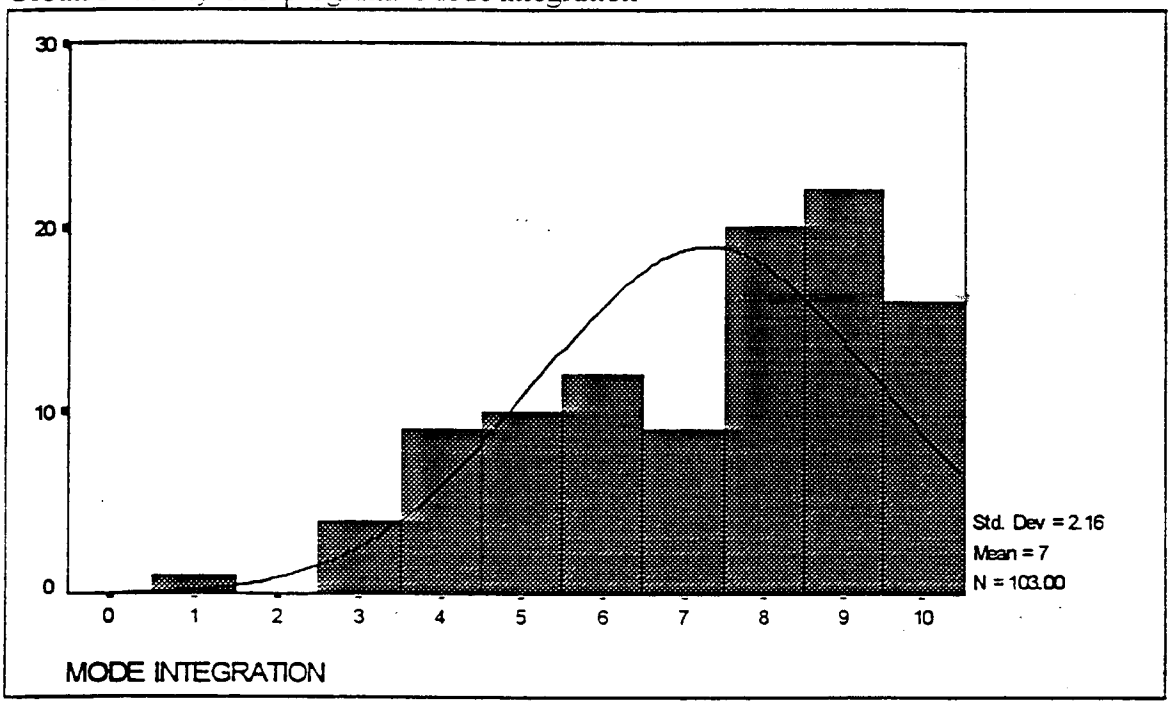


Figure F-2. Urban Mobility Sub-Program Histograms (continued)

Urban Mobility Sub-program: Mode integration



Urban Mobility Sub-program: Land use

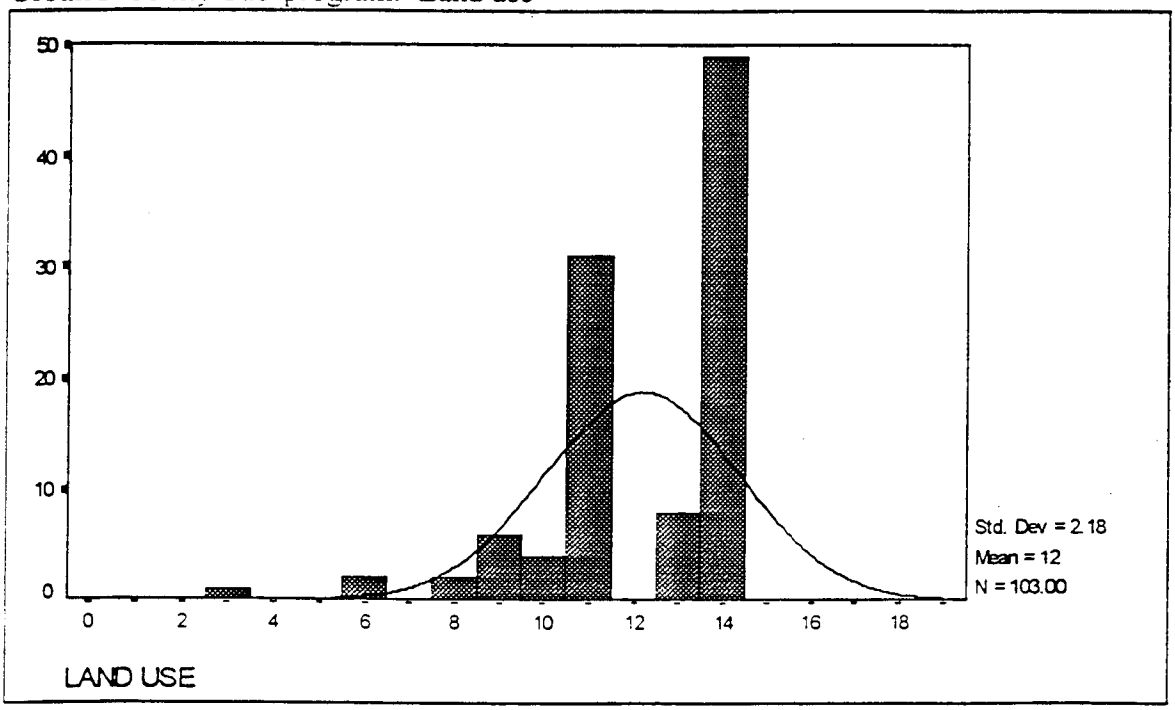
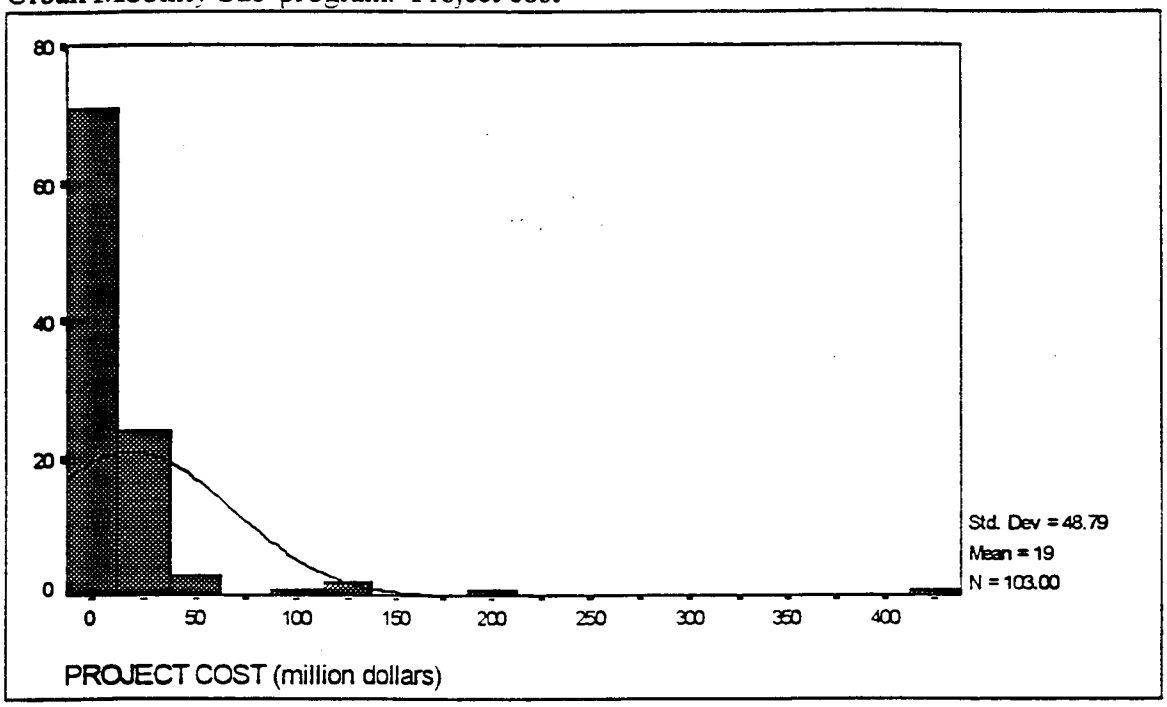


Figure F-2. Urban Mobility Sub-Program Histograms (continued)

Urban Mobility Sub-program: Project cost



Urban Mobility Sub-program: Project net present value

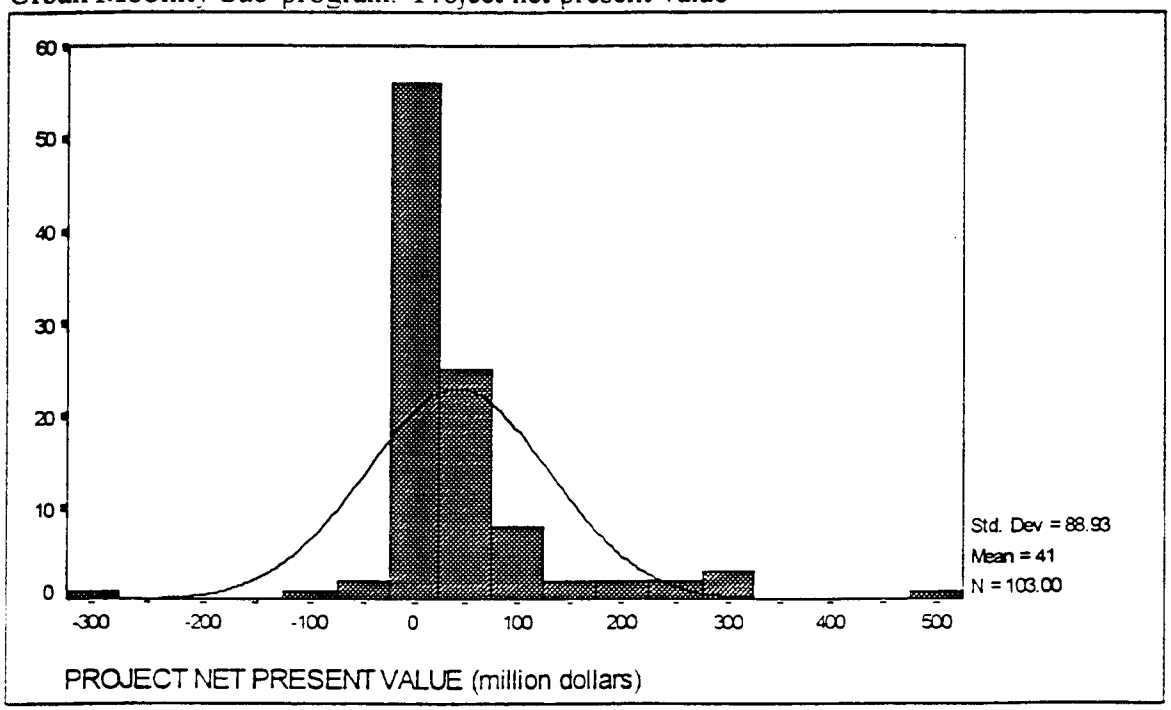


Figure F-2. Urban Mobility Sub-Program Histograms (continued)

APPENDIX G. ALTERNATE PRIORITIZATION EXAMPLES

Table G-1. Rural Alternate Prioritization Example

			Budget Allocation: $120 million			Budget Allocation: $150 million		
I.D.	Type	cost	TOPSIS	OPT_NPV	OPT_B/C. >1.0	TOPSIS	OPT_NPV	OPT_B/C. >1.0
1	truck climbing lane	503,109	Funded	Funded	Funded	Funded	Funded	Funded
2	truck climbing lane	1,096,800	Funded	Funded	Funded	Funded	Funded	Funded
3	widening	1,355,750	Funded	Funded	Funded	Funded	Funded	Funded
4	truck climbing lane	5,270,516	Funded	Funded	Funded	Funded	Funded	Funded
5	passing lane	595,400	Funded	Funded	Funded	Funded	Funded	Funded
6	widening	1,950,000	Funded	Funded	Funded	Funded	Funded	Funded
7	widening	6,662,500	Funded	Funded	Funded	Funded	Funded	Funded
8	widening	6,889,155	Funded	Funded	Funded	Funded	Funded	Funded
9	widening	8,012,319	Funded	Funded	Funded	Funded	Funded	Funded
10	widening	35,995,000	Funded	Funded	-	Funded	Funded	Funded
11	truck climbing lane	1,592,464	Funded	Funded	Funded	Funded	Funded	Funded
12	interchange	14,500,000	Funded	-	Funded	Funded	Funded	Funded
13	interchange	797,000	Funded	-	Funded	Funded	Funded	Funded
14	widening	850,000	Funded	Funded	Funded	Funded	Funded	Funded
15	park and ride lot	1,271,000	Funded	-	-	Funded	-	-
16	truck climbing lane	372,879	Funded	Funded	Funded	Funded	Funded	Funded
17	widening	20,565,000	Funded	Funded	Funded	Funded	Funded	Funded
18	traffic circulation	6,377,000	Funded	Funded	Funded	Funded	Funded	Funded
19	passing lane	644,600	Funded	Funded	Funded	Funded	Funded	Funded
20	widening	4,516,000	Funded	-	Funded	Funded	Funded	Funded
21	truck climbing lane	912,000	-	Funded	Funded	Funded	Funded	Funded
22	truck climbing lane	1,868,900	-	Funded	Funded	Funded	Funded	Funded
23	TWLTL	338,000	-	-	Funded	Funded	-	Funded
24	truck climbing lane	1,391,801	-	-	Funded	Funded	Funded	Funded
25	widening	1,516,640	-	-	Funded	Funded	Funded	Funded
26	passing lane	599,400	-	-	Funded	Funded	Funded	Funded
27	widening	1,069,260	-	Funded	Funded	Funded	Funded	Funded
28	widening	3,382,000	-	-	-	Funded	-	-
29	pace lane	2,366,000	-	-	-	Funded	-	-
30	widening	17,450,000	-	-	-	-	-	-
31	by-pass	5,401,792	-	-	-	-	-	-
32	passing lane	623,540	-	-	Funded	-	Funded	Funded
33	widening	9,915,350	-	-	-	-	-	-
34	widening	24,307,500	-	-	-	-	-	-
35	widening	1,150,000	-	-	-	-	-	-
36	passing lane	290,900	-	-	-	-	-	-
37	passing lane	299,800	-	-	-	-	-	-
38	interchange	12,920,000	-	-	-	-	-	-
39	passing lane	587,900	-	-	-	-	-	-
40	widening	17,331,550	-	Funded	Funded	-	Funded	Funded
41	passing lane	765,110	-	-	-	-	-	-
42	by-pass	28,534,000	-	-	-	-	-	-
43	widening	12,078,200	-	-	-	-	-	-
44	interchange	8,000,000	-	-	-	-	-	-
45	realignment	1,176,000	-	-	-	-	-	-
46	realignment	2,067,000	-	-	-	-	-	-
47	realignment	1,561,000	-	-	-	-	-	-
48	widening	17,300,000	-	-	-	-	-	-
49	truck climbing lane	2,879,000	-	-	Funded	-	-	Funded
50	widening	9,508,800	-	-	-	-	-	-
51	SC&DI	2,386,000	-	-	Funded	-	-	Funded
52	widening	1,062,000	-	-	-	-	-	-
53	widening	16,208,740	-	-	-	-	-	-
54	widening	18,053,000	-	-	-	-	-	-

Table G-1. Rural Alternate Prioritization Example (continued)

			Budget Allocation: $120 million			Budget Allocation: $150 million		
I.D.	Type	cost	TOPSIS	OPT_NPV	OPT_B/C. >1.0	TOPSIS	OPT_NPV	OPT_B/C. >1.0
55	widening	12,502,525	-	-	-	-	-	-
56	passing lane	1,047,864	-	-	-	-	-	-
57	widening	34,000,000	-	-	-	-	-	-
58	truck climbing lane	5,655,000	-	-	-	-	-	-
59	interchange	6,049,480	-	-	*Funded*	-	*Funded*	*Funded*
60	widening	38,498,000	-	-	-	-	-	-
61	interchange	777,230	-	-	-	-	-	-
62	truck climbing lane	3,789,000	-	-	-	-	-	-
63	interchange	26,838,000	-	-	-	-	-	-
64	realignment	15,960,000	-	-	-	-	-	-

***Note Project i.d.'s are assigned in descending rank order as produced by the TOPSIS algorithm (i.e., the priority index) and WSDOT's Mobility method.

Exhibit G-1. Manual Comparison Example (@ $150million):

Project Nos. 32 & 40 are Funded ONLY by the two optimization methods.

Project Nos. 28 & 29 are Funded by WSDOT's Mobility Prioritization Method (TOPSIS).

Consider:	*B/C*	*Cmty*	*Wets*	*Water Q.*	*Noise*	*Mode*	*Landuse*
(*) Top 10th percentile	*>18.9*	*<2*	*0.5*	*<1.0*	*0*	*<6.5*	*>14*
(+) Top 25%	*>3.49*	*<4*	*0.5*	*<6.3*	*0*	*<8*	*>13.5*
(-) Bottom 25%	*<0.5*	*>5*	*>2.5*	*>15.4*	*>22*	*>9*	*<9.0*
(#) Bottom 10%	*<0.27*	*>6*	*>11.9*	*>24*	*>107*	*>10*	*<4.5*

Input Scores with percentiles:

ID	*B/C*	*Cmty*	*Wets*	*Water Q.*	*Noise*	*Mode*	*Landuse*
	65%	*14%*	*2.6%*	*2.6%*	*2.6%*	*7%*	*8%*
28	0.83	3 (+)	2.5 (-)	27 (#)	3	9 (-)	14 (*)
29	0.78	3 (+)	0.5 (*)	0.5 (*)	25 (-)	10 (#)	5 (-)
32	1.61	4 (+)	0.5 (*)	15	0 (*)	10 (#)	11
40	3.9 (+)	8 (#)	24 (#)	16 (-)	408 (#)	9 (-)	14 (*)

ID	*Total Weight carried in bottom 10%*	*...carried in bottom 25%*	*...carried in top 25%*	*...carried in top 10%*
28	2.6	12.2	22	8
29	7	17.6	19.5	5.2
32	7	7	19.5	5.2
40	19.2	28.8	73	8

Note how it is apparently the degree of weight carried in the bottom 10th percentile that makes the difference in rank order. In particular, for Project No.40 using the Mobility method (where it ranks lowest of the four) and also for Project No.28 (which ranks highest of the four).

Table G-2. Urban Alternate Prioritization Example

			Budget Allocation: $120 million			Budget Allocation: $150 million		
I.D.	Type	cost	TOPSIS	OPT_NPV	OPT_B/C. >1.0	TOPSIS	OPT_NPV	OPT_B/C. >1.0
1	widening	1,014,000	Funded	Funded	Funded	Funded	Funded	Funded
2	widening	1,217,000	Funded	Funded	Funded	Funded	Funded	Funded
3	interchange	3,253,200	Funded	Funded	Funded	Funded	Funded	Funded
4	ramp	505,336	Funded	Funded	Funded	Funded	Funded	Funded
5	widening	7,706,016	Funded	Funded	Funded	Funded	Funded	Funded
6	interchange	1,360,000	Funded	Funded	Funded	Funded	Funded	Funded
7	widening	2,801,803	Funded	Funded	Funded	Funded	Funded	Funded
8	intersection	626,730	Funded	Funded	Funded	Funded	Funded	Funded
9	right-turn lane	168,000	Funded	Funded	Funded	Funded	Funded	Funded
10	extension	500,000	Funded	Funded	Funded	Funded	Funded	Funded
11	widening	3,441,469	Funded	Funded	Funded	Funded	Funded	Funded
12	widening	2,948,500	Funded	Funded	Funded	Funded	Funded	Funded
13	TSM	4,052,000	Funded	Funded	Funded	Funded	Funded	Funded
14	HOV	200,000	Funded	Funded	Funded	Funded	Funded	Funded
15	interchange	13,000,000	Funded	Funded	Funded	Funded	Funded	Funded
16	widening	4,695,530	Funded	Funded	Funded	Funded	Funded	Funded
17	interchange	3,540,589	Funded	Funded	Funded	Funded	Funded	Funded
18	interchange	460,000	Funded	Funded	Funded	Funded	Funded	Funded
19	interchange	4,157,504	Funded	Funded	Funded	Funded	Funded	Funded
20	O-xing	9,104,160	Funded	Funded	Funded	Funded	Funded	Funded
21	widening	3,608,693	Funded	Funded	Funded	Funded	Funded	Funded
22	intersection	1,056,000	Funded	Funded	Funded	Funded	Funded	Funded
23	interchange	10,180,799	Funded	Funded	Funded	Funded	Funded	Funded
24	interchange	4,215,120	Funded	Funded	Funded	Funded	Funded	Funded
25	HOV	6,409,000	Funded	Funded	Funded	Funded	Funded	Funded
26	rechannelization	2,090,000	Funded	Funded	Funded	Funded	Funded	Funded
27	widening	2,925,000	Funded	-	Funded	Funded	Funded	Funded
28	widening	4,792,000	Funded	-	Funded	Funded	Funded	Funded
29	widening	14,573,000	Funded	Funded	-	Funded	Funded	-
30	widening	6,839,000	-	Funded	-	Funded	Funded	Funded
31	widening	5,467,000	-	Funded	Funded	Funded	Funded	Funded
32	widening	10,232,000	-	-	-	Funded	Funded	-
33	widening	2,800,000	-	-	Funded	Funded	-	Funded
34	widening	7,565,730	-	-	-	Funded	Funded	Funded
35	widening	4,210,000	-	-	Funded	-	Funded	Funded
36	interchange	3,260,000	-	-	Funded	-	-	Funded
37	widening	5,800,941	-	-	-	-	-	-
38	I/C & widening	29,488,000	-	-	-	-	-	-
39	widening	15,800,000	-	-	-	-	-	-
40	widening	15,138,675	-	-	-	-	-	-
41	widening	8,077,000	-	-	-	-	-	-
42	interchange	37,765,775	-	-	-	-	-	-
43	widening & HOV	17,998,000	-	-	-	-	-	-
44	interchange	13,281,000	-	-	-	-	-	-
45	interchange	1,248,000	-	-	-	-	-	-
46	interchange	5,860,000	-	-	-	-	-	-
47	interchange	17,589,000	-	-	-	-	-	-
48	channelization	1,399,000	-	-	Funded	-	-	Funded
49	widening	45,813,311	-	-	-	-	-	-
50	widening	13,578,000	-	-	-	-	-	-
51	widening	8,046,000	-	-	-	-	-	-
52	on-ramp	1,435,000	-	-	-	-	-	-
53	HOV	130,130,000	-	-	-	-	-	-
54	truck climbing lane	864,529	-	-	Funded	-	Funded	Funded
55	truck climbing lane	383,936	-	Funded	Funded	-	-	Funded
56	TWLTL	362,265	-	Funded	Funded	-	-	Funded
57	widening	2,106,000	-	-	-	-	-	-

Table G-2. Urban Alternate Prioritization Example (continued)

			Budget Allocation: $120 million			Budget Allocation: $150 million		
I.D.	Type	cost	TOPSIS	OPT_NPV	OPT_B/C. >1.0	TOPSIS	OPT_NPV	OPT_B/C. >1.0
58	widening	3,478,555	-	-	-	-	-	*Funded*
59	widening	12,209,000	-	-	-	-	-	-
60	widening	4,850,000	-	-	-	-	-	-
61	park and ride lot	6,503,000	-	-	-	-	-	-
62	widening	10,967,191	-	-	-	-	-	-
63	widening	21,541,000	-	-	-	-	-	-
64	widening	13,295,000	-	-	-	-	-	-
65	interchange	21,000,000	-	-	-	-	-	-
66	truck climbing lane	455,750	-	-	*Funded*	-	-	*Funded*
67	park and ride lot	5,750,000	-	-	-	-	-	-
68	interchange	17,686,000	-	-	-	-	-	-
69	widening	3,988,000	-	-	-	-	-	-
70	interchange	5,161,800	-	-	-	-	-	-
71	TWLTL	500,300	-	-	*Funded*	-	-	*Funded*
72	auxiliary lane	4,031,000	-	-	-	-	-	*Funded*
73	TWLTL and access	5,657,000	-	-	-	-	-	-
74	TWLTL	2,345,346	-	-	-	-	-	*Funded*
75	widening	25,309,000	-	-	-	-	-	-
76	auxiliary lane	16,035,000	-	-	-	-	-	-
77	interchange	9,577,157	-	-	-	-	-	-
78	widening	3,400,000	-	-	-	-	-	-
79	widening	8,241,551	-	-	-	-	-	-
80	connection	27,500,000	-	-	-	-	-	-
81	interchange	10,899,500	-	-	-	-	-	-
82	truck climbing lane	3,574,000	-	-	-	-	-	-
83	interchange	29,155,000	-	-	-	-	-	-
84	interchange	15,085,000	-	-	-	-	-	-
85	interchange	8,138,550	-	-	-	-	-	-
86	interchange	8,606,000	-	-	-	-	-	-
87	widening	30,456,000	-	-	-	-	-	-
88	widening	2,974,390	-	-	-	-	-	-
89	widening	11,142,272	-	-	-	-	-	-
90	widening	28,554,240	-	-	-	-	-	-
91	interchange	5,876,000	-	-	-	-	-	-
92	widening	36,220,000	-	-	-	-	-	-
93	interchange	30,684,000	-	-	-	-	-	-
94	widening	10,553,000	-	-	-	-	-	-
95	widening	3,630,000	-	-	-	-	-	-
96	widening	18,722,000	-	-	-	-	-	-
97	widening	7,914,000	-	-	-	-	-	-
98	widening	421,200,000	-	-	-	-	-	-
99	extension	196,030,000	-	-	-	-	-	-
100	new alignment	46,186,400	-	-	-	-	-	-
101	widening	121,868,000	-	-	-	-	-	-
102	widening	109,584,000	-	-	-	-	-	-
103	widening	19,778,000	-	-	-	-	-	-

APPENDIX H. VISUAL BASIC MACROS AND SAMPLE OUTPUT

```
' VaryErrorChg Macro
' written by TReed, 12/5/95 -modified 12/20/95
' Changes the random error mean,st.dev. in PERCENT ERROR terms.
' *Automatically goes  to Sheet1.
' **Can be revised for normally distributed %error simulations by using 'mary' and the
'         CheckNeg subroutine.  In order to modify the STD.DEV cases the user MUST edit this
'         macro. User must also edit for input length.

Dim mary As Variant
Dim june As Variant

Sub VaryErrorChg()
   Sheets("Sheet1").Select
   For k = 1 To 5     'loop for No. of cases desired
      For j = 1 To 15     'loop for No. of iterations desired
'  Each iteration consumes 6 columns in sheet2.  Combined, loops must use < 415 columns
      Range("L11:l74").Select
      Selection.Clear
      Select Case k
         Case 1
'           mary = 0.025
'           -0.2877 is ln(0.75) i.e., 25% error, -0.3567 is 30%, and -0.4308 is 35%
            Application.ExecuteExcel4Macro String:= _
               "Random([rln_bc2.xls]Sheet1!r11c12:r74c12,  1,  64,  2,  ,  0,  -0.2877)"
               'third number in this command is the type of distribution to select from
               'last two numbers in this command are the mean, and standard deviation
            Range("c11:c74").Select
            Selection.Copy
            CheckZeroEquation
'           CheckNeg
         Case 2
'           mary = 0.05
            Application.ExecuteExcel4Macro String:= _
               "Random([rln_bc2.xls]Sheet1!r11c12:r74c12,  1,  64,  2,  ,  0,  -0.3567)"
            Range("c11:c74").Select
            Selection.Copy
            CheckZeroEquation
'           CheckNeg
         Case 3
'           mary = 0.10
            Application.ExecuteExcel4Macro String:= _
               "Random([rln_bc2.xls]Sheet1!r11c12:r74c12,  1,  64,  2,  ,  0,  -0.4308)"
            Range("c11:c74").Select
            Selection.Copy
            CheckZeroEquation
'           CheckNeg
         Case 4
```

```
'           mary = 0.15
            Application.ExecuteExcel4Macro String:= _
              "Random([rln_bc2.xls]Sheet1!r11c12:r74c12,  1,  64,  2,  ,  0,  -0.1625)"
            Range("c11:c74").Select
            Selection.Copy
            CheckZeroEquation
'           CheckNeg
        Case 5
'           mary = 0.20
            Application.ExecuteExcel4Macro String:= _
              "Random([rln_bc2.xls]Sheet1!r11c12:r74c12,  1,  64,  2,  ,  0,  -0.2231)"
            Range("c11:c74").Select
            Selection.Copy
            CheckZeroEquation
'           CheckNeg
      End Select
      Range("m11:m74").Select
      Selection.Copy
      Range("o11").Select
      Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
        SkipBlanks:=False, Transpose:=False
'
' next section should label the standard deviation in first cell of iteration
      Sheets("Sheet2").Select
      ActiveCell.FormulaR1C1 = "Std.Dev."
      ActiveCell.Offset(1, 0).Range("A1").Select
      ActiveCell.FormulaR1C1 = k
      ActiveCell.Offset(-1, 0).Range("A1:A2").Select
      With Selection
        .HorizontalAlignment = xlCenter
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
      End With
      With Selection.Borders(xlLeft)
        .Weight = xlThick
        .ColorIndex = xlAutomatic
      End With
      ActiveCell.Offset(0, 1).Range("A1").Select
      Sheets("Sheet1").Select
' end of labeling section {returns to the criteria worksheet}
      Range("n8:v74").Select
      Application.Run Macro:=Range("rln_bc2.xls!Topsis__t")
      Sheets("Sheet1").Select
      Next j
    Next k
End Sub          ' End of VaryErrorChg Macro.
```

```
' CheckZeroEquation Macro
' Use for logNormal simulations
' written by T.Reed 12/29/95
'
Sub CheckZeroEquation()
   Range("m11:m74").Select 'corresponds to copied category score
   'Range("m11").Select
   Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
      SkipBlanks:=False, Transpose:=False
   For Each Cell In Selection
   If Cell.Value = 0 Then
      Cell.Clear
      Cell.FormulaR1C1 = "=exp(0+RC[-1])"
   Else
      june = Cell.Value
      Cell.Clear
      Cell.FormulaR1C1 = "=exp(ln(" & june & ")+rc[-1])"
   End If
   Next Cell
End Sub
```

```
' CheckNeg routine
' Use to truncate a normally distributed percent error.
' written 12/13 with MS help
'
Sub CheckNeg()
   bob = 1
   Set first = Selection
   fad = first.Address()
   For Each Cell In Selection
   If Cell.Value <= 0 Then
      Cell.Clear
      Application.ExecuteExcel4Macro String:= _
         "random([rln_bc2.xls]Sheet1!" & Cell.Address(, , xlR1C1) & ", 1, 1, 2, , 1," & mary &
")"
      bob = bob + 1
   End If
   Next Cell
   If bob > 1 Then
      Range("" & fad & "").Select
      Application.OnTime Now + TimeValue("00:00:01"), "CheckNeg"
   End If
End Sub
```

```
' ChgWeights macro
' written T.Reed 11/29/95
'
Dim j As Integer
Dim k As Integer

Sub ChgWeights()
  MsgBox "User must manually edit for length of input file ", , "Alert"
  Application.Run macro:=("ResetOutput")
  For j = 1 To 6 'begin loop for no. of cases you want to test
  Sheets("Sheet1").Select
  Range(Cells(6, 4), Cells(6, 10)).Select
  Selection.Copy
  Range(Cells(9, 4), Cells(9, 10)).Select
  ActiveSheet.Paste
    For k = 4 To 10
    Cells(9, k).Select
    x = Cells(6, k) 'original WSTC catweights
'redistribute weight evenly or proportionately across each other category. The cases are
'modified for each different weight scenario.
    Select Case j
      Case 1
        w = 0.65 * 0.1    'ten percent of cost-efficiency to cmtysupport
        If k = 4 Then y = x - w
        If k = 5 Then y = x + w
        If k < 9 And k > 5 Then y = x
        If k > 8 Then y = x
        ActiveCell.FormulaR1C1 = y
      Case 2    'ten percent from each other category to cmtysupport
        w = (0.65 * 0.1) + (0.08 * 0.1) + (0.07 * 0.1) + (0.06 * 0.1)
        If k = 4 Then y = x - (x * 0.1)
        If k = 5 Then y = x + w  'equals 22.6 percent of 100
        If k < 9 And k > 5 Then y = x - (x * 0.1)
        If k > 8 Then y = x - (x * 0.1)
        ActiveCell.FormulaR1C1 = y
      Case 3
        w = 0.08 * 0.1 '10 percent of environ redistributed
        If k = 4 Then y = x
        If k = 5 Then y = x + w
        If k < 9 And k > 5 Then y = x - (x * 0.1)
        If k > 8 Then y = x
        ActiveCell.FormulaR1C1 = y
      Case 4
        w = 0.07 * 0.1 'ten percent of modeint. redistributed
        If k = 4 Or k = 10 Then y = x
        If k = 5 Then y = x + w
        If k < 9 And k > 5 Then y = x
```

```
            If k = 9 Then y = x - w
            ActiveCell.FormulaR1C1 = y
        Case 5
            w = 0.06 * 0.1    'ten percent of landuse redistributed to cmtysupport
            If k = 4 Or k = 9 Then y = x
            If k = 5 Then y = x + w
            If k < 9 And k > 5 Then y = x
            If k = 10 Then y = x - w
            ActiveCell.FormulaR1C1 = y
        Case 6    'cmty and modeint. switch org.WSTC weights
            If k = 5 Then y = 0.07
            If k = 9 Then y = 0.14
            If k = 4 Or k > 5 And k < 9 Or k = 10 Then y = x
            ActiveCell.FormulaR1C1 = y
    End Select
    Next k
  Range("c8:k74").Select    'MUST edit this line when numprojects to analyze changes!!
  Application.Run macro:=Range("WEIGHTS6.XLS!TOPSIS__t")
  Next j
  Application.Run macro:=("Label")
End Sub
```

*** These first two macros require a data input worksheet (called 'Sheet1') formatted to match and an empty, initialized output worksheet (called 'Sheet2') in the same Excel 5.0 workbook. The following three macros are subroutines utilized by the second.
***

```
' Borders Macro
' written by T.Reed 11/30/95
'
Sub Borders()
  ActiveCell.Range("A1").Select
  Selection.Font.Bold = True
  ActiveCell.Range("A1:A2").Select
  With Selection.Borders(xlLeft)
    .Weight = xlThick
    .ColorIndex = xlAutomatic
  End With
End Sub
```

```
' ResetOutput Macro
' Macro recorded 11/30/95 by University of Washington
'
Sub ResetOutput()
   Sheets("Sheet2").Select
   ActiveCell.Cells.Select
   Selection.Clear
   ActiveCell.Select
End Sub
```

```
' Label Macro
' Macro recorded 11/30/95 by University of Washington
' modified by T.Reed
'
Sub Label()
   Sheets("Sheet2").Select
   ActiveCell.Rows("1:1").EntireRow.Select
   Selection.Insert Shift:=xlDown
   ActiveCell.Select
   ActiveCell.FormulaR1C1 = "'10% redistributed"
   Application.Run macro:=("Borders")
   ActiveCell.Offset(0, 5).Range("A1").Select
   ActiveCell.FormulaR1C1 = "'10% redistributed"
   Application.Run macro:=("Borders")
   ActiveCell.Offset(0, 5).Range("A1").Select
   ActiveCell.FormulaR1C1 = "'10% redistributed"
   Application.Run macro:=("Borders")
   ActiveCell.Offset(0, 5).Range("A1").Select
   ActiveCell.FormulaR1C1 = "'10% redistributed"
   Application.Run macro:=("Borders")
   ActiveCell.Offset(0, 5).Range("A1").Select
   ActiveCell.FormulaR1C1 = "'Bait and switch"
   Application.Run macro:=("Borders")
   MsgBox "That is the End!, " & "Now compute differences in rank.", , "Alert"
End Sub
```

```
' Absolute Value of Differences Macro
' Macro written 11/16/95 by Tracy Reed on "Innovations-EDM"
'
Sub ABVdiff()
   Sheets("AbV").Select
   Cells(1, 1).Select      'starts from corner cell in AbV sheet
   ActiveCell.FormulaR1C1 = "CALCULATE THE ABSOLUTE VALUE OF DEVIATION"
   FName = InputBox("Enter the sourcefile name:", "Prompt")  'must all be in this same
workbook
   SDCase = InputBox("Enter the number of cases:", "Prompt")
   NumIts = InputBox("Enter the number of topsis iterations/case:", "Prompt")
   Projs = InputBox("Enter the number of projects to analyze:", "Prompt")
   Range("A2").Select
   ActiveCell.FormulaR1C1 = "BASE"
   Range("A4").Select
   For m = 1 To Projs
   ActiveCell.FormulaR1C1 = m
   N = 4 + m
   Cells(N, 1).Select
   Next m
   Cells(N + 1, 1).FormulaR1C1 = Projs
   Cells(N + 3, 1).FormulaR1C1 = "CASE:"
   p = -3
   For s = 1 To SDCase
   Sheets("AbV").Select    'again for each iteration
   Cells(N + 3, 2).FormulaR1C1 = s
   counter = 0
   x = 2
      For q = 1 To NumIts      'begin q loop.
      p = p + 5 'CHANGED from TEMP.xls
      counter = counter + 2
      Cells(2, counter).Select
      ActiveCell.FormulaR1C1 = "RUN #"
      Select Case q
         Case 1
            Cells(3, q + 1).Select
            ActiveCell.FormulaR1C1 = q
            Sheets(FName).Select
            Range(Cells(3, p), Cells(m + 2, p)).Select
            Selection.Copy
            Sheets("AbV").Select
            Cells(4, q + 1).Select
            ActiveSheet.Paste
         Case Else
            Cells(3, counter).Select
            ActiveCell.FormulaR1C1 = q
            Sheets(FName).Select
```

```
            Range(Cells(3, p), Cells(m + 2, p)).Select
            Selection.Copy
            Sheets("AbV").Select
            Cells(4, counter).Select
            ActiveSheet.Paste
        End Select
'following puts in Absolute Value calculations
        Cells(2, 1 + counter).Select
        ActiveCell.FormulaR1C1 = "Ab.Value"
        Cells(4, 1 + counter).FormulaR1C1 = "=ABS(RC1-RC[-1])"
        Cells(4, 1 + counter).Select
        Selection.AutoFill Destination:=Range(Cells(4, 1 + counter), Cells(m + 2, 1 + counter)), _
          Type:=xlFillDefault 'where m+2 is, there used to be just 67.
        Cells(m + 3, 1 + counter).Select
        ActiveCell.FormulaR1C1 = "=sum(r1c:r[-1]c)/r[1]c1" ' &-m& doesn't work, was [-65]
        Selection.Copy
        x = x + 1
        Cells(N + 3, x).Select
        Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
          SkipBlanks:=False, Transpose:=False
        Next q
    Columns("B:Z").EntireColumn.AutoFit
    Range(Cells(N + 3, 1), Cells(N + 3, x)).Copy
    Sheets("AbV_table").Select
    Cells(s + 1, 1).Select
    ActiveSheet.Paste
    Next s
    Sheets("AbV").Select
    Columns("B:Z").EntireColumn.AutoFit
    Sheets("AbV_table").Select
    Range("A1").Select
    ActiveCell.FormulaR1C1 = "Absolute Value of Difference"
    MsgBox "That is the End!, " & "Use this data for graphics.", , "Alert"
    Cells(3, 1).Select
'
End Sub
```

```
' Funded Project Comparisons Macro
' Macro written 11/16/95 by Tracy Reed on "Innovations-EDM", MODIFIED 12/20
' 29 PROJECTS were ORIGINALLY. FUNDED in 95-97 RURAL SET
'
Sub Funded()
   Sheets("Funded").Select
   Cells(1, 1).Select      'starts from corner cell in "Funded" sheet
   ActiveCell.FormulaR1C1 = "Compare Funded Set of Projects"
   FName = InputBox("Enter the source filename:", "Prompt") 'must all be in this same
workbook
   SDCase = InputBox("Enter the number of cases:", "Prompt")
   NumIts = InputBox("Enter the number of topsis iterations/case:", "Prompt")
   Projs = InputBox("Enter the number of projects to analyze:", "Prompt")
   NumFun = InputBox("Enter the number of projects originally funded:", "Prompt")
   Range("A2").Select
   ActiveCell.FormulaR1C1 = "BASE"
'  a = 0, could init. q, s, m OR Dim as integers
   Range("A4").Select
' begin base loop, writes numbers in left column
   For m = 1 To Projs
      ActiveCell.FormulaR1C1 = m
      N = 4 + m
      Cells(N, 1).Select
'     If m > 1 And m < NumFun Then a = 1 + m  'adds up the funded project i.d.'s (+1 extra)
   Next m
'end base loop, 'a' not used now
   Cells(N + 1, 1).FormulaR1C1 = NumFun
   Cells(N + 3, 1).FormulaR1C1 = "CASE:"
   p = 0 'init.datafile column counter
'begin case loop
   For s = 1 To SDCase
   Sheets("Funded").Select  'again for each iteration
   Columns("B:AZ").EntireColumn.Clear
   Cells(N + 3, 2).FormulaR1C1 = s
   counter = 0 'init.working column counter
   x = 2 'init.column counter for pasting to "Fun_table"
      For q = 1 To NumIts      'begin q loop.
      p = p + 5    'rotate datafile counter
      y = 4 'initialize
      Rowcounter = 2    'init.the first project in priority order if funded
      If q = 1 Then
         counter = counter + 3
      Else
         counter = counter + 2
      End If
'begin pasting the runs next to one another on Funded worksheet
      Cells(2, counter - 1).Select
```

```
    ActiveCell.FormulaR1C1 = "RUN #"
    Cells(3, counter - 1).Select
    ActiveCell.FormulaR1C1 = q
    Sheets(FName).Select
    ActiveSheet.Cells(3, p).Select
    Do Until Cells(Rowcounter, p).Value = ""
      Rowcounter = Rowcounter + 1
    Loop
    ActiveSheet.Range(Cells(3, p), Cells(Rowcounter - 1, p)).Select
    Selection.Copy
    Sheets("Funded").Select
    Cells(4, counter - 1).Select
    ActiveSheet.Paste
'following calculates # of previously funded projects now dropped
      For y = 4 To Rowcounter + 1
      Match = 0
      temp = Cells(y, counter - 1) 'i.e., the proj no. in new rank order
      Cells(2, counter).Select
      ActiveCell.FormulaR1C1 = "Match"
      z = 4 'initialize
        For z = 4 To NumFun + 3
        If Cells(z, 1) = temp Then Match = 1
        Next z
      Cells(y, counter).FormulaR1C1 = Match
      Next y
    Cells(N + 1, counter).Select
    ActiveCell.FormulaR1C1 = "=(rc1)-(sum(r1c:r[-2]c))"  'when modifying CHECK HERE
    Selection.Copy
    x = x + 1
    Cells(N + 3, x).Select
    Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
      SkipBlanks:=False, Transpose:=False
'end computing # dropped
'begin calculating the number of additional projects funded with same budget
    Cells(N + 2, 1).Select
'subtract three b/c of 1 extra column header in datafiles
    ActiveCell.FormulaR1C1 = Rowcounter - 3
'this changes with each iteration, MUST paste to bottom row before next q
    Cells(N + 2, counter).Select
    ActiveCell.FormulaR1C1 = "=(rc1)-(r[-1]c1)" 'AND HERE
    Selection.Copy
    Cells(N + 4, x).Select
    Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
      SkipBlanks:=False, Transpose:=False
'end comparing gross number of projects
    Next q
'end of iteration loop
```

```
  Range(Cells(N + 3, 1), Cells(N + 4, x)).Copy
  Sheets("Fun_table").Select
  If s = 1 Then
    formatx = 2
  Else
    formatx = formatx + 2
  End If
  Cells(formatx, 1).Select
  ActiveSheet.Paste
  Next s
'end of case loop
  Sheets("Funded").Select
  Columns("B:Z").EntireColumn.AutoFit
  Sheets("Fun_table").Select
  Range("A1").Select
  ActiveCell.FormulaR1C1 = "How Many Previously Funded Projects were dropped? and
Number additional funded."
  MsgBox "That is the End!, " & "Use this data for graphics.", , "Alert"
  Cells(3, 1).Select
End Sub
```

*** These last two macros utilize data output from the Chgweights or VaryErrorChange macros and require four output worksheets named 'AbV,' 'AbV_table,' 'Funded,' and 'Fun_table' to compute the three measures of difference studied in this thesis. All macros operate in the same Excel 5.0 workbook. These samples are from the "WEIGHTS6.XLS" simulation.

*** Note that, as listed here in the appendix, these macros must be edited to accomodate the original output format of VaryErrorChange. ***

	A	B	C	D	E	F	G	H	I	J	K	L
1	2.5% error, run #15						5% error, run #1					
2	Std.Dev.	Priority Index	Rank Order by Code	Project cost	Total Budget	Funded Proj's	Std.Dev.	Priority Index	Rank Order by Code	Project cost	Total Budget	Funded Proj's
3	1	0.9588	1	503,109	150000000	1	2	0.958	1	503,109	150000000	1
4		0.6464	2	1,096,800	Remainings	2		0.629	2	1,096,800	Remainings	2
5		0.5561	3	1,355,750	10714175	3		0.592	3	1,355,750	11337715	3
6		0.4726	4	5,270,516		4		0.519	4	5,270,516		4
7		0.422	5	595,400		5		0.439	5	595,400		5
8		0.4021	6	1,950,000		6		0.379	6	1,950,000		6
9		0.3043	7	6,662,500		7		0.309	7	6,662,500		7
10		0.2633	8	6,889,155		8		0.27	8	6,889,155		8
11		0.1759	9	8,012,319		9		0.179	9	8,012,319		9
12		0.1505	10	35,995,000		10		0.164	10	35,995,000		10
13		0.1213	11	1,592,464		11		0.122	12	14,500,000		12
14		0.1168	12	14,500,000		12		0.121	11	1,592,464		11
15		0.1165	13	797,000		13		0.119	13	797,000		13
16		0.1093	14	850,000		14		0.11	14	850,000		14
17		0.1085	15	1,271,000		15		0.11	17	20,565,000		17
18		0.1077	16	372,879		16		0.11	15	1,271,000		15
19		0.1027	17	20,565,000		17		0.104	16	372,879		16
20		0.1019	18	6,377,000		18		0.104	19	644,600		19
21		0.1013	19	644,600		19		0.103	18	6,377,000		18
22		0.1011	20	4,516,000		20		0.102	20	4,516,000		20
23		0.1007	21	912,000		21		0.102	21	912,000		21
24		0.099	22	1,868,900		22		0.101	22	1,868,900		22
25		0.0966	23	338,000		23		0.098	24	1,391,801		24
26		0.0951	24	1,391,801		24		0.098	23	338,000		23
27		0.0928	26	599,400		26		0.094	25	1,516,640		25
28		0.092	25	1,516,640		25		0.093	26	599,400		26
29		0.0916	27	1,069,260		27		0.093	27	1,069,260		27
30		0.0902	28	3,382,000		28		0.092	28	3,382,000		28
31		0.0893	29	2,366,000		29		0.091	29	2,366,000		29
32		0.0891	31	5,401,792		31		0.09	31	5,401,792		31
33		0.0889	32	623,540		32		0.09	30	17,450,000		
34		0.0889	30	17,450,000				0.09	32	623,540		
35		0.0878	33	9,915,350				0.089	33	9,915,350		
36		0.0873	40	17,331,550				0.087	34	24,307,500		
37		0.0857	35	1,150,000				0.087	35	1,150,000		
38		0.0857	34	24,307,500				0.087	36	290,900		
39		0.0856	38	12,920,000				0.087	38	12,920,000		
40		0.0855	36	290,900				0.087	37	299,800		
41		0.0854	37	299,800				0.086	40	17,331,550		
42		0.0853	39	587,900				0.086	39	587,900		
43		0.0846	41	765,110				0.086	41	765,110		
44		0.0837	42	28,534,000				0.085	42	28,534,000		
45		0.0831	43	12,078,200				0.085	43	12,078,200		
46		0.0827	44	8,000,000				0.084	44	8,000,000		
47		0.0825	45	1,176,000				0.084	45	1,176,000		
48		0.0809	46	2,067,000				0.082	46	2,067,000		
49		0.08	47	1,561,000				0.081	47	1,561,000		
50		0.0793	48	17,300,000				0.08	48	17,300,000		
51		0.0784	49	2,879,000				0.08	49	2,879,000		
52		0.0783	50	9,508,800				0.079	50	9,508,800		
53		0.0777	51	2,386,000				0.078	52	1,062,000		
54		0.0774	52	1,062,000				0.078	51	2,386,000		
55		0.0769	53	16,208,740				0.078	53	16,208,740		
56		0.0762	54	18,053,000				0.077	56	1,047,864		
57		0.0757	56	1,047,864				0.077	55	12,502,525		
58		0.0757	55	12,502,525				0.076	57	34,000,000		
59		0.0752	57	34,000,000				0.076	54	18,053,000		
60		0.0747	58	5,655,000				0.076	58	5,655,000		
61		0.0744	59	6,049,480				0.075	59	6,049,480		
62		0.0731	60	38,498,000				0.074	60	38,498,000		
63		0.0703	61	777,230				0.071	61	777,230		
64		0.0668	62	3,789,000				0.068	62	3,789,000		
65		0.062	63	26,838,000				0.063	63	26,838,000		
66		0.0533	64	15,960,000				0.054	64	15,960,000		

Figure H-1. 'VaryErrorChange' or 'Chgweight' Sample Output

CALCULATE THE ABSOLUTE VALUE OF DEVIATION										
BASE	RUN #	Ab.Value	RUN #	Ab.Value	RUN #	Ab.Value	RUN #	Ab.Value	RUN #	Ab.Value
	1		2		3		4		5	
1	1	0	1	0	1	0	2	1	3	2
2	4	2	5	3	4	2	1	1	7	5
3	2	1	4	1	6	3	6	3	1	2
4	3	1	3	1	5	1	3	1	4	0
5	5	0	2	3	2	3	4	1	2	3
6	8	2	7	1	7	1	5	1	6	0
7	7	0	6	1	3	4	8	1	8	1
8	6	2	8	0	8	0	7	1	5	3
9	9	0	9	0	11	2	9	0	9	0
10	19	9	10	0	40	30	26	16	10	0
11	12	1	12	1	9	2	19	8	12	1
12	10	2	13	1	18	6	10	2	13	1
13	13	0	16	3	12	1	11	2	18	5
14	15	1	15	1	13	1	16	2	11	3
15	16	1	11	4	10	5	12	3	15	0
16	17	1	20	4	24	8	15	1	14	2
17	20	3	14	3	19	2	25	8	20	3
18	23	5	18	0	15	3	13	5	16	2
19	14	5	24	5	20	1	20	1	22	3
20	25	5	23	3	22	2	14	6	23	3
...	...	...	...	...	...	...	...	...	...	...
50	53	3	50	0	50	0	48	2	52	2
51	49	2	52	1	49	2	52	1	49	2
52	51	1	51	1	48	4	53	1	50	2
53	57	4	53	0	53	0	55	2	51	2
54	56	2	58	4	59	5	57	3	57	3
55	55	0	56	1	51	4	56	1	56	1
56	58	2	59	3	56	0	51	5	55	1
57	60	3	57	0	57	0	58	1	58	1
58	54	4	55	3	58	0	60	2	60	2
59	61	2	60	1	54	5	61	2	54	5
60	59	1	61	1	60	0	54	6	61	1
61	62	1	62	1	61	0	40	21	62	1
62	40	22	40	22	62	0	62	0	40	22
63	63	0	63	0	63	0	63	0	63	0
64	64	0	64	0	64	0	64	0	64	0
64		1.375		1.14063		1.51563		1.73438		1.3125
CASE:	2	2.5625	3	3.3125	3.71875	3.53125	2.344	2.6875	3.1875	3.1875

Figure H-2. 'AbV' Sample Worksheet

Absolute Value of Difference						
CASE:	1	0.40625	0.5	0.53125	0.438	0.1875
CASE:	2	0.375	0.65625	0.65625	0.75	0.875
Absolute Value of Difference						
CASE:	1	0.40625	0.5	0.53125	0.438	0.1875
CASE:	2	0.375	0.65625	0.65625	0.75	0.875
CASE:	3	0.8125	1	0.96875	1.156	1.125
CASE:	4	1.8125	1.4375	1.625	1.719	0.875
CASE:	5	2.15625	2.28125	1.59375	1.313	1.5625
Pct. Error	25	2.28125	2.5	1.71875	2.594	2.6875
Pct. Error	30	3.0625	2.5	2.25	2.469	1.84375
Pct. Error	35	2.5625	3	3.3125	3.719	3.53125

Figure H-3. 'AbV_table' Sample Output

Compare Funded Set of Projects									
BASE	RUN #	Match	RUN #	Match	RUN #	Match	RUN #	Match	RUN #
	1		2		3		4		5
1	1	1	1	1	1	1	2	1	3
2	4	1	5	1	4	1	1	1	7
3	2	1	4	1	6	1	6	1	1
4	3	1	3	1	5	1	3	1	4
5	5	1	2	1	2	1	4	1	2
6	8	1	7	1	7	1	5	1	6
7	7	1	6	1	3	1	8	1	8
8	6	1	8	1	8	1	7	1	5
9	9	1	9	1	11	1	9	1	9
10	19	1	10	1	40	0	26	1	10
11	12	1	12	1	9	1	19	1	12
12	10	1	13	1	18	1	10	1	13
13	13	1	16	1	12	1	11	1	18
14	15	1	15	1	13	1	16	1	11
15	16	1	11	1	10	1	12	1	15
16	17	1	20	1	24	1	15	1	14
17	20	1	14	1	19	1	25	1	20
18	23	1	18	1	15	1	13	1	16
19	14	1	24	1	20	1	20	1	22
20	25	1	23	1	22	1	14	1	23
21	21	1	28	1	26	1	18	1	25
22	22	1	25	1	23	1	23	1	17
23	27	1	22	1	16	1	21	1	28
24	24	1	21	1	14	1	17	1	30
25	18	1	30	0	21	1	28	1	24
26	28	1	29	1	17	1	31	0	29
27	26	1	19	1	25	1	32	0	21
28	32	0	36	0	28	1	22	1	
29	30	0	32	0			59	0	
30	29	1	26	1			24	1	
31			31	0			29	1	
32			37	0					
33			39	0					
34									
35									
... *cut*	...								
60									
61									
62									
63									
64									
29		1		2		2		1	
32		3		3		3		3	
CASE:	2	1	2	2	1	3	3	1	1
		1	4	-1	2	-2	-1	2	0

Figure H-4. 'Funded' Sample Worksheet

How Many Previously Funded Projects were dropped? and Number additional funded.							
CASE:	1	0	0	0	1	0	
		1	1	1	1	1	0
CASE:	2	0	1	0	0	0	
		2	1	0	1	1	2

How Many Previously Funded Projects were dropped?							Number additional funded.						
CASE:	1	0	0	0	1	0	CASE:	1	1	1	1	1	0
CASE:	2	0	1	0	0	0	CASE:	2	1	0	1	1	2
CASE:	3	0	0	0	2	1	CASE:	3	0	1	2	0	0
CASE:	4	2	1	1	2	1	CASE:	4	-1	0	0	0	0
CASE:	5	1	3	2	1	0	CASE:	5	0	-2	0	0	2
Pct. Err	25	1	4	2	2	1	Pct. Er	25	2	-3	0	2	1
Pct. Err	30	3	3	2	6	1	Pct. Er	30	0	-2	0	-4	1
Pct. Err	35	1	2	2	1	3	Pct. Er	35	1	4	-1	2	-2

Figure H-5. 'Fun_table' Sample Output

APPENDIX I. SIMULATION OUTPUT CHARTS

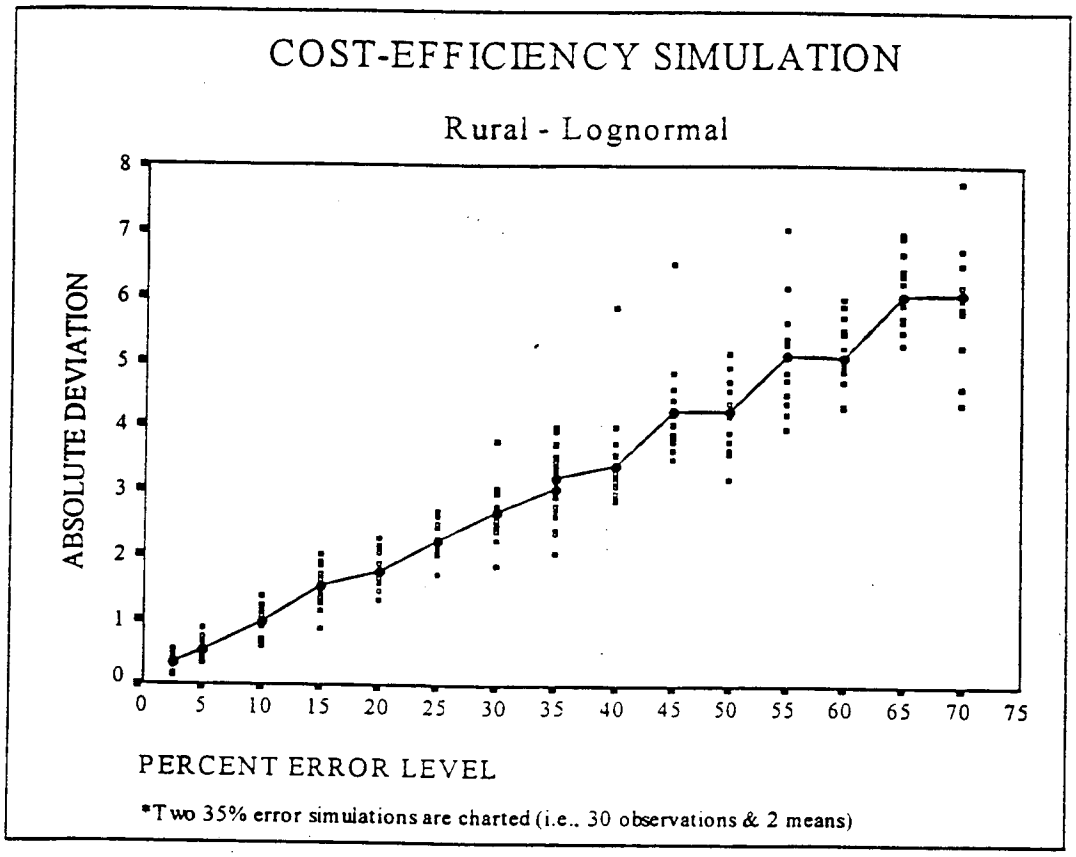
Contents:

- 7 point and line charts of raw output data for 2.5-35 percent error levels (i.e., one per category where the cost-efficiency simulation ranges up to 65 percent error).

- 14 bar charts of mean nos. funded for 2.5-35 percent error levels (i.e. 7 for 'now dropped' and 7 for 'additional' where the cost-efficiency simulation ranges up to 65 percent error).

- 21 measure of difference boxplots, 3 per category (i.e., one of each summary measure).

- 24 error level boxplots, 3 per level (i.e., one of each summary measure).



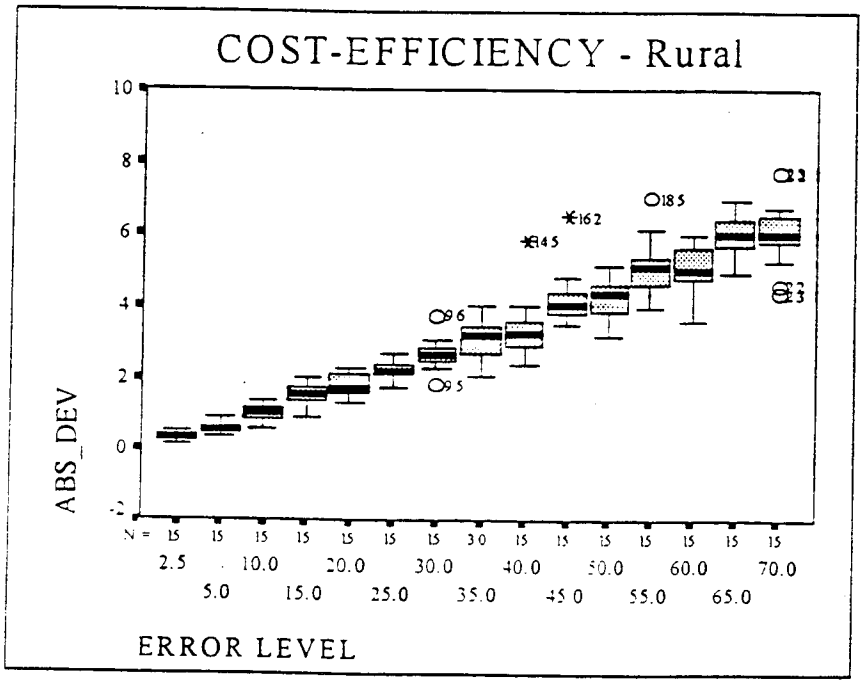
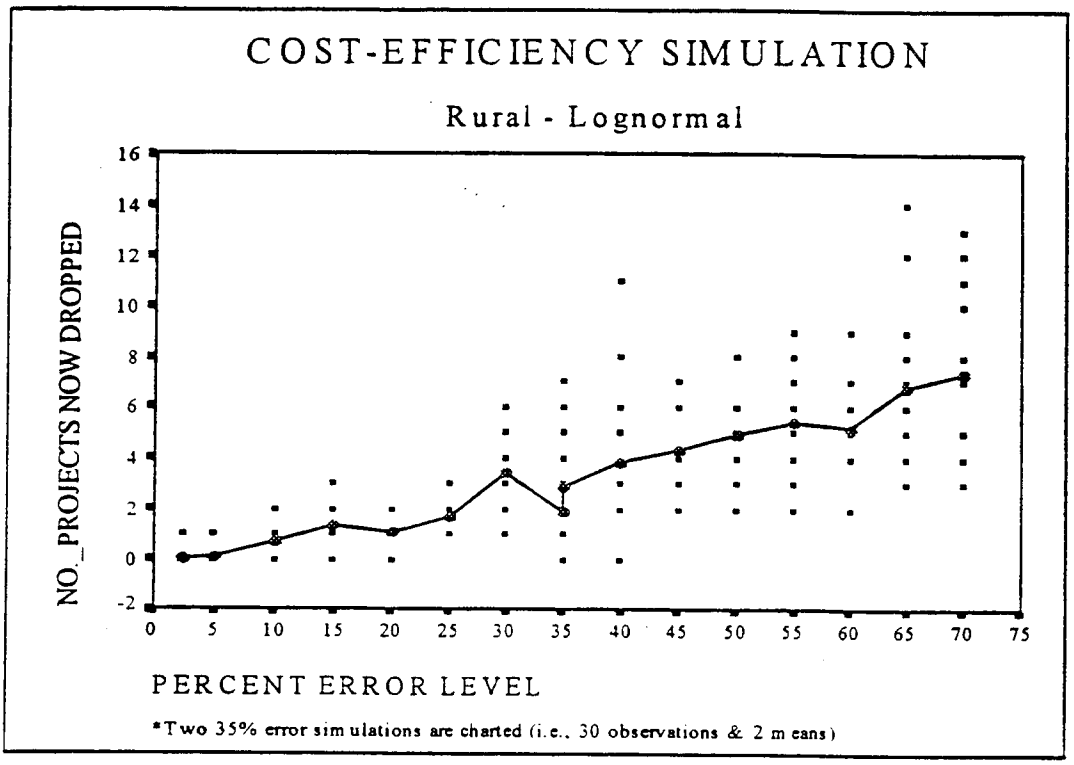


Figure I-1. Cost-efficiency Category Results



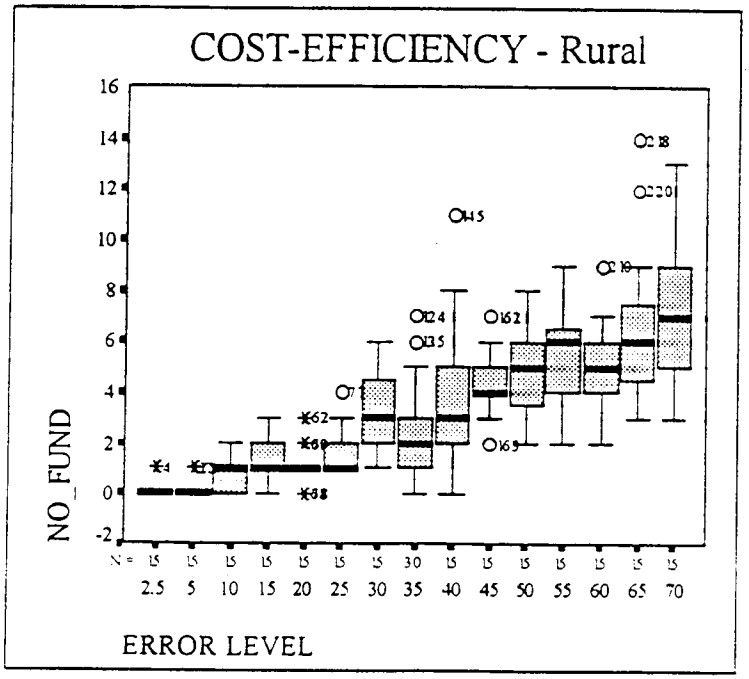
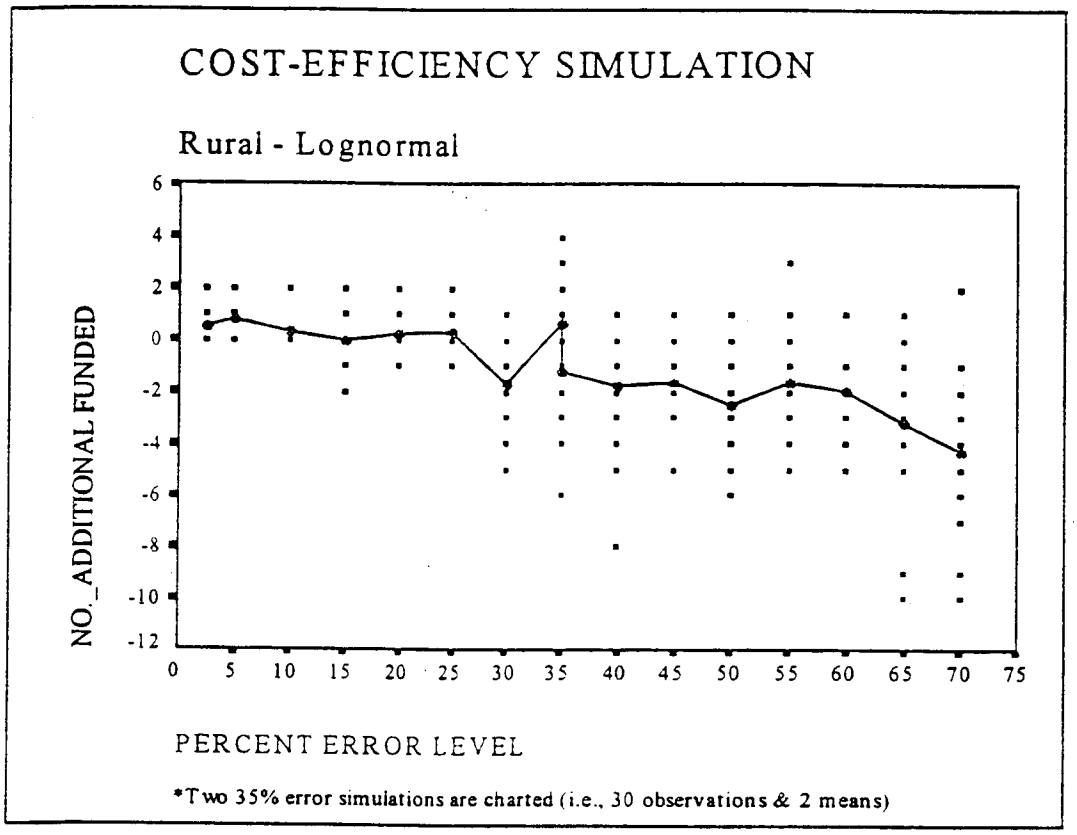


Figure I-1. *Cost-efficiency Category Results (continued)*



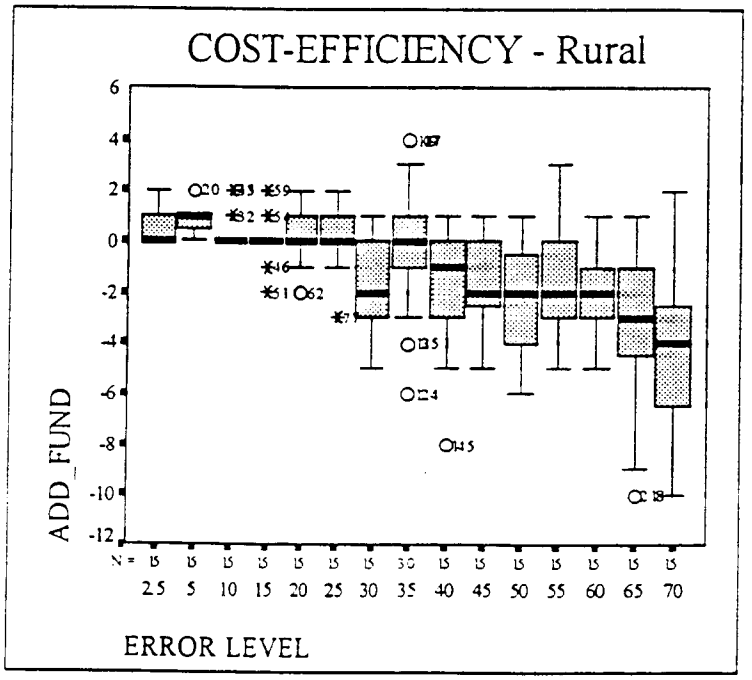
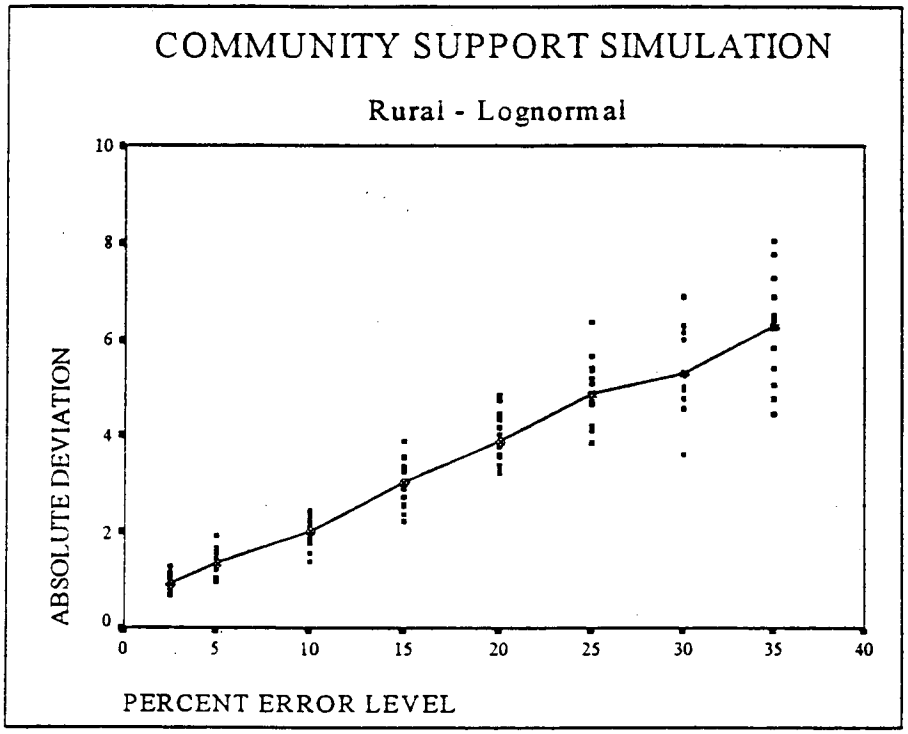


Figure I-1. Cost-efficiency Category Results (continued)



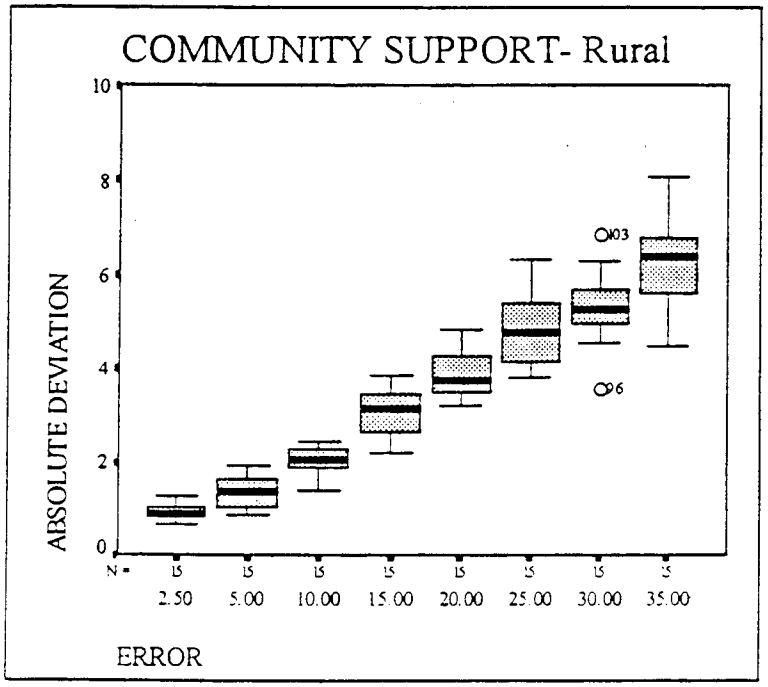
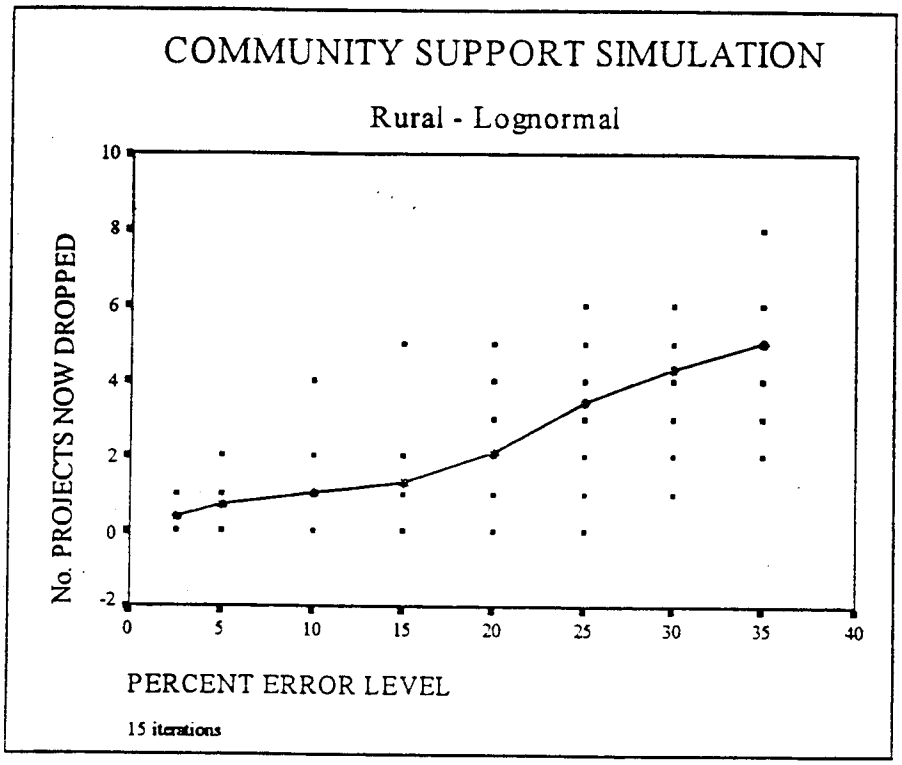


Figure I-2. Community support Category Results



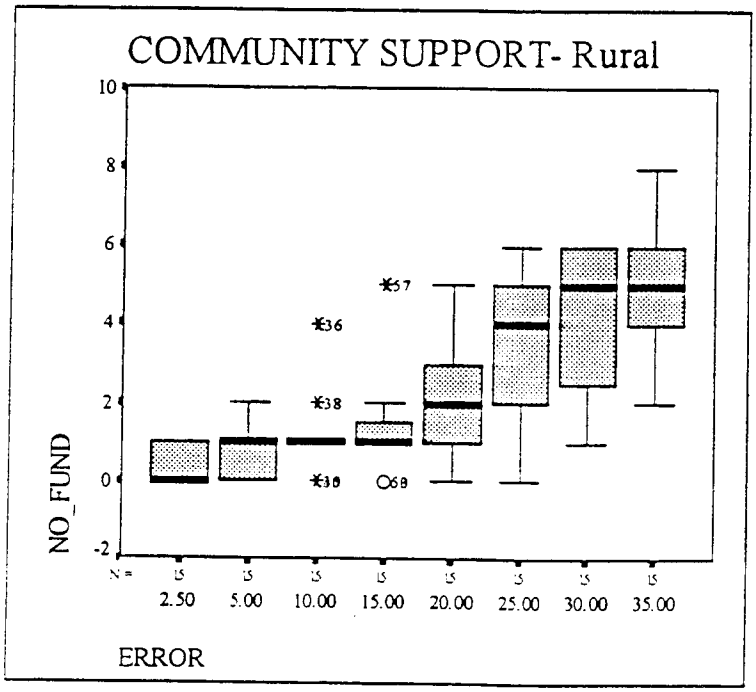
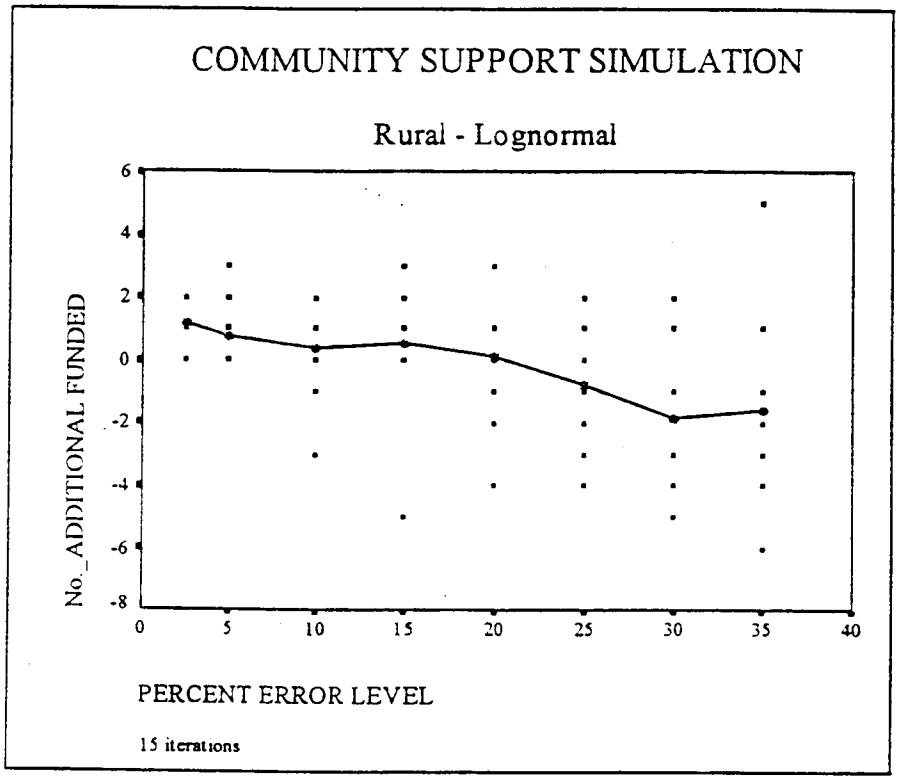


Figure I-2. Community support Category Results (continued)



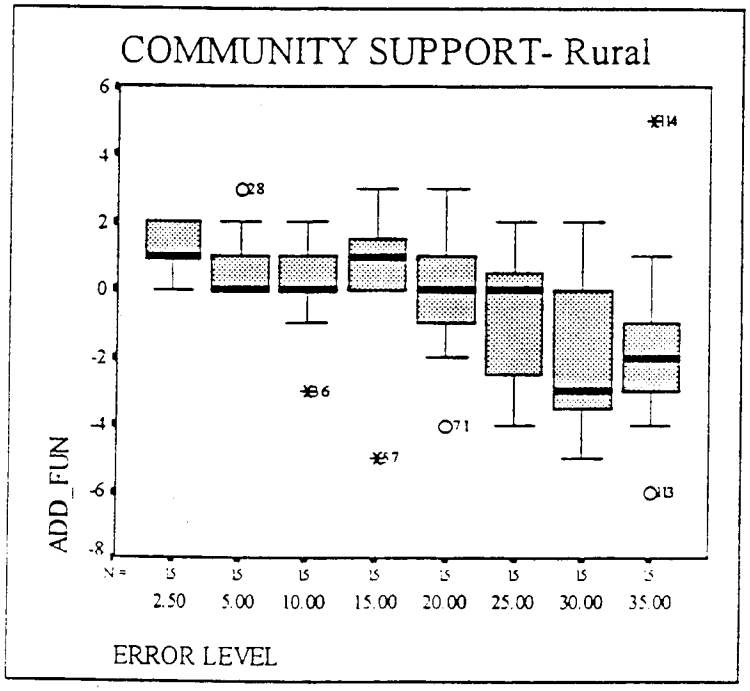
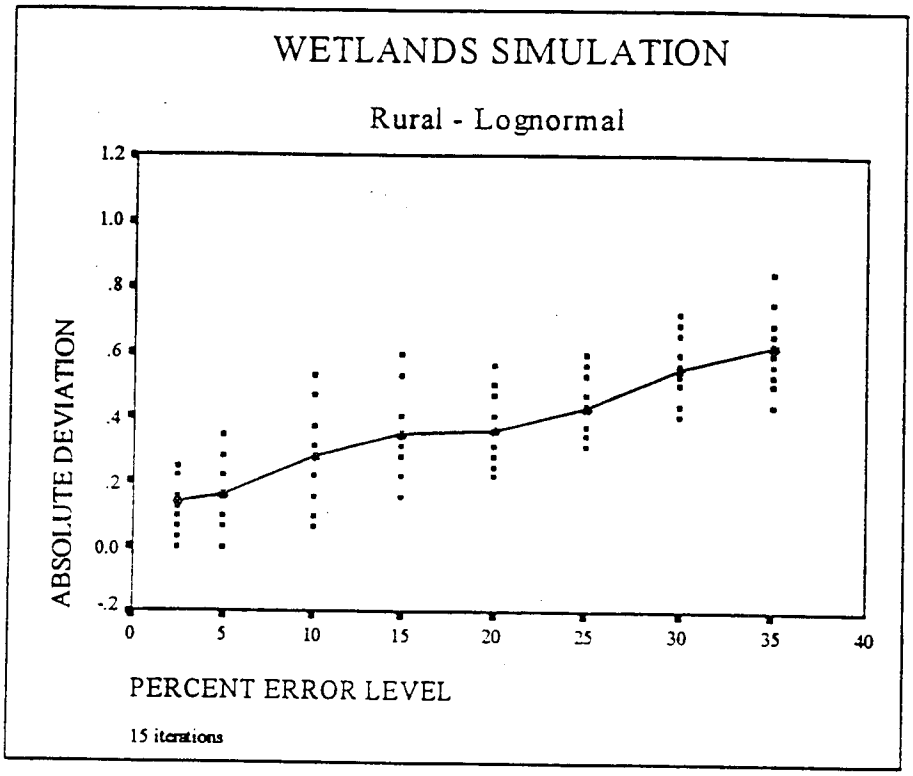


Figure I-2. Community support Category Results (continued)



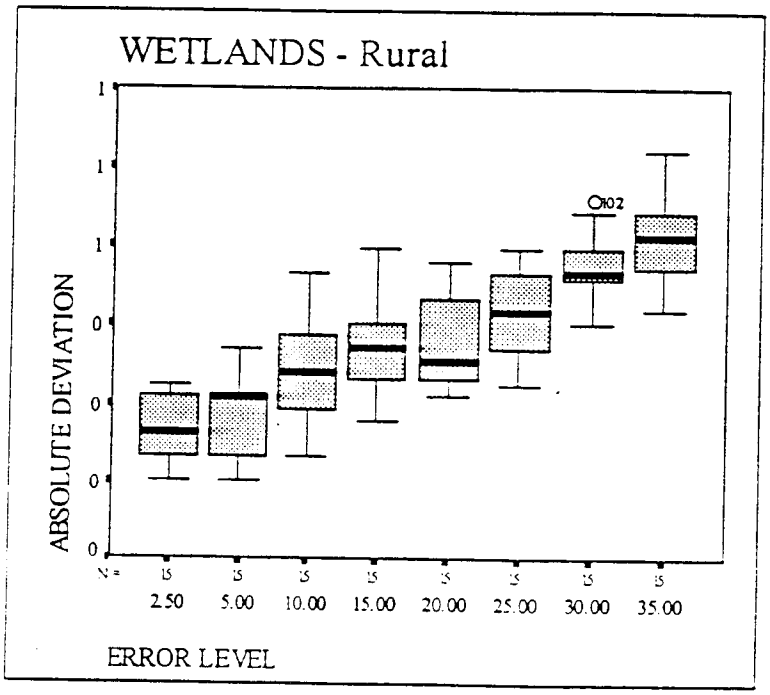
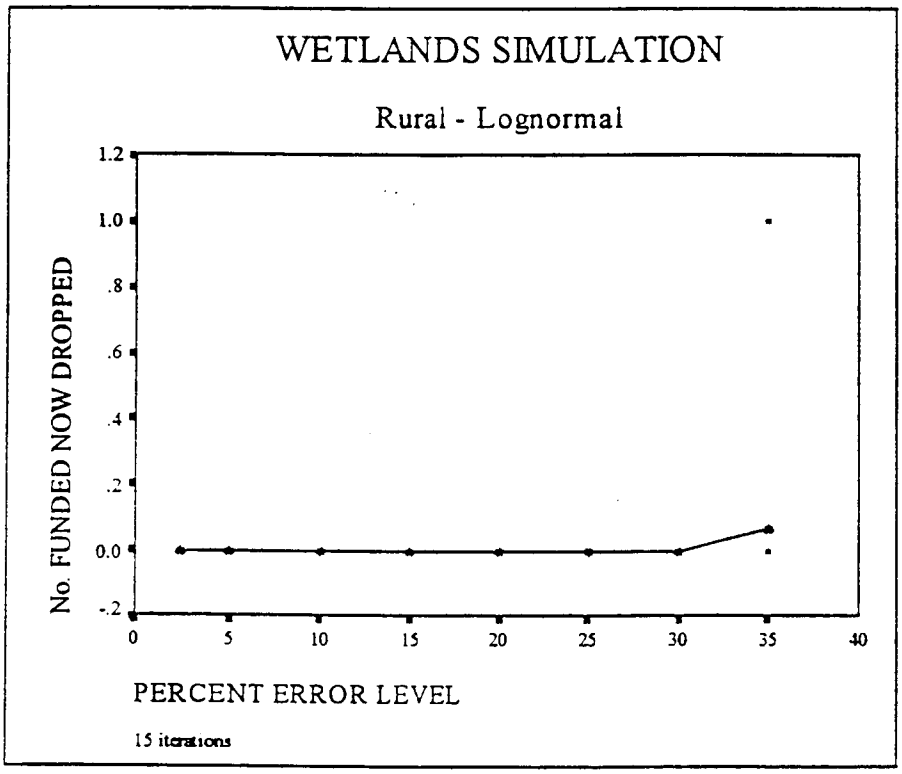


Figure I-3. Wetlands Category Results



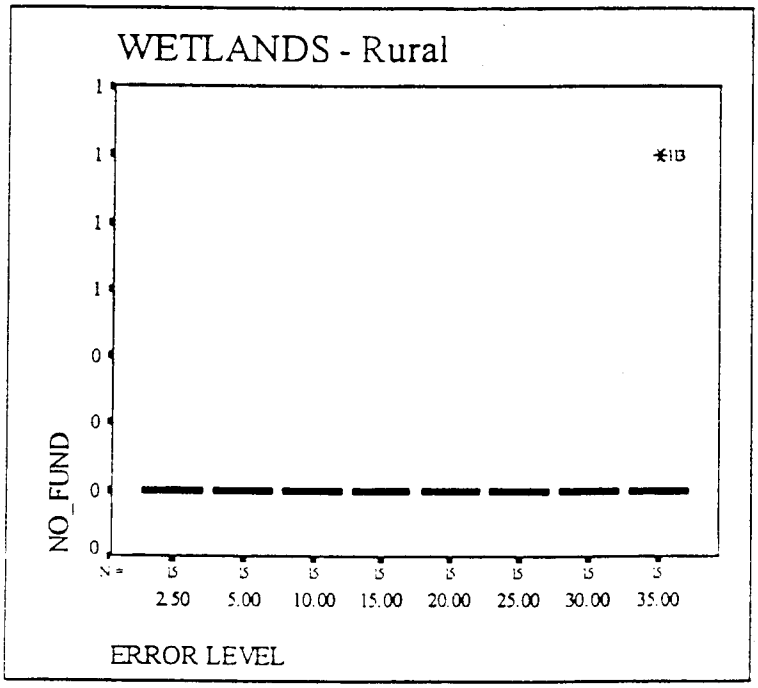
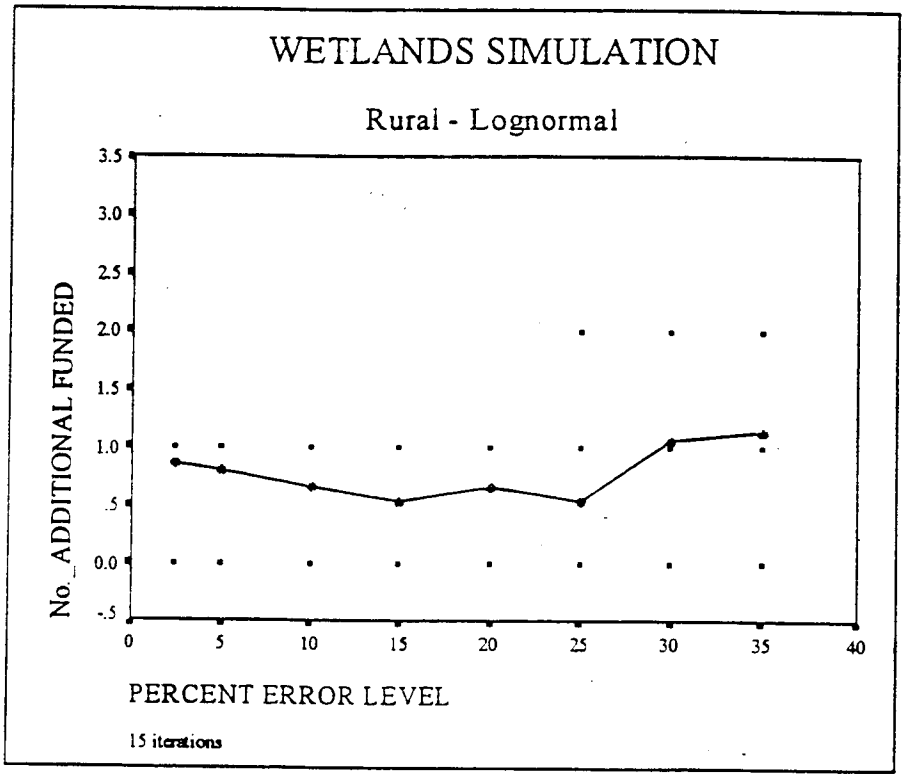


Figure I-3. Wetlands Category Results (continued)



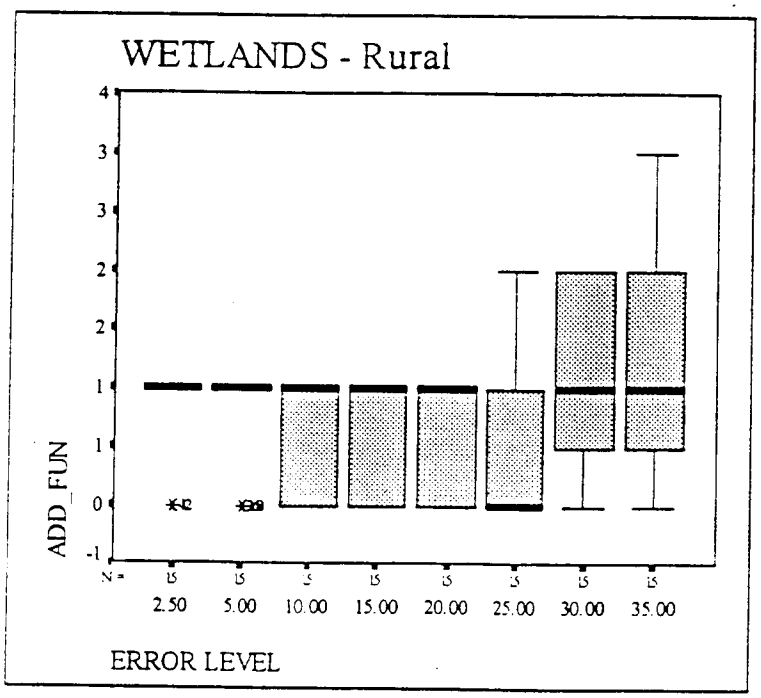
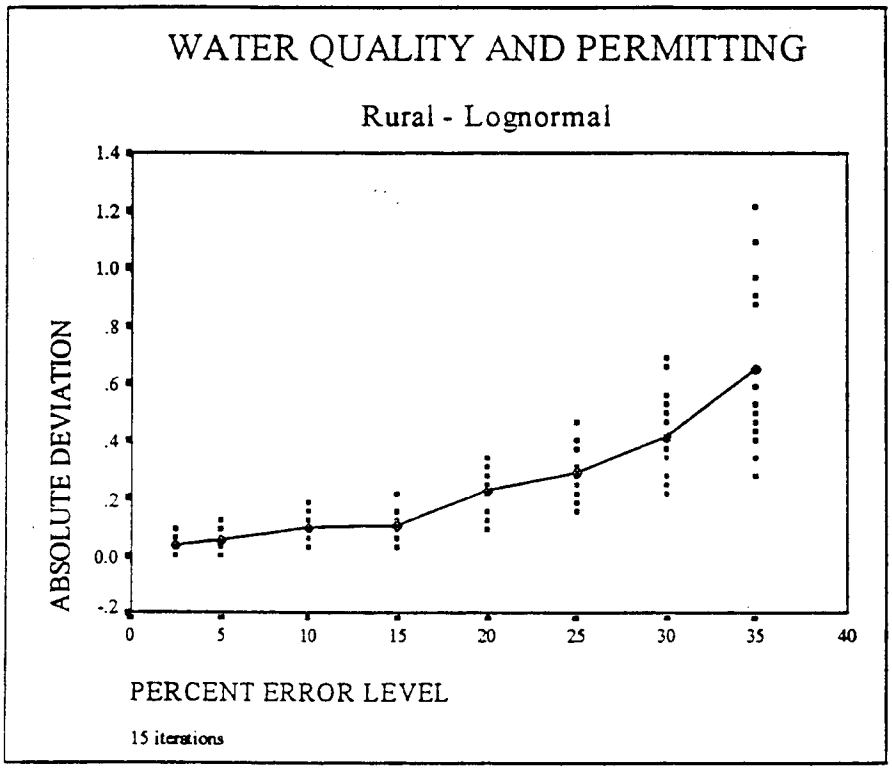


Figure I-3. *Wetlands Category Results (continued)*



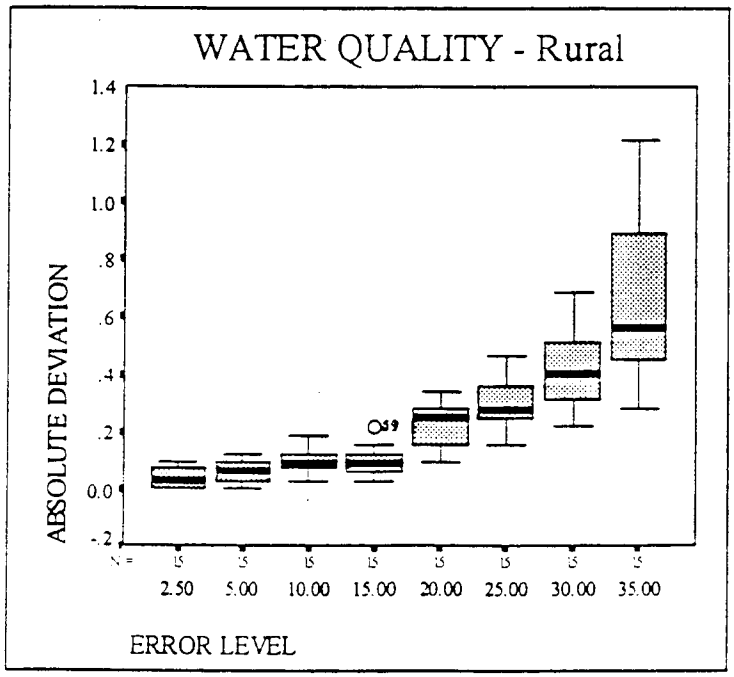
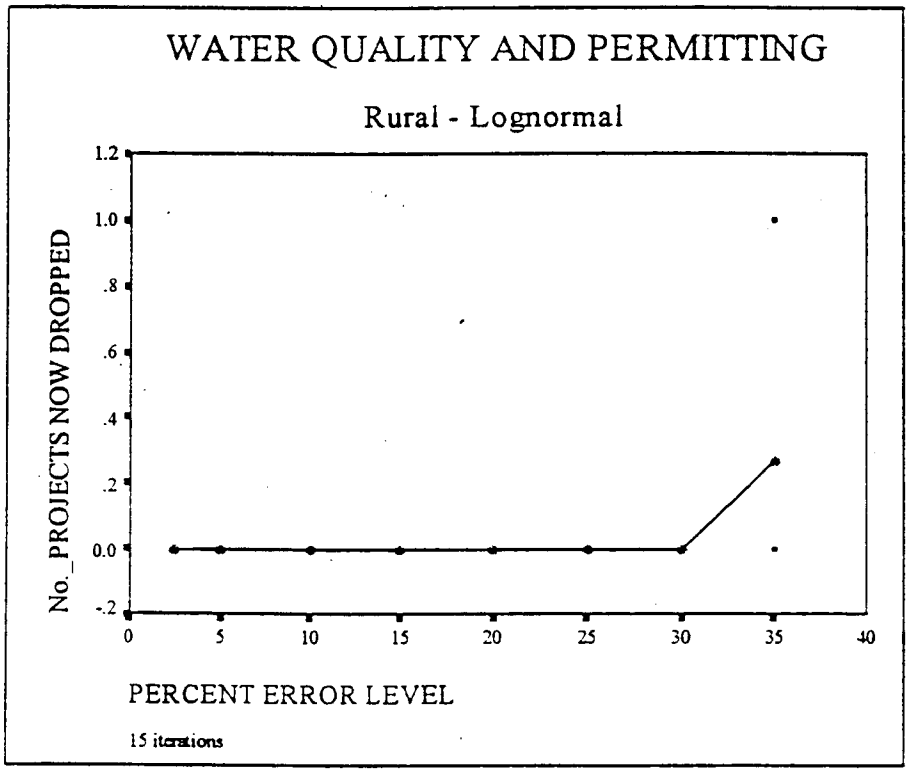


Figure I-4. *Water quality and permitting Category Results*



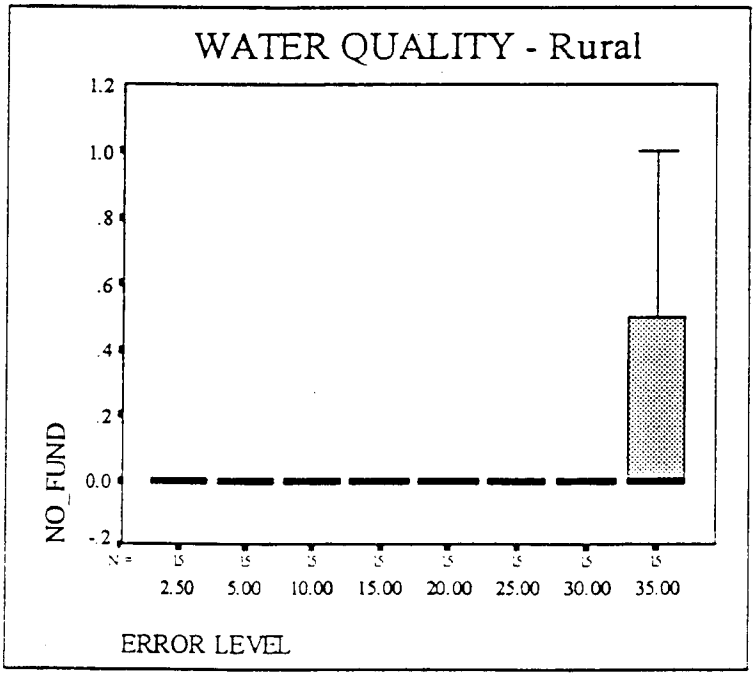
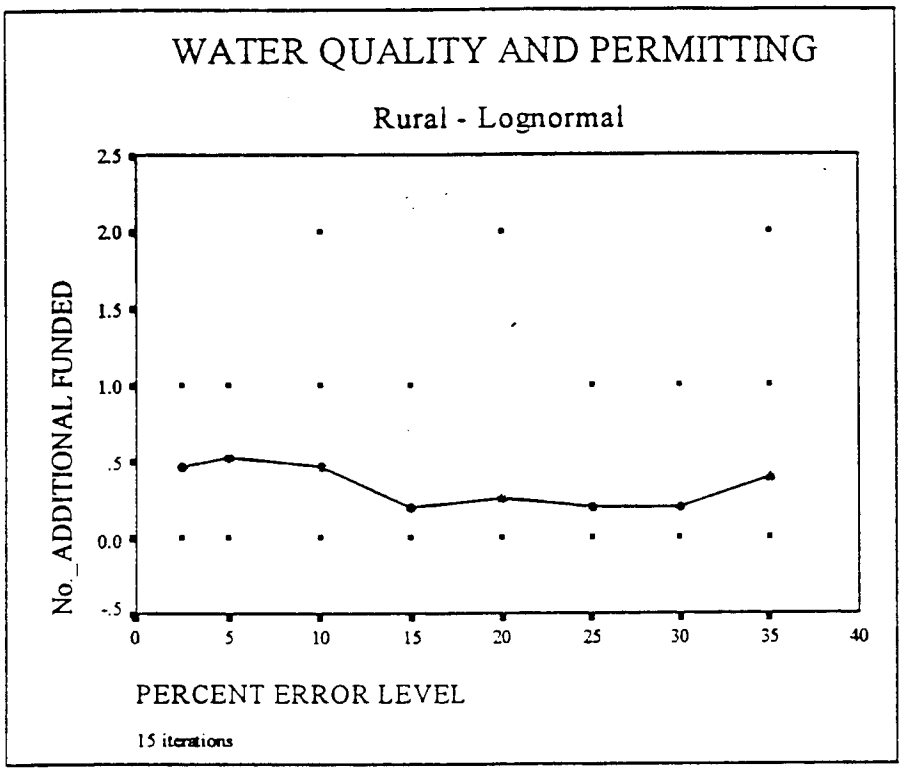


Figure I-4. Water quality and permitting Category Results (continued)



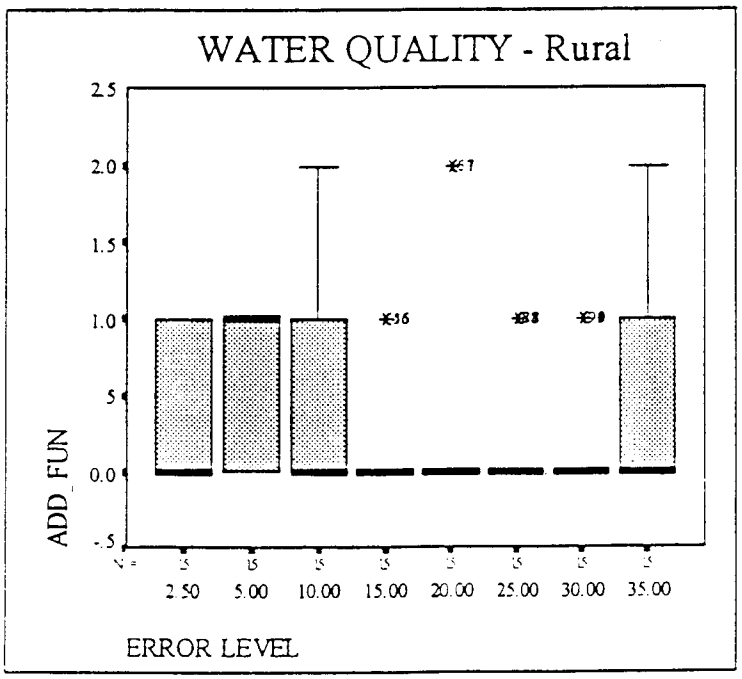
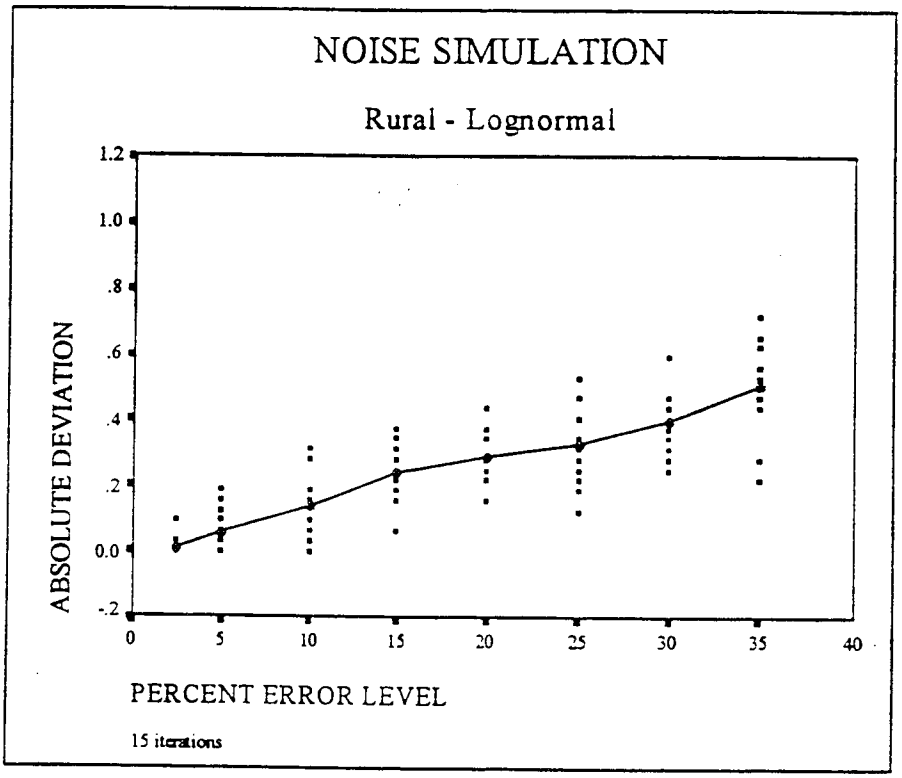


Figure I-4. *Water quality and permitting Category Results (continued)*



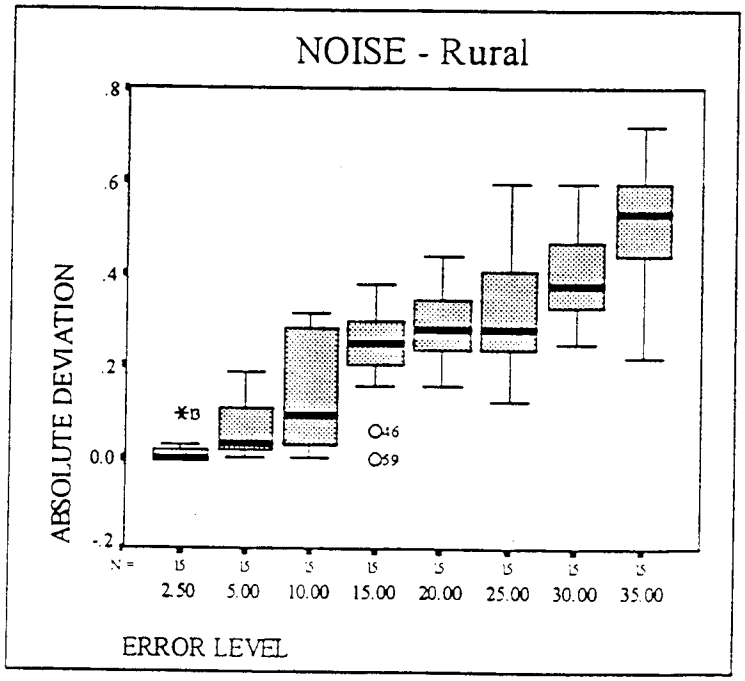
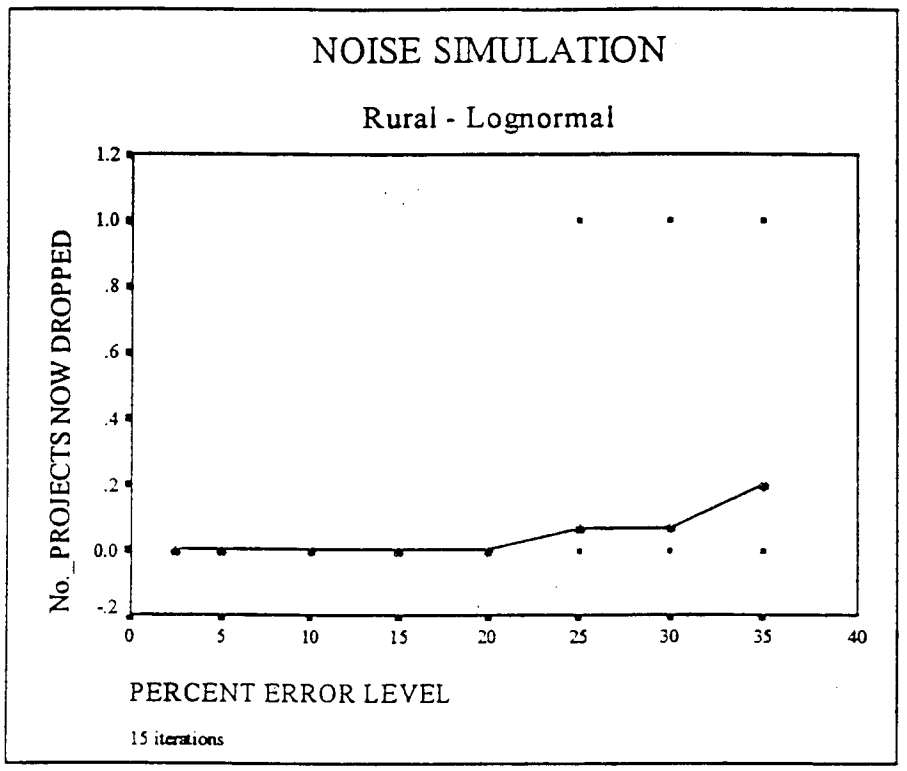


Figure I-5. Noise Category Results



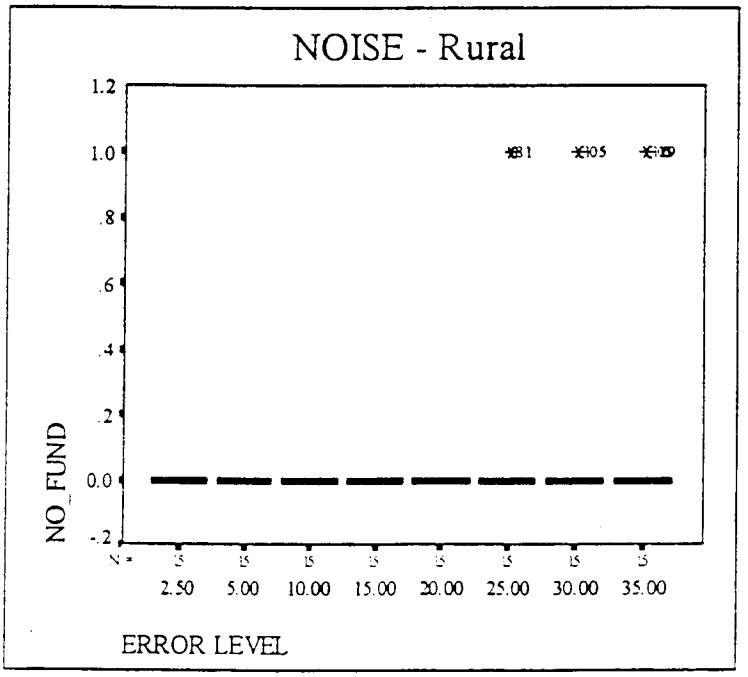
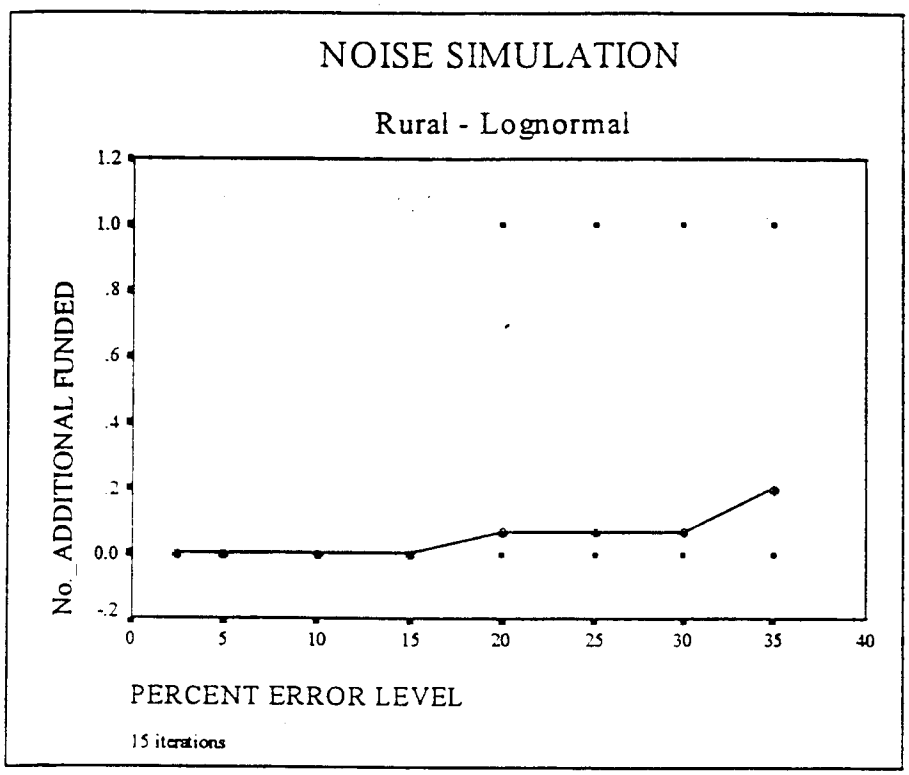


Figure I-5. Noise Category Results (continued)



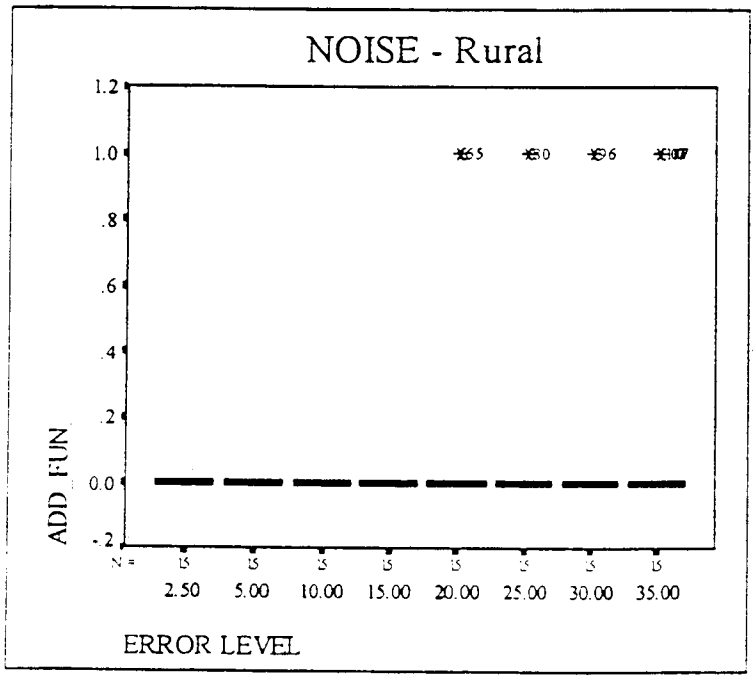
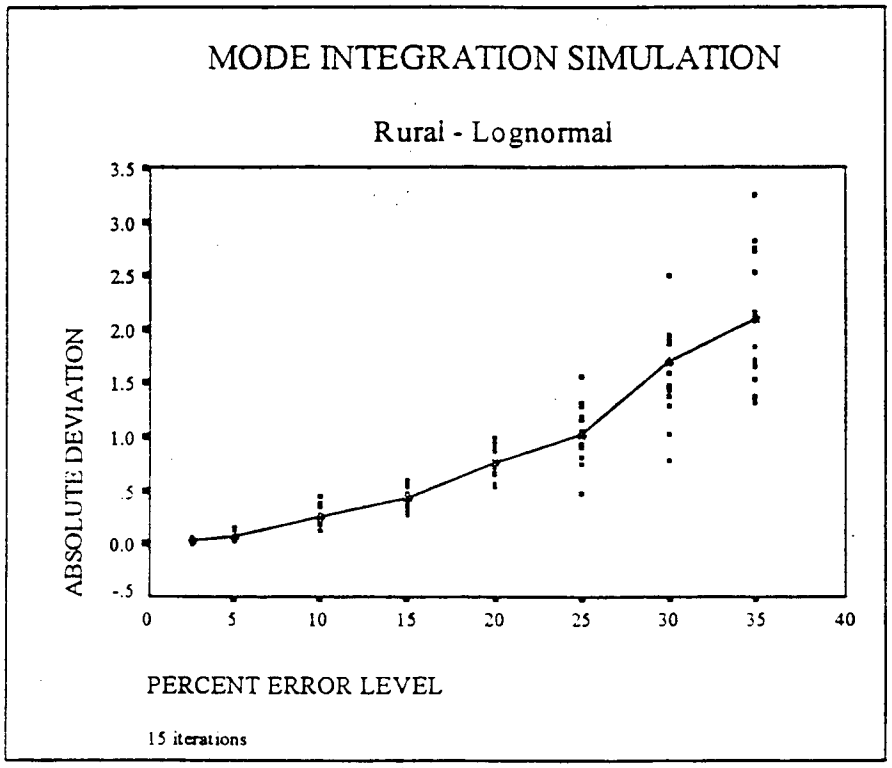


Figure I-5. Noise Category Results (continued)



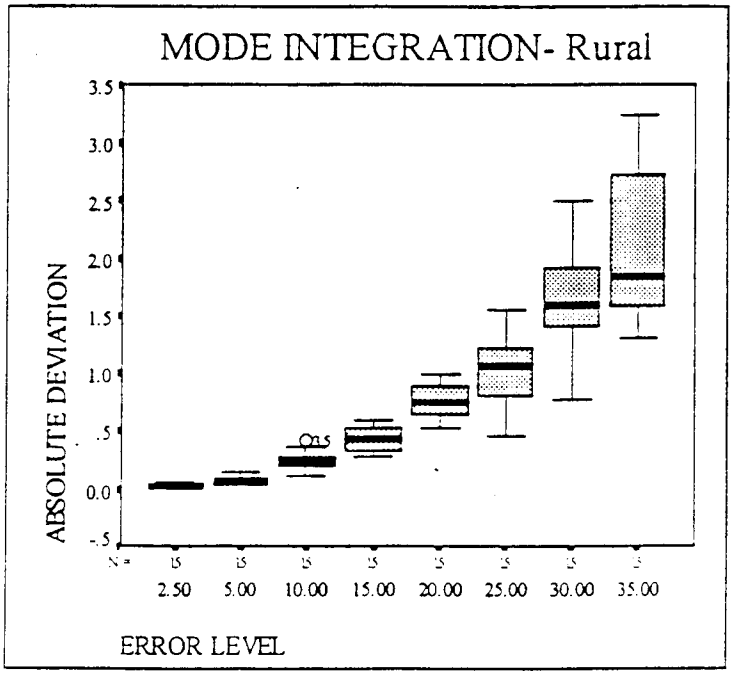
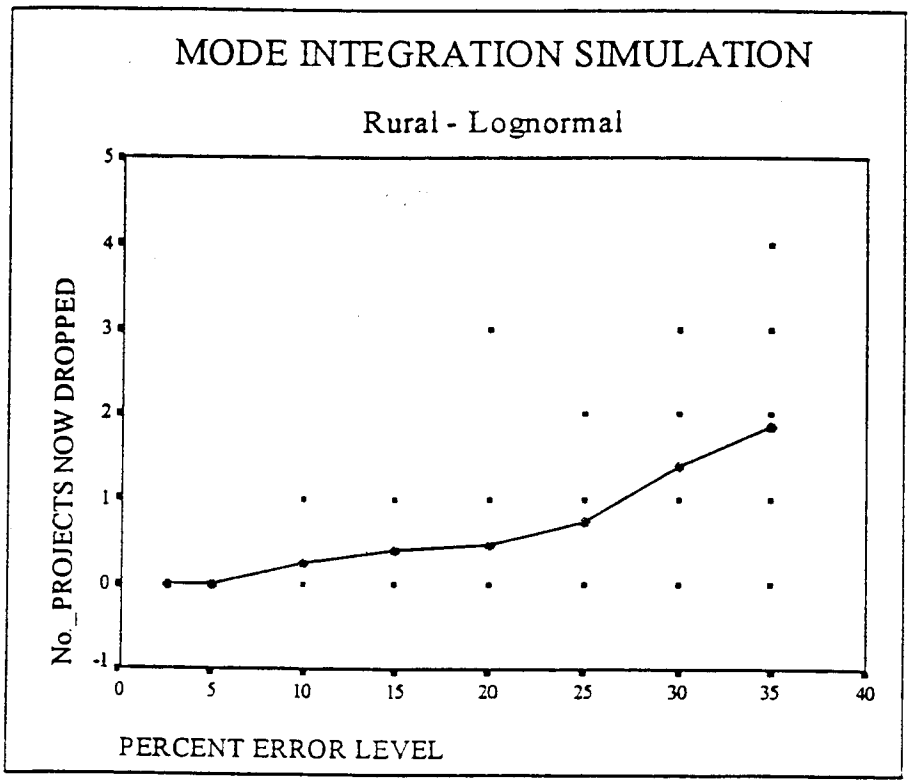


Figure I-6. Mode integration Category Results



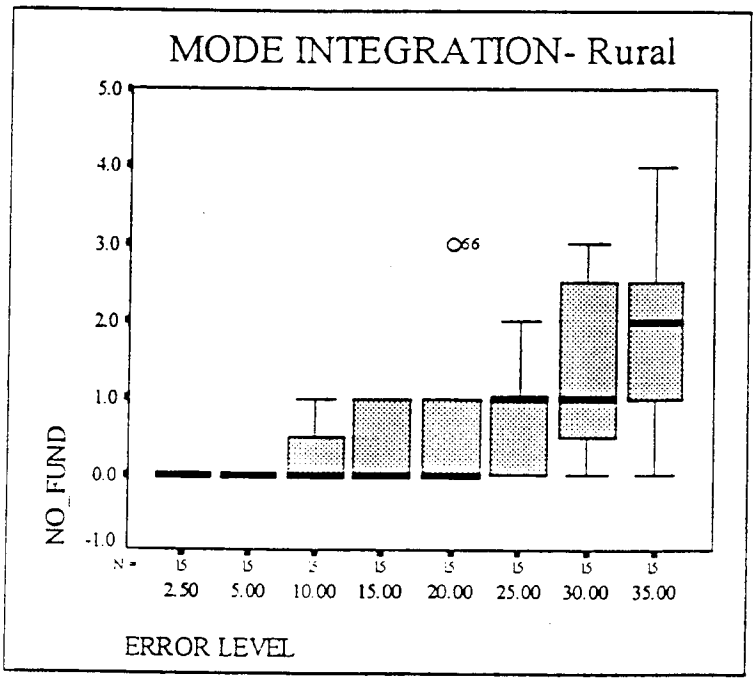
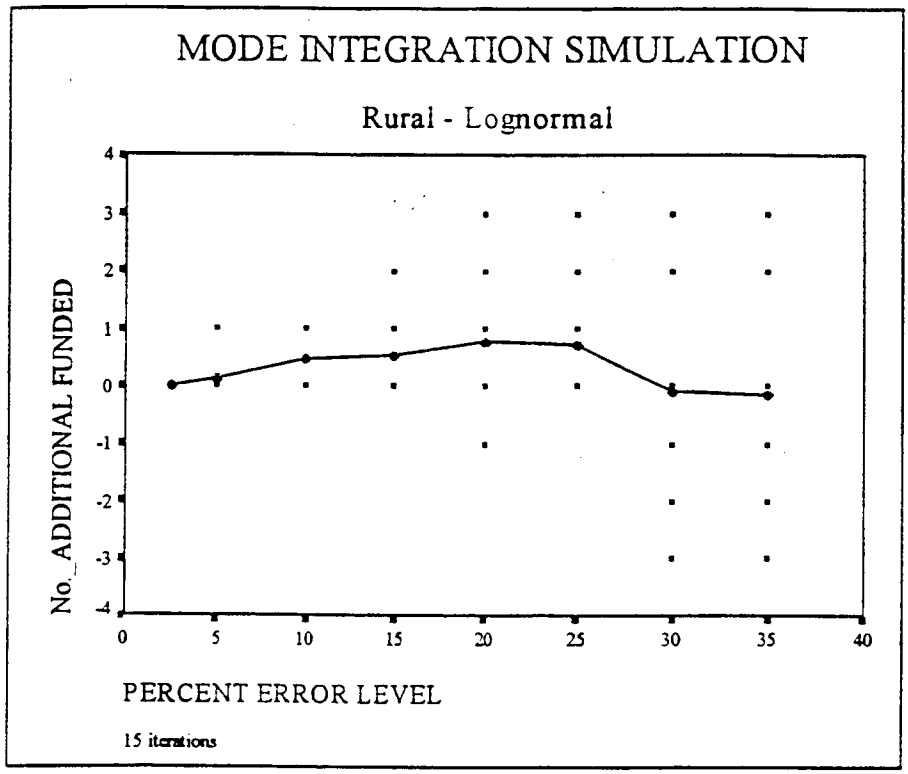


Figure I-6. Mode integration Category Results (continued)



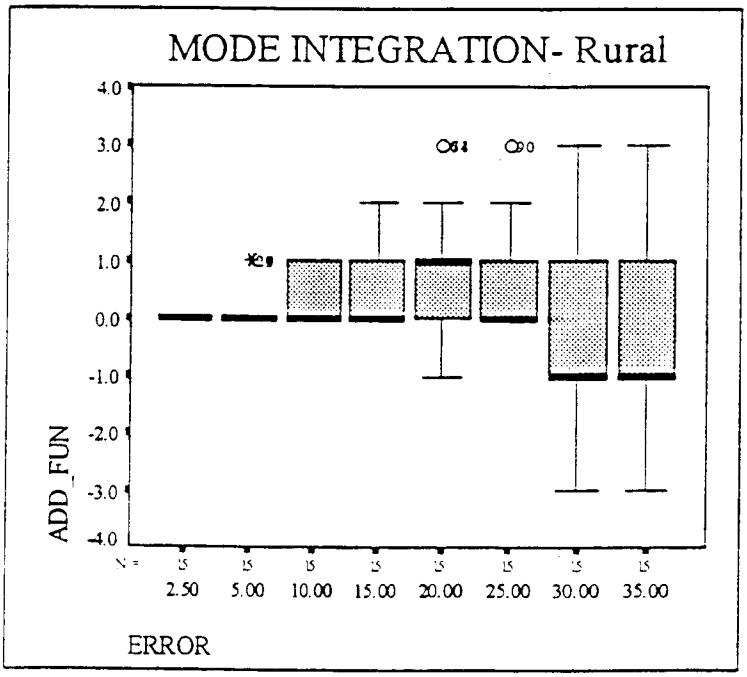
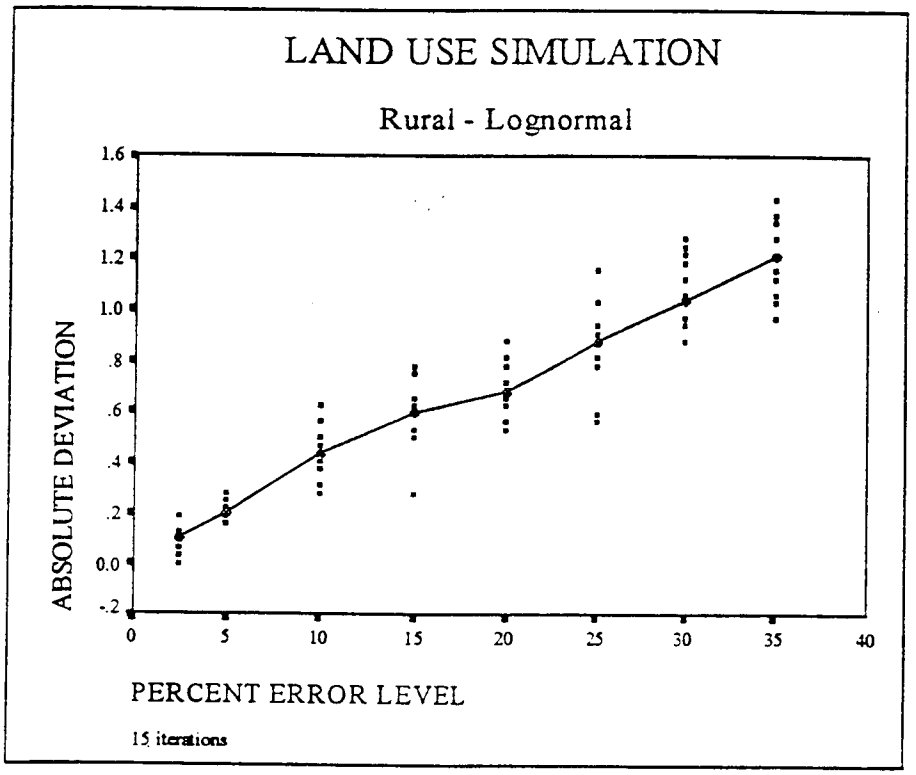


Figure I-6. Mode integration Category Results (continued)



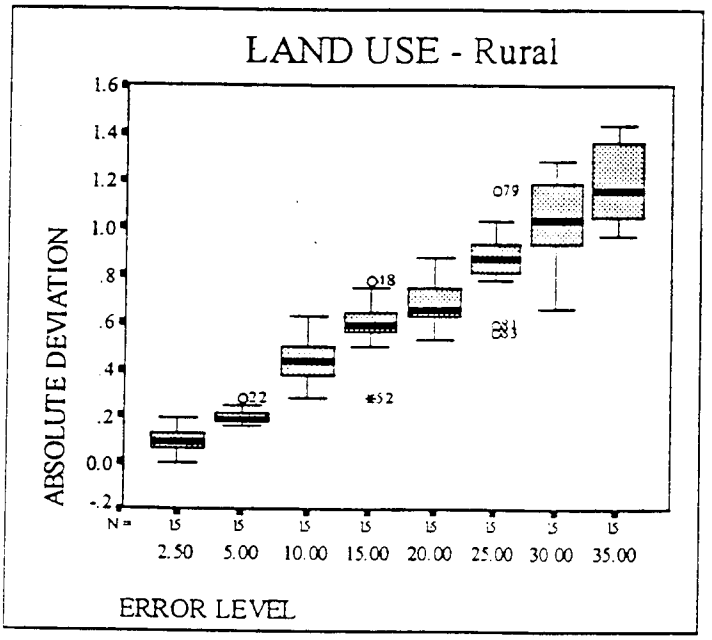
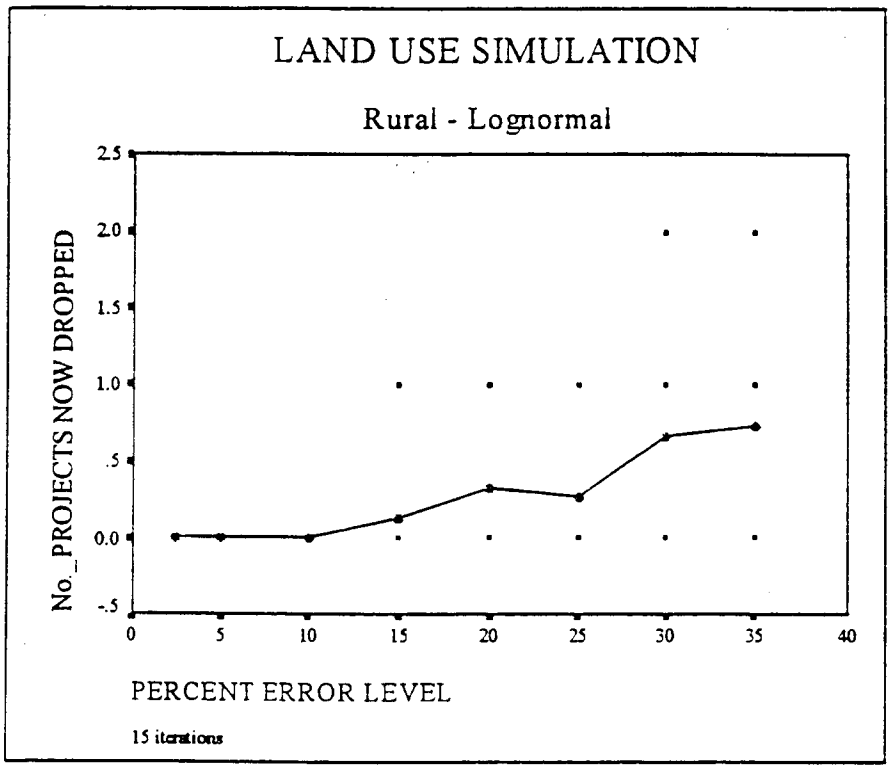


Figure I-7. Land use Category Results



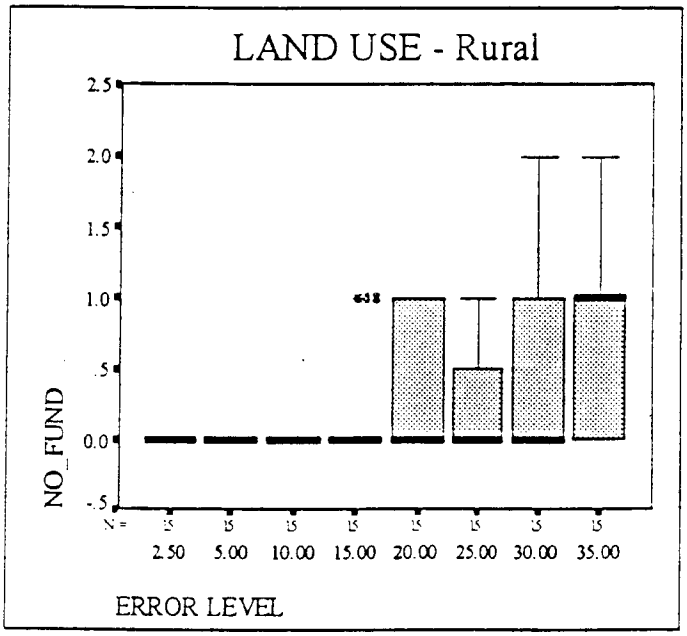
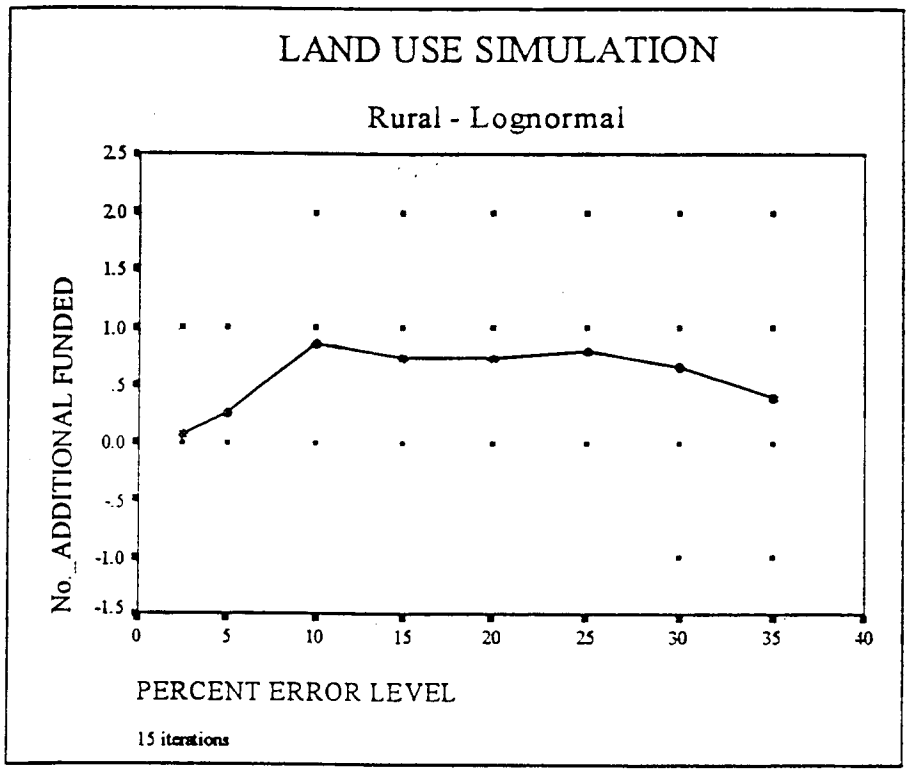


Figure I-7. Land use Category Results (continued)



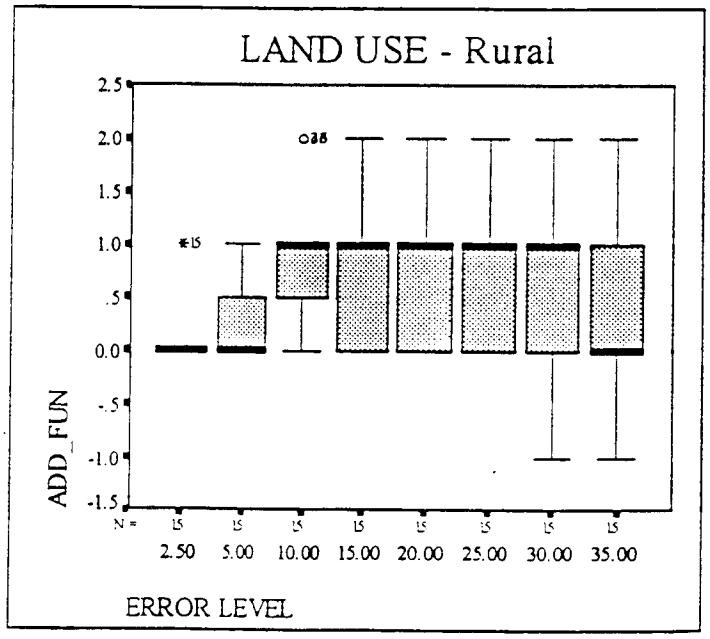


Figure I-7. Land use Category Results (continued)

APPENDIX I. (CONTINUED)

SUMMARY MEASURE BOXPLOTS BY PERCENT ERROR LEVEL

HOW TO READ BOXPLOTS

*	= Extremes > 3 box lengths from 75th percentile
o	= Outliers > 1.5 box lengths from 75th percentile.
___	= Largest observation that is not an outlier.
|	
□	= Box (median is denoted by heavy black line).
⊥	= Smallest observation that is not an outlier.

Figure I-8. Boxplot Symbols

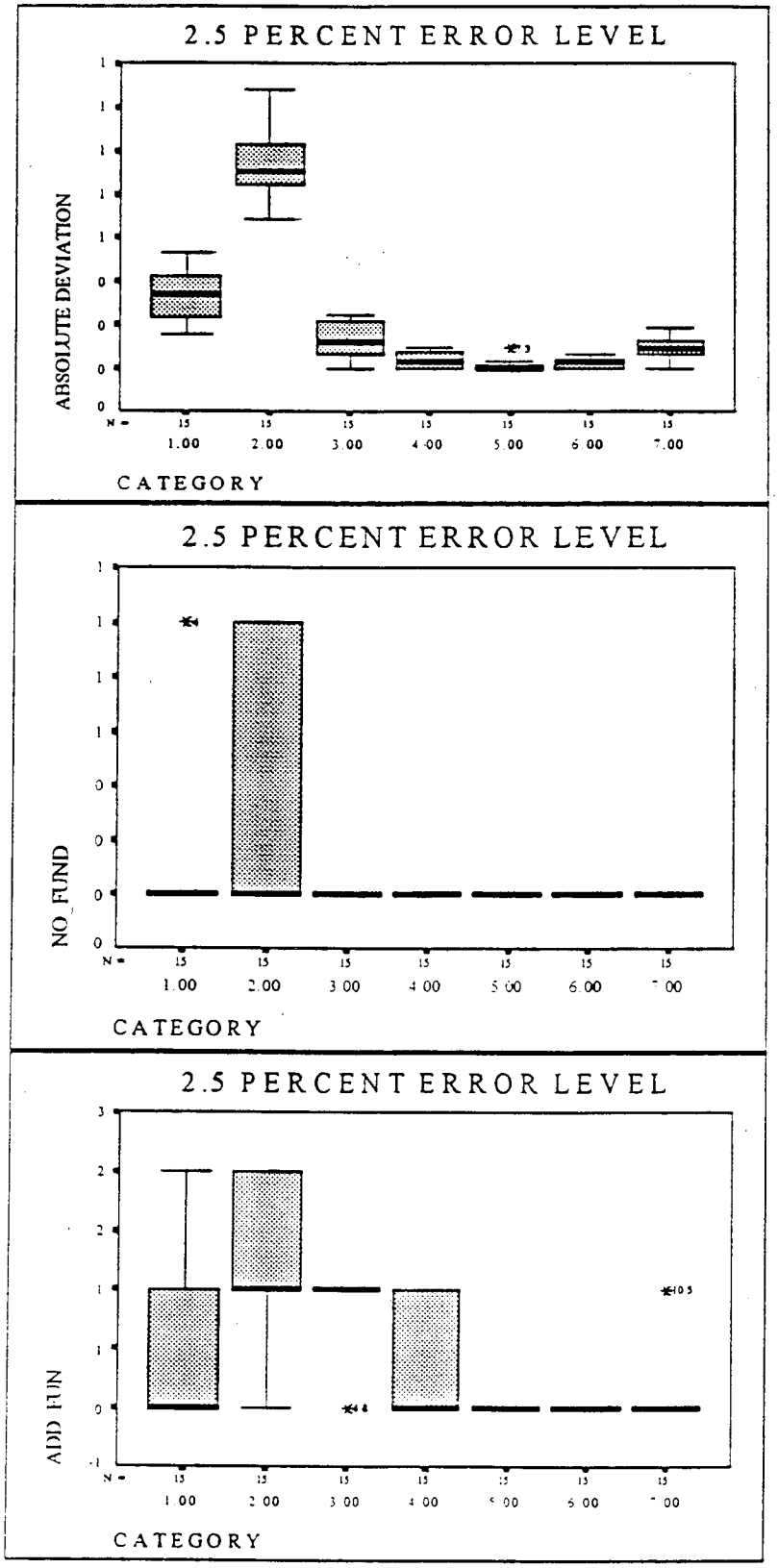


Figure I-9. *Percent Error Results - 2.5*

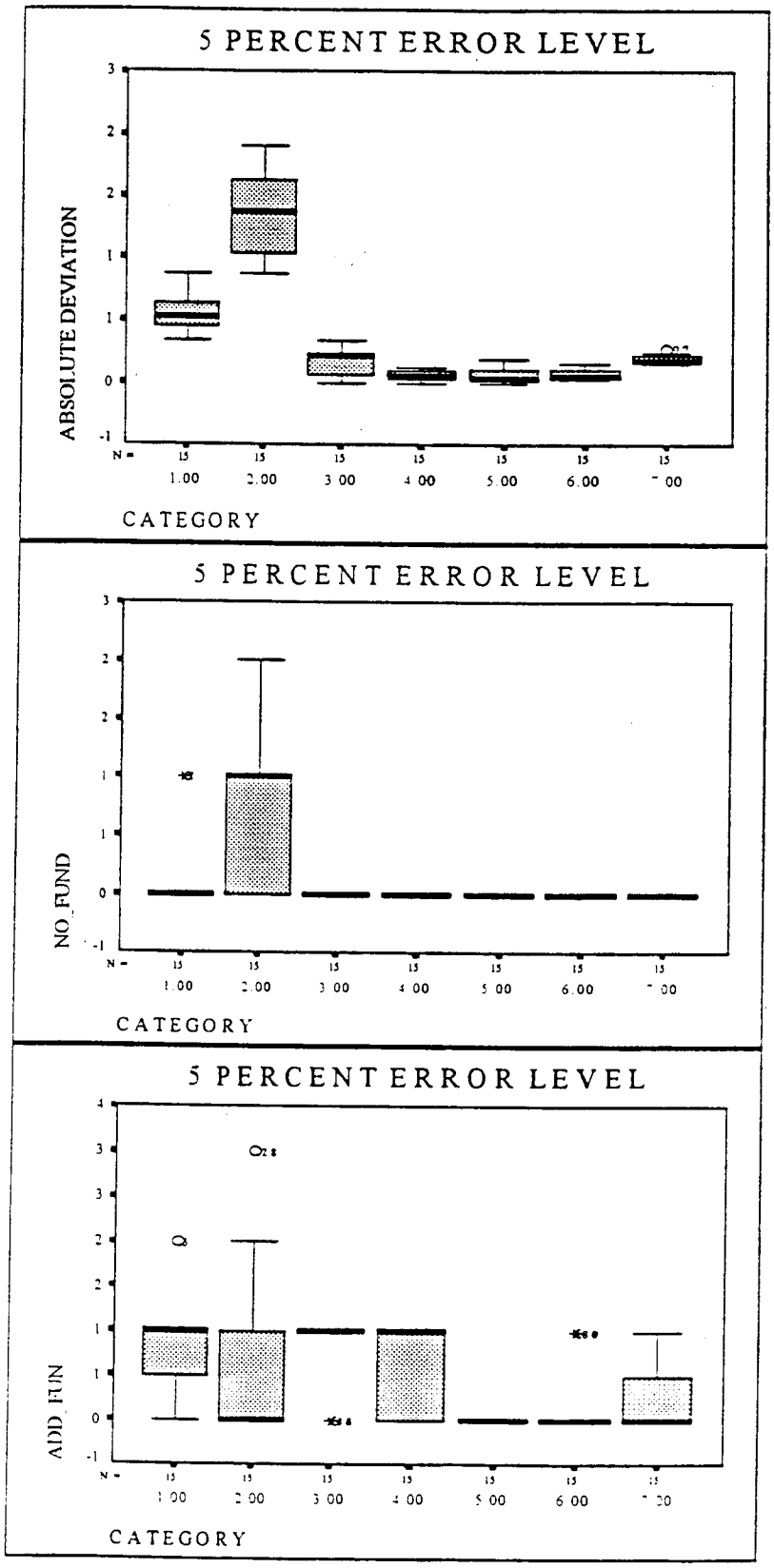


Figure I-10. Percent Error Results - 5.0

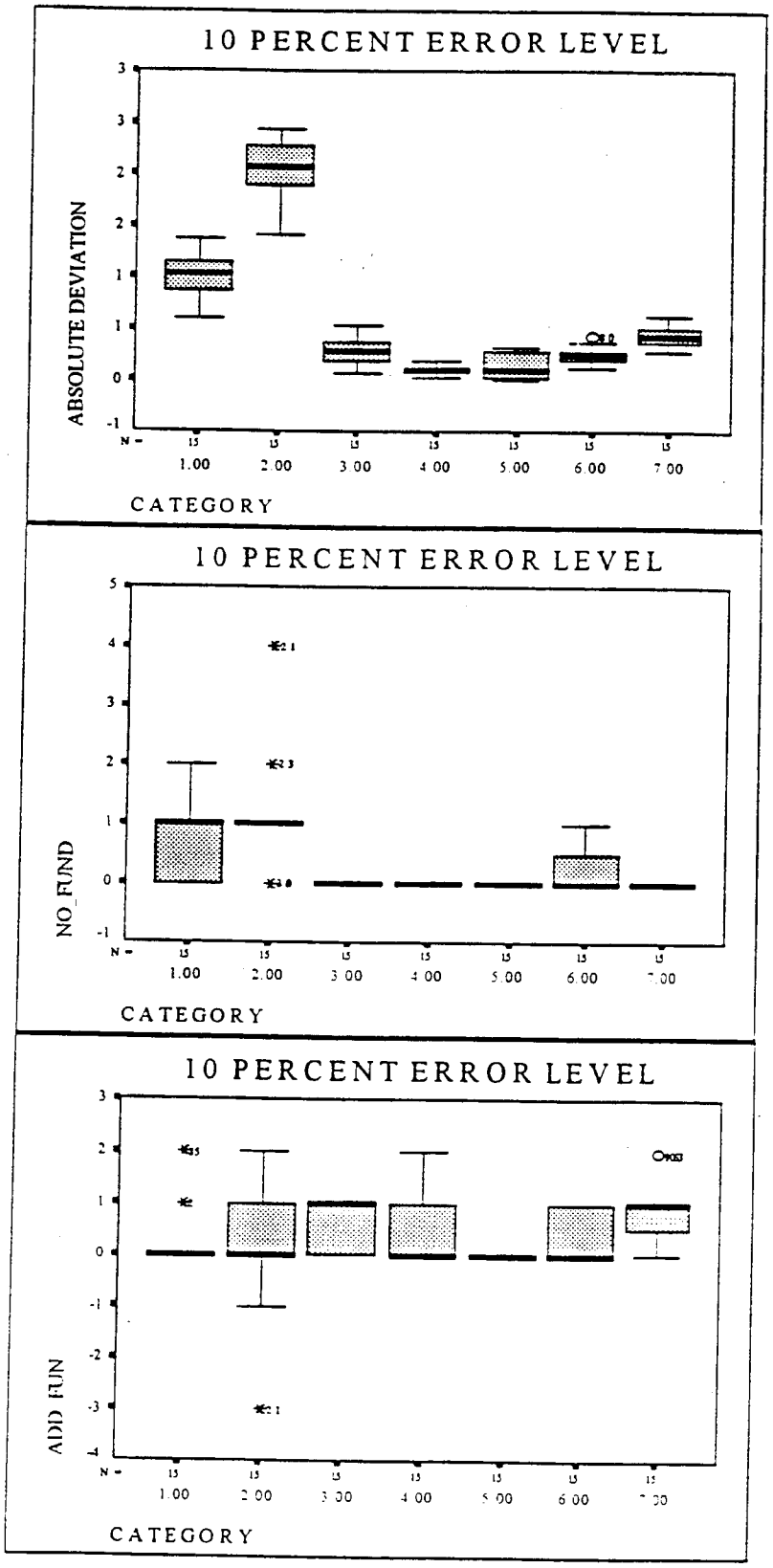


Figure I-11. Percent Error Results - 10

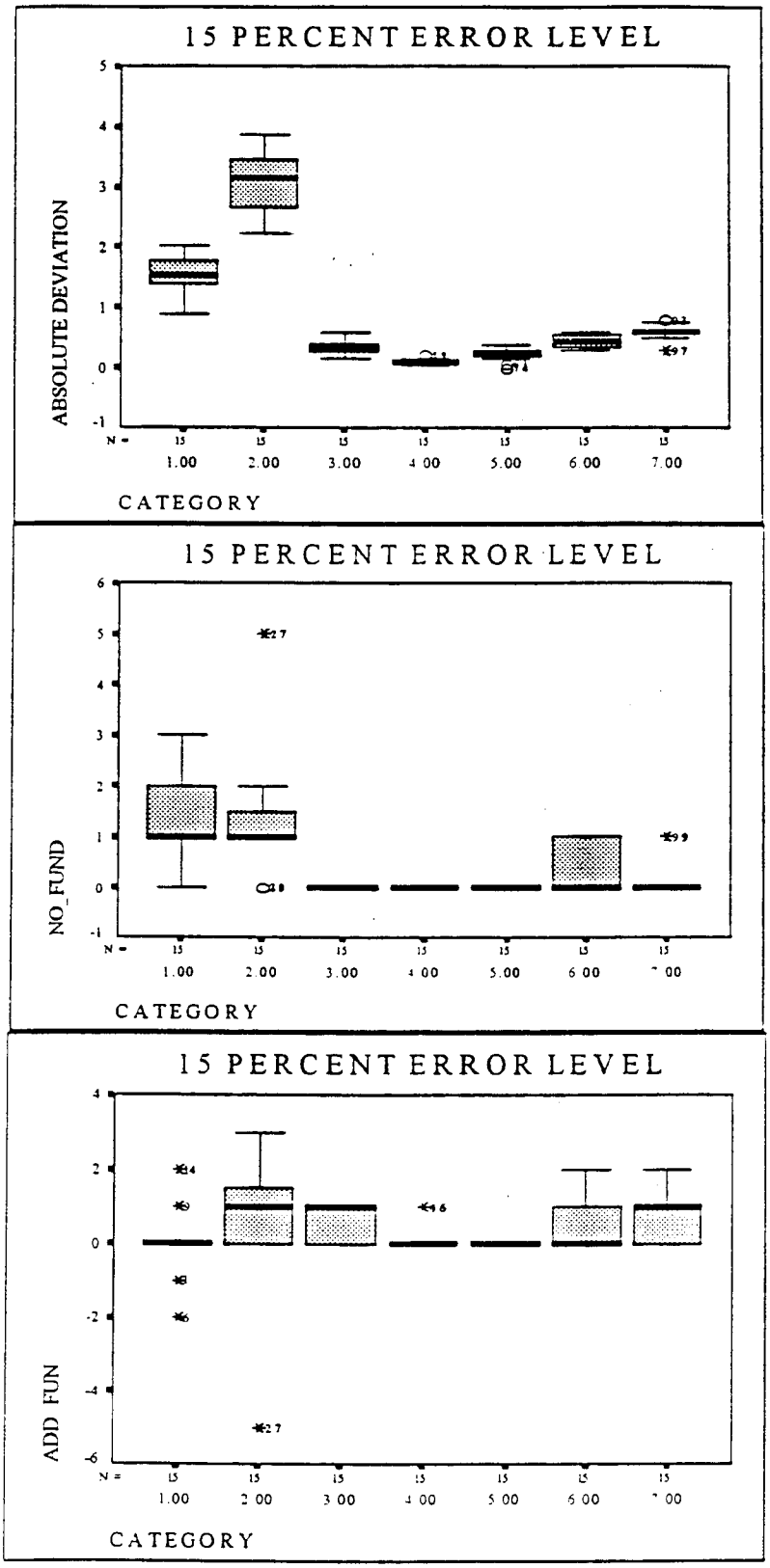


Figure I-12. Percent Error Results - 15

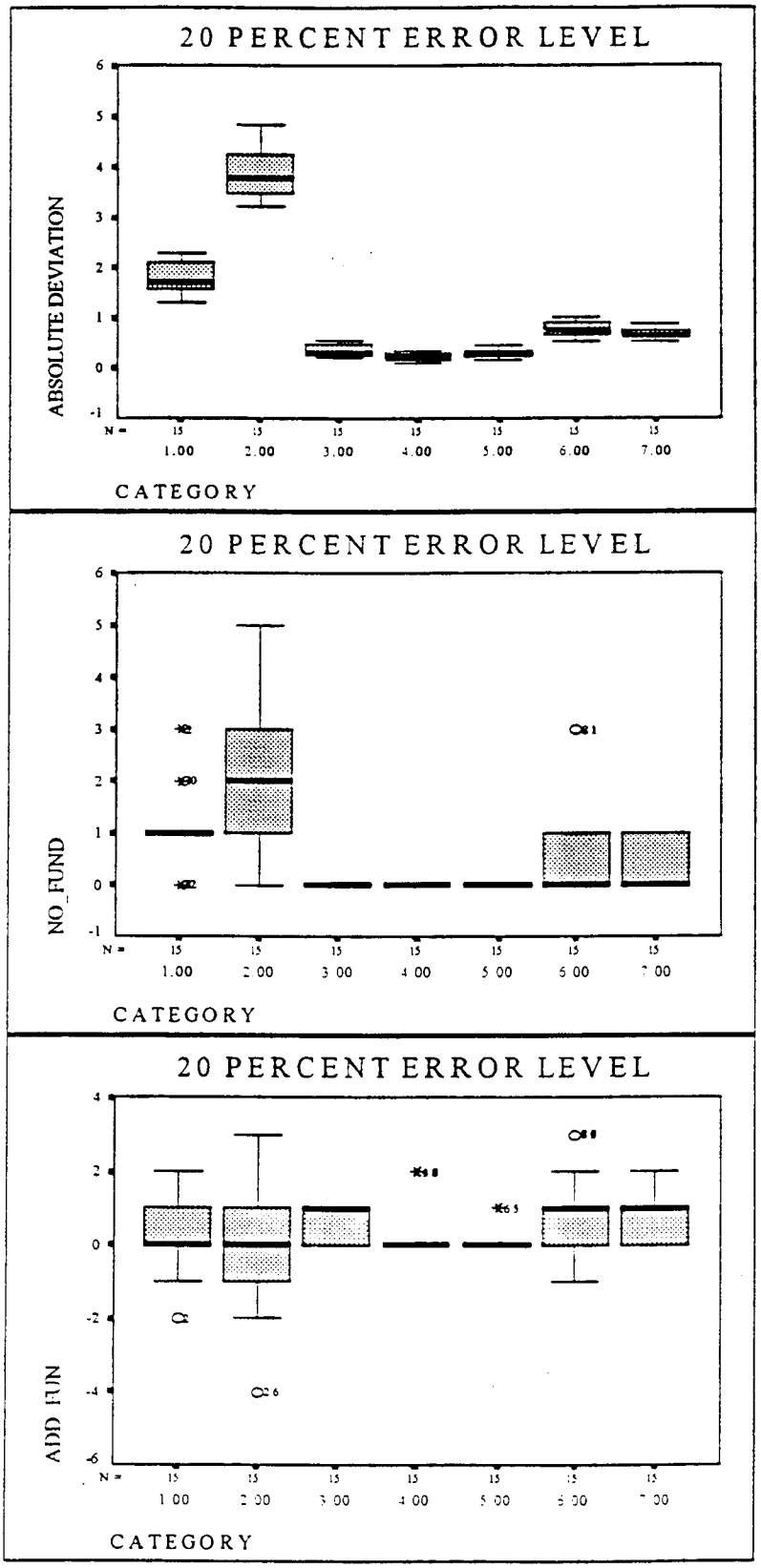


Figure I-13. Percent Error Results - 20

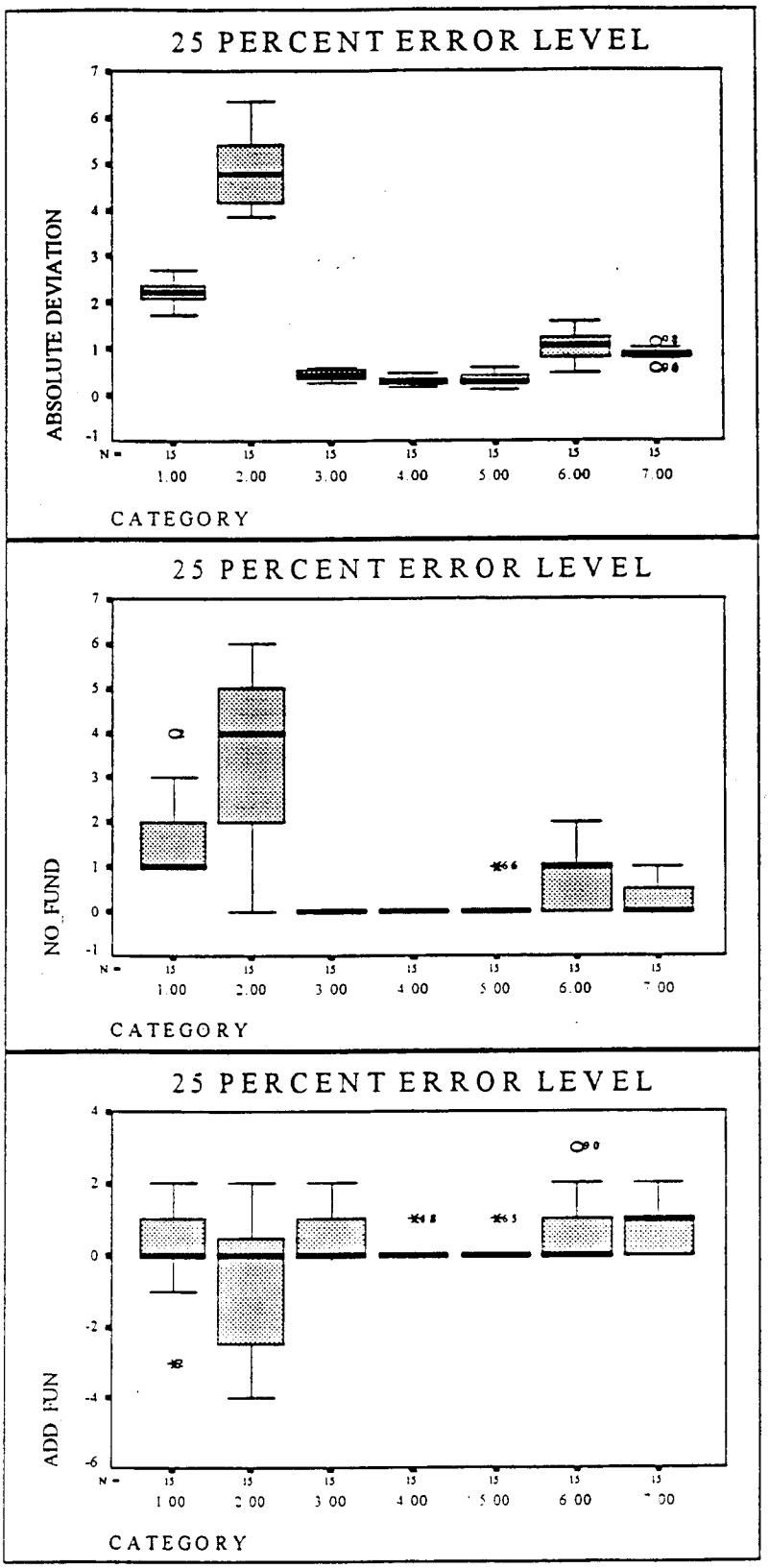


Figure I-14. Percent Error Results - 25

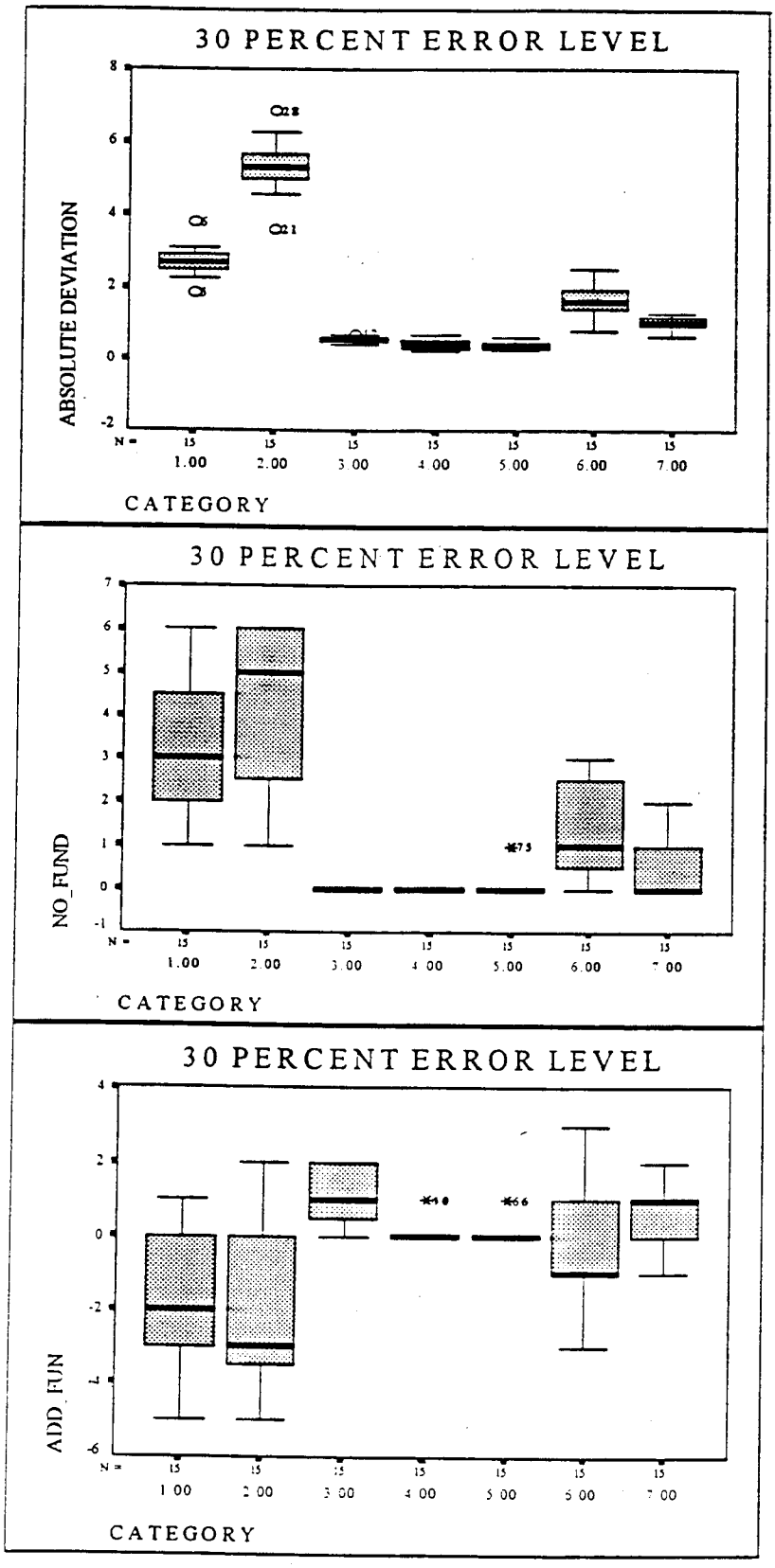


Figure I-15. Percent Error Results - 30

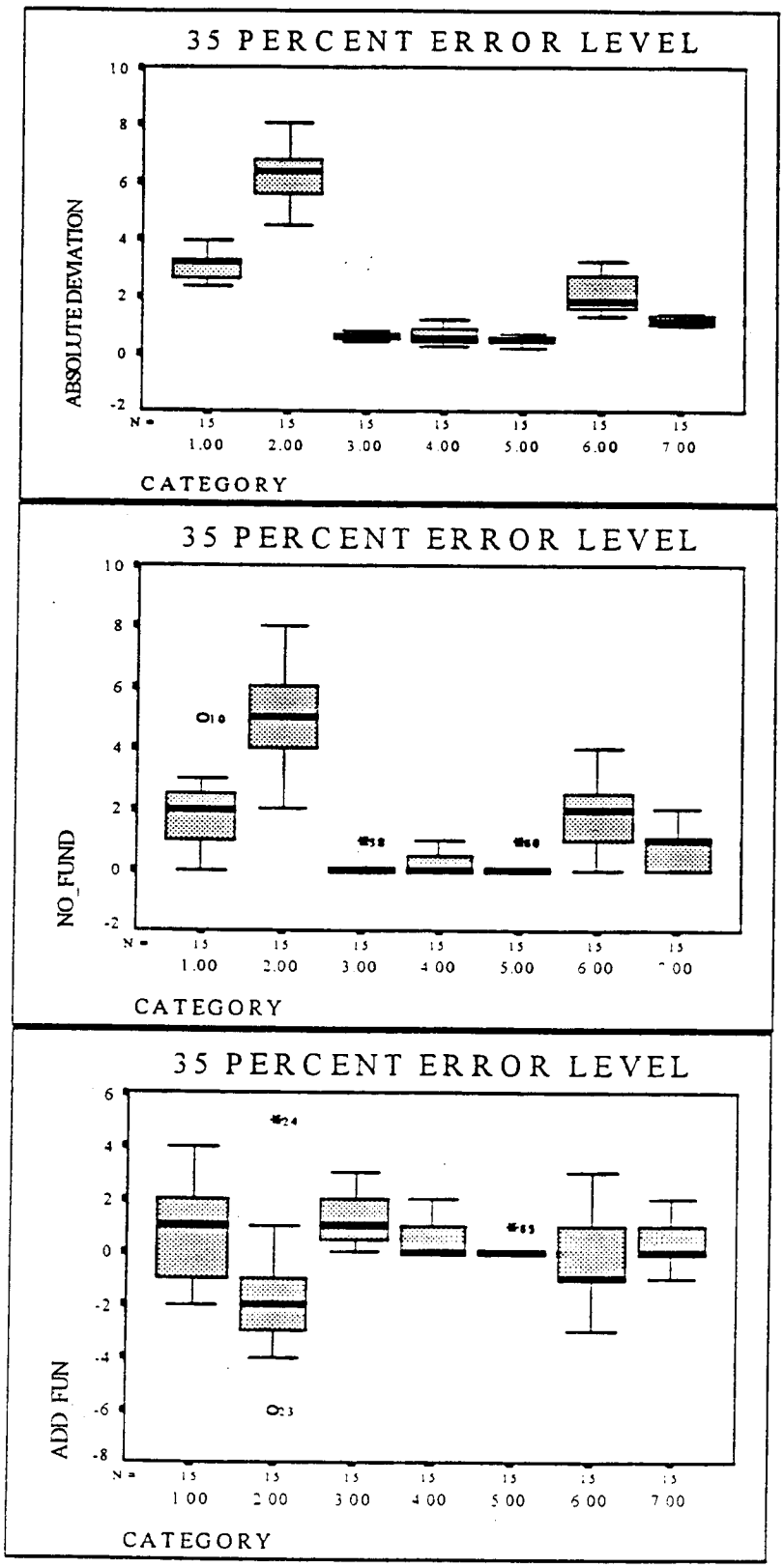


Figure I-16. Percent Error Results - 35

APPENDIX J. SAMPLE ANOVA TEST STATISTICS

Contents:

ANOVA results, descriptive statistics, and Levene, K-S, and Shapiro-Wilks test statistics for two cases (of 21 total), i.e.,

1. Cost-efficiency simulation across all error levels, and

2. 15 percent error applied to every category.

Absolute Difference

file: <err_norm> and <anov.lst>

----- ONEWAY -----
RURAL COST EFFICIENCY

Variable ABS_DEV
By Variable ERROR (2.5 TO 35 PERCENT)

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	7	102.4473	14.6353	156.9432	.0000
Within Groups	112	10.4443	.0933		
Total	119	112.8916			

Levene Test for Homogeneity of Variances

Statistic	df1	df2	2-tail Sig.
4.2628	7	112	.000

Multiple Range Tests: Modified LSD (Bonferroni) test with significance level .05
The difference between two means is significant if
MEAN(J)-MEAN(I) >= .2159 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE: 4.53
(*) Indicates significant differences which are shown in the lower triangle

Mean	ERROR	Grp 2	Grp 5	Grp10	Grp15	Grp20	Grp25	Grp30	Grp35
.3375	Grp 2								
.5458	Grp 5								
.9896	Grp10	*	*						
1.5458	Grp15	*	*	*					
1.7750	Grp20	*	*	*					
2.2375	Grp25	*	*	*	*	*			
2.6917	Grp30	*	*	*	*	*	*		
3.0625	Grp35	*	*	*	*	*	*	*	

Homogeneous Subsets (highest and lowest means are not significantly different)

Subset 1
Group Grp 2 Grp 5
Mean .3375 .5458

Subset 2
Group Grp10
Mean .9896

Subset 3
Group Grp15 Grp20
Mean 1.5458 1.7750

Subset 4
Group Grp25
Mean 2.2375

Subset 5
Group Grp30
Mean 2.6917

Subset 6
Group Grp35
Mean 3.0625

----- ONEWAY -----
RURAL COST-EFFICIENCY

Variable ABS_DEV
By Variable ERROR (2.5 TO 70 PERCENT, with 30 valid observations at the 35% error level)

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	14	776.8846	55.4918	186.5076	.0000
Within Groups	225	66.9444	.2975		
Total	239	843.8290			

2.5 to 70 PERCENT ERROR LEVEL (denoted by group i.d.)
DESCRIPTIVE STATISTICS:

Group	Count	Standard Mean	Standard Deviation	Error	Minimum	Maximum	95 Pct Conf Int for Mean
Grp 2	15	.3375	.1223	.0316	.1563	.5313	.2698 TO .4052
Grp 5	15	.5458	.1479	.0382	.3438	.8750	.4639 TO .6278
Grp10	15	.9896	.2202	.0569	.5938	1.3750	.8676 TO 1.1115
Grp15	15	1.5458	.3091	.0798	.8750	2.0313	1.3747 TO 1.7170
Grp20	15	1.7750	.3176	.0820	1.3125	2.2813	1.5991 TO 1.9509
Grp25	15	2.2375	.2449	.0632	1.7188	2.6875	2.1019 TO 2.3731
Grp30	15	2.6917	.4380	.1131	1.8438	3.7813	2.4491 TO 2.9342
Grp35	30	3.1427	.4853	.0886	2.0625	4.0000	2.9615 TO 3.3239
Grp40	15	3.4063	.7925	.2046	2.3750	5.8438	2.9674 TO 3.8451
Grp45	15	4.2417	.7302	.1885	3.5000	6.5000	3.8373 TO 4.6460
Grp50	15	4.2625	.5594	.1444	3.1875	5.1563	3.9527 TO 4.5723
Grp55	15	5.1146	.7854	.2028	3.9688	7.0313	4.6796 TO 5.5495
Grp60	15	5.0750	.6576	.1698	3.5938	5.9688	4.7108 TO 5.4392
Grp65	15	6.0375	.6039	.1559	4.9063	6.9688	5.7031 TO 6.3719
Grp70	15	6.0708	.9340	.2411	4.3750	7.7500	5.5536 TO 6.5880
Total	240	3.1635	1.8790	.1213	.1563	7.7500	2.9246 TO 3.4025

Levene Test for Homogeneity of Variances

Statistic	df1	df2	2-tail Sig.
3.8920	14	225	.000

Multiple Range Tests: Modified LSD (Bonferroni) test with significance level .05
The difference between two means is significant if
MEAN(J)-MEAN(I) >= .3857 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE: 5.01
(*) Indicates significant differences which are shown in the lower triangle

Mean	ERROR	Grp 2	Grp 5	Grp10	Grp15	Grp20	Grp25	Grp30	Grp35	Grp40	Grp45	Grp50	Grp60	Grp55	Grp65	Grp70
.3375	Grp 2															
.5458	Grp 5															
.9896	Grp10															
1.5458	Grp15	*	*													
1.7750	Grp20	*	*	*												
2.2375	Grp25	*	*	*												
2.6917	Grp30	*	*	*	*	*										
3.1427	Grp35	*	*	*	*	*	*									
3.4063	Grp40	*	*	*	*	*	*	*								
4.2417	Grp45	*	*	*	*	*	*	*	*	*						
4.2625	Grp50	*	*	*	*	*	*	*	*	*						
5.0750	Grp60	*	*	*	*	*	*	*	*	*	*	*				
5.1146	Grp55	*	*	*	*	*	*	*	*	*	*	*				
6.0375	Grp65	*	*	*	*	*	*	*	*	*	*	*	*	*		
6.0708	Grp70	*	*	*	*	*	*	*	*	*	*	*	*	*		

RURAL COST-EFFICIENCY

ABS_DEV
By ERROR 2.5
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.2066 S E Skew .5801
Kurtosis -1.0500 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.1563	.1563	.1875	.3438	.4375	.5125	.
Tukey's Hinges			.2344	.3438	.4219		

	Statistic	df	Significance
Shapiro-Wilks	.9377	15	.3997
K-S (Lilliefors)	.1567	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 5.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .6839 S E Skew .5801
Kurtosis .2228 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.3438	.3625	.4375	.5313	.6563	.8000	.
Tukey's Hinges			.4531	.5313	.6406		

	Statistic	df	Significance
Shapiro-Wilks	.9556	15	.5891
K-S (Lilliefors)	.1218	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 10.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.2922 S E Skew .5801
Kurtosis -.4113 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.5938	.6313	.8125	1.0313	1.1563	1.3000	.
Tukey's Hinges			.8594	1.0313	1.1406		

	Statistic	df	Significance
Shapiro-Wilks	.9705	15	.8282
K-S (Lilliefors)	.0913	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 15.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.4868 S E Skew .5801
Kurtosis .0804 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.8750	1.0438	1.3438	1.5313	1.8125	1.9563	.
Tukey's Hinges			1.3750	1.5313	1.7656		

	Statistic	df	Significance
Shapiro-Wilks	.9792	15	.9421
K-S (Lilliefors)	.0582	15	> .2000

***ACCEPT NORMALITY Ho.

Section J1 - Category Simulation

ABS_DEV
By ERROR 20.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .1498 S E Skew .5801
Kurtosis -1.2367 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	1.3125	1.3125	1.5625	1.7188	2.1250	2.2063	.
Tukey's Hinges			1.5781	1.7188	2.0938		

	Statistic	df	Significance
Shapiro-Wilks	.9342	15	.3707
K-S (Lilliefors)	.1314	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 25.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .0104 S E Skew .5801
Kurtosis .4968 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	1.7188	1.9063	2.0938	2.2188	2.4375	2.6313	.
Tukey's Hinges			2.0938	2.2188	2.3594		

	Statistic	df	Significance
Shapiro-Wilks	.9623	15	.6965
K-S (Lilliefors)	.1624	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 30.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .6552 S E Skew .5801
Kurtosis 2.2723 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	1.8438	2.0875	2.4688	2.6875	2.9688	3.3500	.
Tukey's Hinges			2.4844	2.6875	2.8750		

	Statistic	df	Significance
Shapiro-Wilks	.9433	15	.4455
K-S (Lilliefors)	.1523	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 35.0
Valid cases: 30.0 Missing cases: .0 Percent missing: .0
Skewness -.3399 S E Skew .4269
Kurtosis -.4868 S E Kurt .8327

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.2172	2.4219	2.7109	3.1875	3.4766	3.7469	3.9656
Tukey's Hinges			2.7188	3.1875	3.4688		

	Statistic	df	Significance
Shapiro-Wilks	.9699	30	.5736
K-S (Lilliefors)	.0778	30	> .2000

***ACCEPT NORMALITY Ho.

Section J1 - Category Simulation

ABS_DEV
By ERROR 40.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness 2.1628 S E Skew .5801
Kurtosis 6.5005 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.3750	2.6563	2.9063	3.2500	3.5938	4.7375	.
Tukey's Hinges			2.9375	3.2500	3.5781		

	Statistic	df	Significance
Shapiro-Wilks	.7930	15	< .0100
K-S (Lilliefors)	.2065	15	.0849

***CONFLICTING STATISTICS, TWO OUTLIERS WITH > DEVIATIONS DISTRIBUTION COULD BE PLATYKURTIC (SEE OTHER SUM.STATS)

ABS_DEV
By ERROR 45.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness 2.2762 S E Skew .5801
Kurtosis 6.5892 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.5000	3.5750	3.7813	4.0625	4.4063	5.5063	.
Tukey's Hinges			3.8125	4.0625	4.4063		

	Statistic	df	Significance
Shapiro-Wilks	.7764	15	< .0100
K-S (Lilliefors)	.2108	15	.0716

***CONFLICTING STATISTICS. NPPLOTS SUGGEST NORMALITY (SEE OTHER SUM.STATS)

ABS_DEV
By ERROR 50.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.2756 S E Skew .5801
Kurtosis -.6282 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.1875	3.4313	3.7813	4.3750	4.6875	5.0063	.
Tukey's Hinges			3.8438	4.3750	4.6250		

	Statistic	df	Significance
Shapiro-Wilks	.9772	15	.9219
K-S (Lilliefors)	.0728	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 55.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .9044 S E Skew .5801
Kurtosis 1.3404 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.9688	4.1000	4.5000	5.0938	5.3750	6.5063	.
Tukey's Hinges			4.6094	5.0938	5.3750		

	Statistic	df	Significance
Shapiro-Wilks	.9438	15	.4493
K-S (Lilliefors)	.1701	15	> .2000

***ACCEPT NORMALITY Ho.

Section J1 - Category Simulation

ABS_DEV
By ERROR 60.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.6786 S E Skew .5801
Kurtosis .2513 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.5938	4.0250	4.6875	5.0313	5.6875	5.9125	.
Tukey's Hinges			4.7813	5.0313	5.5938		

	Statistic	df	Significance
Shapiro-Wilks	.9537	15	.5600
K-S (Lilliefors)	.0871	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 65.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness -.1017 S E Skew .5801
Kurtosis -.6610 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	4.9063	5.1313	5.6563	6.0313	6.4375	6.9500	.
Tukey's Hinges			5.6563	6.0313	6.4063		

	Statistic	df	Significance
Shapiro-Wilks	.9743	15	.8895
K-S (Lilliefors)	.1189	15	> .2000

***ACCEPT NORMALITY Ho.

ABS_DEV
By ERROR 70.0
Valid cases: 15.0 Missing cases: .0 Percent missing: .0
Skewness .1140 S E Skew .5801
Kurtosis .3730 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	4.3750	4.5250	5.7813	6.0000	6.5000	7.7313	.
Tukey's Hinges			5.7813	6.0000	6.5000		

	Statistic	df	Significance
Shapiro-Wilks	.9424	15	.4379
K-S (Lilliefors)	.1229	15	> .2000

***ACCEPT NORMALITY Ho.

Number of Projects Previously Funded - Now Dropped

file: <numanov.lst>

----- ONEWAY -----
RURAL COST-EFFICIENCY

Variable NO_FUND
By Variable ERROR

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	14	1219.7167	87.1226	27.3067	.0000
Within Groups	225	717.8667	3.1905		
Total	239	1937.5833			

DESCRIPTIVES:

Group	Count	Standard Mean	Standard Deviation	Error	Minimum	Maximum	95 Pct Conf Int for Mean
Grp 2	15	.0667	.2582	.0667	.0000	1.0000	-.0763 TO .2097
Grp 5	15	.1333	.3519	.0909	.0000	1.0000	-.0615 TO .3282
Grp10	15	.7333	.5936	.1533	.0000	2.0000	.4046 TO 1.0621
Grp15	15	1.3333	.8997	.2323	.0000	3.0000	.8351 TO 1.8316
Grp20	15	1.0667	.7988	.2063	.0000	3.0000	.6243 TO 1.5090
Grp25	15	1.7333	.9612	.2482	1.0000	4.0000	1.2011 TO 2.2656
Grp30	15	3.4667	1.6417	.4239	1.0000	6.0000	2.5575 TO 4.3758
Grp35	30	2.4000	1.7538	.3202	.0000	7.0000	1.7451 TO 3.0549
Grp40	15	3.8667	2.7740	.7163	.0000	11.0000	2.3305 TO 5.4029
Grp45	15	4.3333	1.5430	.3984	2.0000	7.0000	3.4788 TO 5.1878
Grp50	15	4.9333	2.1202	.5474	2.0000	8.0000	3.7592 TO 6.1075
Grp55	15	5.4667	1.8848	.4866	2.0000	9.0000	4.4229 TO 6.5104
Grp60	15	5.2000	1.6987	.4386	2.0000	9.0000	4.2593 TO 6.1407
Grp65	15	6.8000	3.0284	.7819	3.0000	14.0000	5.1229 TO 8.4771
Grp70	15	7.4000	3.0190	.7795	3.0000	13.0000	5.7281 TO 9.0719
Total	240	3.2083	2.8473	.1838	.0000	14.0000	2.8463 TO 3.5704

Levene Test for Homogeneity of Variances

Statistic	df1	df2	2-tail Sig.
6.2243	14	225	.000

Multiple Range Tests: Modified LSD (Bonferroni) test with significance level .05

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 1.2630 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE: 5.01
(*) Indicates significant differences which are shown in the lower triangle

Mean	ERROR	Grp 2	Grp 5	Grp10	Grp15	Grp20	Grp25	Grp30	Grp35	Grp40	Grp45	Grp50	Grp55	Grp60	Grp65	Grp70
.0667	Grp 2															
.1333	Grp 5															
.7333	Grp10															
1.0667	Grp20															
1.3333	Grp15															
1.7333	Grp25															
2.4000	Grp35	*	*													
3.4667	Grp30	*	*	*	*											
3.8667	Grp40	*	*	*	*	*										
4.3333	Grp45	*	*	*	*	*	*									
4.9333	Grp50	*	*	*	*	*	*	*								
5.2000	Grp60	*	*	*	*	*	*	*								
5.4667	Grp55	*	*	*	*	*	*	*								
6.8000	Grp65	*	*	*	*	*	*	*	*	*	*	*				
7.4000	Grp70	*	*	*	*	*	*	*	*	*	*	*	*			

COST-EFFICIENCY CATEGORY

Valid cases: 15.0 **Missing cases:** .0 **Percent missing:** .0 (EXCEPT in 35% error level where two simulations are compared).

NO_FUND
By ERROR 2.5
Skewness 3.8730 S E Skew .5801
Kurtosis 15.0000 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	.0000	.0000	.4000	.
Tukey's Hinges			.0000	.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.2813	15	< .0100
K-S (Lilliefors)	.5352	15	.0000

***REJECT NORMALITY Ho, TWO UNIQUE VALUES (0,1) -- ONE IS AN EXTREME.

NO_FUND
By ERROR 5.0
Skewness 2.4048 S E Skew .5801
Kurtosis 4.3491 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	.0000	.0000	1.0000	.
Tukey's Hinges			.0000	.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.4104	15	< .0100
K-S (Lilliefors)	.5143	15	.0000

***REJECT NORMALITY Ho, TWO UNIQUE VALUES (0,1) -- ONE IS AN EXTREME.

NO_FUND
By ERROR 10.0
Skewness .0911 S E Skew .5801
Kurtosis -.1711 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	1.0000	1.0000	1.4000	.
Tukey's Hinges			.0000	1.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.7582	15	< .0100
K-S (Lilliefors)	.2600	15	.0074

***REJECT NORMALITY Ho, THREE UNIQUE VALUES (0,1,2) -- INCREASING DEVIATIONS

NO_FUND
By ERROR 15.0
Skewness .5784 S E Skew .5801
Kurtosis -.0056 S E Kurt 1.1209

		Percentiles					
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	1.0000	1.0000	2.0000	3.0000	.
Tukey's Hinges			1.0000	1.0000	2.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8526	15	.0188
K-S (Lilliefors)	.3112	15	.0004

***REJECT NORMALITY Ho, BUT NPPLOTS LOOK REASONABLY NORMAL
INCREASING DEVIATIONS AWAY FROM DIRECTION OF SKEW -- BOXPLOT SUGGESTS THAT
THE DISTRIBUTION IS LEPTOKURTIC AROUND MEDIAN (=1 .

Section J1 - Category Simulation

NO_FUND
By ERROR 20.0
Skewness .8422 S E Skew .5801
Kurtosis 1.4592 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	1.0000	1.0000	1.0000	2.4000	.
Tukey's Hinges			1.0000	1.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8174	15	< .0100
K-S (Lilliefors)	.3333	15	.0001

***REJECT NORMALITY Ho, 3 OF 4 UNIQUE VALUES ARE EXTREMES--INCREASING DEVIATIONS DISTRIBUTION IS LEPTOKURTIC.

NO_FUND
By ERROR 25.0
Skewness 1.1724 S E Skew .5801
Kurtosis .5932 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	1.0000	1.0000	1.0000	1.0000	2.0000	3.4000	.
Tukey's Hinges			1.0000	1.0000	2.0000		

	Statistic	df	Significance
Shapiro-Wilks	.7730	15	< .0100
K-S (Lilliefors)	.3106	15	.0004

***REJECT NORMALITY Ho, 4 UNIQUE VALUES -- INCREASING DEVIATIONS FROM NORMAL DISTRIBUTION IS NEGATIVELY SKEWED AND LOOKS TRUNCATED.

NO_FUND
By ERROR 30.0
Skewness .4591 S E Skew .5801
Kurtosis -.9711 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	1.0000	1.6000	2.0000	3.0000	5.0000	6.0000	.
Tukey's Hinges			2.0000	3.0000	4.5000		

	Statistic	df	Significance
Shapiro-Wilks	.8990	15	.0950
K-S (Lilliefors)	.2119	15	.0686

***ACCEPT NORMALITY Ho.

NO_FUND
By ERROR 35.0
Skewness 1.1440 S E Skew .4269
Kurtosis .8788 S E Kurt .8327

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	1.0000	1.0000	2.0000	3.0000	5.9000	6.4500
Tukey's Hinges			1.0000	2.0000	3.0000		

Valid cases: 15.0 **Missing cases:** .0 **Percent missing:** .0

	Statistic	df	Significance
Shapiro-Wilks	.8967	15	.0892
K-S (Lilliefors)	.2116	15	.0694

***ACCEPT NORMALITY Ho.

NOTE ALSO @:
Valid cases: 30.0 **Missing cases:** .0 **Percent missing:** .0

	Statistic	df	Significance
Shapiro-Wilks	.8688	30	< .0100
K-S (Lilliefors)	.2569	30	.0000

***REJECT NORMALITY Ho, COULD BE PLATYKURTIC (SEE OTHER SUM.STATISTICS)

NO_FUND
By ERROR 40.0
Skewness 1.3866 S E Skew .5801
Kurtosis 2.1321 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	1.2000	2.0000	3.0000	5.0000	9.2000	.
Tukey's Hinges			2.0000	3.0000	5.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8570	15	.0223
K-S (Lilliefors)	.2893	15	.0014

***REJECT NORMALITY Ho, COULD BE PLATYKURTIC B/C OF OUTLIERS (SEE OTHER STAT)

NO_FUND
By ERROR 45.0
Skewness .4287 S E Skew .5801
Kurtosis -.2972 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.0000	2.0000	4.0000	4.0000	6.0000	7.0000	.
Tukey's Hinges			4.0000	4.0000	5.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8590	15	.0247
K-S (Lilliefors)	.3188	15	.0002

***REJECT NORMALITY Ho, CAN'T SEE IN NPPLOTS WHY.

NO_FUND
By ERROR 50.0
Skewness .0483 S E Skew .5801
Kurtosis -1.0131 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.0000	2.0000	3.0000	5.0000	6.0000	8.0000	.
Tukey's Hinges			3.5000	5.0000	6.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9156	15	.2190
K-S (Lilliefors)	.1167	15	> .2000

***ACCEPT NORMALITY Ho.

NO_FUND
By ERROR 55.0
Skewness .0228 S E Skew .5801
Kurtosis -.2525 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.0000	2.6000	4.0000	6.0000	7.0000	8.4000	.
Tukey's Hinges			4.0000	6.0000	6.5000		

	Statistic	df	Significance
Shapiro-Wilks	.9775	15	.9254
K-S (Lilliefors)	.1219	15	> .2000

***ACCEPT NORMALITY Ho.

NO_FUND
By ERROR 60.0
Skewness .4479 S E Skew .5801
Kurtosis .7963 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	2.0000	3.2000	4.0000	5.0000	6.0000	7.8000	.
Tukey's Hinges			4.0000	5.0000	6.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9410	15	.4267
K-S (Lilliefors)	.1600	15	> .2000

***ACCEPT NORMALITY Ho.

NO_FUND
By ERROR 65.0
Skewness 1.1815 S E Skew .5801
Kurtosis 1.2588 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.0000	3.6000	4.0000	6.0000	8.0000	12.8000	.
Tukey's Hinges			4.5000	6.0000	7.5000		

	Statistic	df	Significance
Shapiro-Wilks	.8930	15	.0800
K-S (Lilliefors)	.2070	15	.0832

***ACCEPT NORMALITY Ho.

NO_FUND
By ERROR 70.0
Skewness .4371 S E Skew .5801
Kurtosis -.6557 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	3.0000	3.6000	5.0000	7.0000	10.0000	12.4000	.
Tukey's Hinges			5.0000	7.0000	9.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9451	15	.4597
K-S (Lilliefors)	.1546	15	> .2000

***ACCEPT NORMALITY Ho.
Hi-Res Chart # 65:Boxplot of no_fund by error

Number of Additional Projects Funded

file: <numanov.lst>

----- ONEWAY -----
RURAL COST-EFFICIENCY

Variable ADD_FUND
By Variable ERROR

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	14	495.4292	35.3878	9.1199	.0000
Within Groups	225	873.0667	3.8803		
Total	239	1368.4958			

DESCRIPTIVES:

Group	Count	Standard Mean	Standard Deviation	Error	Minimum	Maximum	95 Pct Conf Int for Mean
Grp 2	15	.5333	.6399	.1652	.0000	2.0000	.1789 TO .8877
Grp 5	15	.8000	.5606	.1447	.0000	2.0000	.4895 TO 1.1105
Grp10	15	.3333	.7237	.1869	.0000	2.0000	-.0675 TO .7341
Grp15	15	.0000	.8452	.2182	-2.0000	2.0000	-.4680 TO .4680
Grp20	15	.2667	1.0998	.2840	-2.0000	2.0000	-.3424 TO .8757
Grp25	15	.3333	1.2344	.3187	-3.0000	2.0000	-.3503 TO 1.0169
Grp30	15	-1.6667	1.8387	.4748	-5.0000	1.0000	-2.6849 TO -.6484
Grp35	30	-.2667	2.3034	.4205	-6.0000	4.0000	-1.1268 TO .5934
Grp40	15	-1.7333	2.4919	.6434	-8.0000	1.0000	-3.1133 TO -.3534
Grp45	15	-1.6000	1.5946	.4117	-5.0000	1.0000	-2.4831 TO -.7169
Grp50	15	-2.4667	2.2318	.5762	-6.0000	1.0000	-3.7026 TO -1.2307
Grp55	15	-1.6000	2.1314	.5503	-5.0000	3.0000	-2.7803 TO -.4197
Grp60	15	-1.9333	1.7099	.4415	-5.0000	1.0000	-2.8803 TO -.9864
Grp65	15	-3.2000	3.0752	.7940	-10.0000	1.0000	-4.9030 TO -1.4970
Grp70	15	-4.2667	3.5550	.9179	-10.0000	2.0000	-6.2354 TO -2.2980
Total	240	-1.0458	2.3929	.1545	-10.0000	4.0000	-1.3501 TO -.7416

Levene Test for Homogeneity of Variances

Statistic	df1	df2	2-tail Sig.
5.8180	14	225	.000

Multiple Range Tests: Modified LSD (Bonferroni) test with significance level .05

The difference between two means is significant if
MEAN(J)-MEAN(I) >= 1.3929 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE: 5.01
(*) Indicates significant differences which are shown in the lower triangle

Mean	ERROR	Grp70	Grp65	Grp50	Grp60	Grp40	Grp30	Grp45	Grp55	Grp35	Grp15	Grp20	Grp10	Grp25	Grp 2	Grp 5
-4.2667	Grp70															
-3.2000	Grp65															
-2.4667	Grp50															
-1.9333	Grp60															
-1.7333	Grp40															
-1.6667	Grp30	*														
-1.6000	Grp45	*														
-1.6000	Grp55	*														
-.2667	Grp35	*	*													
.0000	Grp15	*	*													
.2667	Grp20	*	*	*												
.3333	Grp10	*	*	*												
.3333	Grp25	*	*	*												
.5333	Grp 2	*	*	*												
.8000	Grp 5	*	*	*	*											

Section J1 - Category Simulation

COST EFFICIENCY CATEGORY

Valid cases: 15.0 **Missing cases:** .0 **Percent missing:** .0 (EXCEPT in 35% error level where two simulations are compared).

ADD_FUND
By ERROR 2.5
Skewness .8023 S E Skew .5801
Kurtosis -.1267 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	.0000	1.0000	1.4000	.
Tukey's Hinges			.0000	.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.7452	15	< .0100
K-S (Lilliefors)	.3310	15	.0001

***REJECT NORMALITY Ho, THREE UNIQUE VALUES (0,1,2) -- INCREASING DEVIATIONS AWAY FROM DISTRIBUTION SKEW.

ADD_FUND
By ERROR 5.0
Skewness -.1123 S E Skew .5801
Kurtosis .3783 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	1.0000	1.0000	1.4000	.
Tukey's Hinges			.5000	1.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.7340	15	< .0100
K-S (Lilliefors)	.2940	15	.0011

***REJECT NORMALITY Ho, THREE UNIQUE VALUES (0,1,2) -- INCREASING DEVIATIONS

ADD_FUND
By ERROR 10.0
Skewness 1.9808 S E Skew .5801
Kurtosis 2.5499 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0000	.0000	.0000	.0000	2.0000	.
Tukey's Hinges			.0000	.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.6123	15	< .0100
K-S (Lilliefors)	.4774	15	.0000

***REJECT NORMALITY Ho, THREE UNIQUE VALUES (0,1,2) -- TWO ARE EXTREMES.

ADD_FUND
By ERROR 15.0
Skewness .0000 S E Skew .5801
Kurtosis 3.5538 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-2.0000	-1.4000	.0000	.0000	.0000	1.4000	.
Tukey's Hinges			.0000	.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.7353	15	< .0100
K-S (Lilliefors)	.3667	15	.0000

***REJECT NORMALITY Ho, FIVE UNIQUE VALUES -- 4 OF WHICH ARE EXTREME VALUES.

ADD_FUND
By ERROR 20.0
Skewness -.2374 S E Skew .5801
Kurtosis .0456 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-2.0000	-1.4000	.0000	.0000	1.0000	2.0000	.
Tukey's Hinges			.0000	.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9267	15	.3101
K-S (Lilliefors)	.1958	15	.1263

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 25.0
Skewness -1.2658 S E Skew .5801
Kurtosis 3.0036 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-3.0000	-1.8000	.0000	.0000	1.0000	2.0000	.
Tukey's Hinges			.0000	.0000	1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8532	15	.0191
K-S (Lilliefors)	.1612	15	> .2000

***CONFLICTING STATS, NPPLOTS SHOW DECREASING DEVIATIONS SLIGHTLY SKEWED AWAY FROM ONE EXTREME VALUE. OTHERWISE LOOKS PRETTY NORMAL.

ADD_FUND
By ERROR 30.0
Skewness -.3300 S E Skew .5801
Kurtosis -1.0924 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-5.0000	-4.4000	-3.0000	-2.0000	.0000	.4000	.
Tukey's Hinges			-3.0000	-2.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9221	15	.2725
K-S (Lilliefors)	.1157	15	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 35.0
Skewness -.2670 S E Skew .4269
Kurtosis .3454 S E Kurt .8327

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-4.9000	-3.9000	-1.2500	.0000	1.2500	2.9000	4.0000
Tukey's Hinges			-1.0000	.0000	1.0000		

Valid cases: 15.0 Missing cases: .0 Percent missing: .0

	Statistic	df	Significance
Shapiro-Wilks	.9215	15	.2675
K-S (Lilliefors)	.1949	15	.1299

***ACCEPT NORMALITY Ho.

Valid cases: 30.0 Missing cases: 0 Percent missing: .0

	Statistic	df	Significance
Shapiro-Wilks	.9670	30	.4993
K-S (Lilliefors)	.1206	30	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 40.0
Skewness -1.2455 S E Skew .5801
Kurtosis 1.4641 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-8.0000	-6.2000	-3.0000	-1.0000	.0000	1.0000	.
Tukey's Hinges			-3.0000	-1.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.8831	15	.0553
K-S (Lilliefors)	.1363	15	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 45.0
Skewness -.2781 S E Skew .5801
Kurtosis -.0758 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-5.0000	-3.8000	-3.0000	-2.0000	.0000	.4000	.
Tukey's Hinges			-2.5000	-2.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9301	15	.3373
K-S (Lilliefors)	.1990	15	.1130

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 50.0
Skewness -.1620 S E Skew .5801
Kurtosis -1.0036 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-6.0000	-6.0000	-4.0000	-2.0000	.0000	.4000	.
Tukey's Hinges			-4.0000	-2.0000	-.5000		

	Statistic	df	Significance
Shapiro-Wilks	.9486	15	.4887
K-S (Lilliefors)	.0873	15	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 55.0
Skewness .4658 S E Skew .5801
Kurtosis .0700 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-5.0000	-4.4000	-3.0000	-2.0000	.0000	1.8000	.
Tukey's Hinges			-3.0000	-2.0000	.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9638	15	.7215
K-S (Lilliefors)	.1744	15	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 60.0
Skewness .0793 S E Skew .5801
Kurtosis -.1876 S E Kurt 1.1209

Percentiles

Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-5.0000	-4.4000	-3.0000	-2.0000	-1.0000	1.0000	.
Tukey's Hinges			-3.0000	-2.0000	-1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9471	15	.4765
K-S (Lilliefors)	.1593	15	> .2000

***ACCEPT NORMALITY Ho.

Section J1 - Category Simulation

ADD_FUND
By ERROR 65.0
Skewness -1.0753 S E Skew .5801
Kurtosis .8772 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-10.0000	-9.4000	-5.0000	-3.0000	-1.0000	.4000	.
Tukey's Hinges			-4.5000	-3.0000	-1.0000		

	Statistic	df	Significance
Shapiro-Wilks	.9014	15	.1032
K-S (Lilliefors)	.1039	15	> .2000

***ACCEPT NORMALITY Ho.

ADD_FUND
By ERROR 70.0
Skewness .0327 S E Skew .5801
Kurtosis -.5979 S E Kurt 1.1209

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	-10.0000	-9.4000	-7.0000	-4.0000	-2.0000	1.4000	.
Tukey's Hinges			-6.5000	-4.0000	-2.5000		

	Statistic	df	Significance
Shapiro-Wilks	.9694	15	.8105
K-S (Lilliefors)	.1085	15	> .2000

***ACCEPT NORMALITY Ho.

----- ONEWAY -----
15 PERCENT ERROR LEVEL

file: <cat_norm> and <anov.lst>

Variable MAD
By Variable CATEGORY

Source	Analysis of Variance D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	6	101.7491	16.9582	305.3886	0.0000
Within Groups	98	5.4419	.0555		
Total	104	107.1911			

Group	Count	Mean	Standard Deviation	Standard Error	Minimum	Maximum	95 Pct Conf Int for Mean
Grp 1	15	1.5458	.3091	.0798	.8750	2.0313	1.3747 TO 1.7170
Grp 2	15	3.0646	.4895	.1264	2.2188	3.8750	2.7935 TO 3.3357
Grp 3	15	.3458	.1178	.0304	.1563	.5938	.2806 TO .4111
Grp 4	15	.1104	.0552	.0143	.0313	.2188	.0798 TO .1410
Grp 5	15	.2396	.1061	.0274	.0000	.3750	.1808 TO .2983
Grp 6	15	.4292	.1092	.0282	.2813	.5938	.3687 TO .4896
Grp 7	15	.5958	.1160	.0300	.2813	.7813	.5316 TO .6601
Total	105	.9045	1.0152	.0991	.0000	3.8750	.7080 TO 1.1009

Levene Test for Homogeneity of Variances

Statistic	df1	df2	2-tail Sig.
15.7170	6	98	.000

----- **ONEWAY** -----
15 PERCENT ERROR LEVEL

Variable MAD
By **Variable CATEGORY**

Multiple Range Tests: Modified LSD (Bonferroni) test with significance level .05
The difference between two means is significant if

MEAN(J)-MEAN(I) >= .1666 * RANGE * SQRT(1/N(I) + 1/N(J))
with the following value(s) for RANGE: 4.41
(*) Indicates significant differences which are shown in the lower triangle

Mean	CATEGORY	Grp 4	Grp 5	Grp 3	Grp 6	Grp 7	Grp 1	Grp 2
.1104	Grp 4							
.2396	Grp 5							
.3458	Grp 3							
.4292	Grp 6	*						
.5958	Grp 7	*	*					
1.5458	Grp 1	*	*	*	*	*		
3.0646	Grp 2	*	*	*	*	*	*	

Homogeneous Subsets (highest and lowest means are not significantly different)

Subset 1

Group	Grp 4	Grp 5	Grp 3
Mean	.1104	.2396	.3458

Subset 2

Group	Grp 5	Grp 3	Grp 6
Mean	.2396	.3458	.4292

Subset 3

Group	Grp 3	Grp 6	Grp 7
Mean	.3458	.4292	.5958

Subset 4

Group	Grp 1
Mean	1.5458

Subset 5

Group	Grp 2
Mean	3.0646

Section J2 - Error Simulation

15 PERCENT ERROR LEVEL

DESCRIPTIVES:

Variable	Mean (std err)	Std.Dev	Median	Variance	Min	Max	Range	Skewness (std.err)	Kurtosis (std.err)	95% CI for Mean
Cost-efficiency	1.55 (.0798)	0.3091	1.53	0.0955	0.875	2.03	1.16	-0.4868 (.5801)	0.0804 (1.12)	1.37, 1.72
Community support	3.06 (.1264)	0.4895	3.16	0.2396	2.22	3.88	1.66	-0.2004 (.5801)	-0.9381 (1.12)	2.79, 3.34
Wetlands	0.3458 (.0304)	0.1178	0.3438	0.0139	0.1563	0.594	0.4375	0.5219 (.5801)	0.1860 (1.12)	0.2806, 0.4111
Water quality	0.1104 (.0143)	0.0552	0.0938	0.0031	0.0313	0.2188	0.1875	0.8322 (.5801)	0.2535 (1.12)	0.0798, 0.1410
Noise	0.2396 (.0274)	0.1061	0.25	0.0113	0.00	0.375	0.375	-0.9209 (.5801)	0.7096 (1.12)	0.1808, 0.2983
Mode integration	0.4292 (.0282)	0.1092	0.4375	0.0119	0.2813	0.5938	0.3125	0.0599 (.5801)	-1.4692 (1.12)	0.3687, 0.4896
Land use	0.5958 (.03)	0.116	0.5938	0.0135	0.2813	0.7813	0.5	-1.1335 (.5801)	3.3569 (1.12)	0.5316, 0.6601

NOTE: Categories are numbered in the order shown above. [i.e., cost-efficiency is category 1.00, community support is 2.00, etc.]

Hi-Res Charts: Normal q-q plots and Detrended normal q-q plots were produced for each summary measure (i.e., mad, no_fund, add_fund) for each criteria category (see samples in Appendix K).
Shapiro-Wilks and K-S Lillifors test statistics for normality as recorded below.
Finally, a Hi-Res Boxplot for each summary measure by category is produced (see Appendix I).

Stat OUTPUT: 11 Dec 96 SPSS for MS WINDOWS Release 6.1 This software is functional through February 28, 1997.

Absolute Difference

Valid cases: 15.0 Missing cases: .0 Percent missing: .0

Variable MAD
By Variable CATEGORY 1.00

```
Percentiles
                                  -----------
 Percentiles          5.0000   10.0000   25.0000   50.0000   75.0000   90.0000   95.0000
 Haverage              .8750    1.0438    1.3438    1.5313    1.8125    1.9563         .
 Tukey's Hinges                         1.3750    1.5313    1.7656
                          Statistic        df        Significance
 Shapiro-Wilks               .9792        15            .9421
 K-S (Lilliefors)            .0582        15          > .2000

***ACCEPT NORMALITY Ho
```

Variable MAD
By Variable CATEGORY 2.00

```
                                  Percentiles
                                  -----------
 Percentiles          5.0000   10.0000   25.0000   50.0000   75.0000   90.0000   95.0000
 Haverage             2.2188    2.3125    2.5938    3.1563    3.5313    3.6875         .
 Tukey's Hinges                         2.6563    3.1563    3.4531

Statistic          df        Significance
 Shapiro-Wilks               .9672        15            .7755
 K-S (Lilliefors)            .0986        15          > .2000
***ACCEPT NORMALITY Ho
```

Variable MAD
By Variable CATEGORY 3.00

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.1563	.1938	.2500	.3438	.4063	.5563	.
Tukey's Hinges			.2656	.3438	.4063		

	Statistic	df	Significance
Shapiro-Wilks	.9574	15	.6179
K-S (Lilliefors)	.1707	15	> .2000

***ACCEPT NORMALITY Ho

Variable MAD
By Variable CATEGORY 4.00

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0313	.0500	.0625	.0938	.1250	.2188	.
Tukey's Hinges			.0625	.0938	.1250		

	Statistic	df	Significance
Shapiro-Wilks	.8990	15	.0951
K-S (Lilliefors)	.1959	15	.1260

***ACCEPT NORMALITY Ho

Variable MAD
By Variable CATEGORY 5.00

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.0000	.0375	.1875	.2500	.3125	.3750	.
Tukey's Hinges			.2031	.2500	.2969		

	Statistic	df	Significance
Shapiro-Wilks	.9260	15	.3044
K-S (Lilliefors)	.1009	15	> .2000

***ACCEPT NORMALITY Ho

Variable MAD
By Variable CATEGORY 6.00

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.2813	.2813	.3125	.4375	.5313	.5750	.
Tukey's Hinges			.3281	.4375	.5313		

	Statistic	df	Significance
Shapiro-Wilks	.9253	15	.2983
K-S (Lilliefors)	.1240	15	> .2000

***ACCEPT NORMALITY Ho

Variable MAD
By Variable CATEGORY 7.00

	Percentiles						
Percentiles	5.0000	10.0000	25.0000	50.0000	75.0000	90.0000	95.0000
Haverage	.2813	.4125	.5313	.5938	.6563	.7625	.
Tukey's Hinges			.5625	.5938	.6406		

	Statistic	df	Significance
Shapiro-Wilks	.8880	15	.0875
K-S (Lilliefors)	.1341	15	> .2000

***ACCEPT NORMALITY Ho

Number of Projects Previously Funded - Now Dropped

15 PERCENT ERROR LEVEL

Valid cases: 15.0 Missing cases: .0 Percent missing: .0

NO_FUND
By CATEGORY 1.00

	Statistic	df	Significance
Shapiro-Wilks	.8526	15	.0188
K-S (Lilliefors)	.3112	15	.0004

***REJECT NORMALITY Ho. FOUR UNIQUE VALUES {0,1,2,3} NPPLOTS SHOW INCREASING DEVIATION FROM NORMAL.

NO_FUND
By CATEGORY 2.00

	Statistic	df	Significance
Shapiro-Wilks	.6949	15	< .0100
K-S (Lilliefors)	.3450	15	.0000

***REJECT NORMALITY Ho. FOUR UNIQUE VALUES. NPPLOTS SHOW ONE EXTREME DEVIATION FROM NORMAL. IN OPPOSITE DIRECTION OF SKEW AS SHOWN IN BOXPLOT.

NO_FUND
By CATEGORY 3.00
>Note # 17570. Command name: EXAMINE
>The number of unique data values for this cell is equal to one. The cell will be included in any boxplots produced but other output will be omitted.

NO_FUND
By CATEGORY 4.00
>Note # 17570. Command name: EXAMINE
>The number of unique data values for this cell is equal to one. The cell will be included in any boxplots produced but other output will be omitted.

NO_FUND
By CATEGORY 5.00
>Note # 17570. Command name: EXAMINE
>The number of unique data values for this cell is equal to one. The cell will be included in any boxplots produced but other output will be omitted.

NO_FUND
By CATEGORY 6.00

	Statistic	df	Significance
Shapiro-Wilks	.6339	15	< .0100
K-S (Lilliefors)	.3849	15	.0000

***REJECT NORMALITY Ho. TWO UNIQUE VALUES {0,1} – NO DISCERNABLE TREND.

NO_FUND
By CATEGORY 7.00

	Statistic	df	Significance
Shapiro-Wilks	.4104	15	< .0100
K-S (Lilliefors)	.5143	15	.0000

***REJECT NORMALITY Ho. TWO UNIQUE VALUES {0,1} – NO DISCERNABLE TREND.

Number of Additional Projects Funded

15 PERCENT ERROR LEVEL

Valid cases: 15.0 **Missing cases:** .0 **Percent missing:** .0

ADD_FUN
By CATEGORY 1.00

	Statistic	df	Significance
Shapiro-Wilks	.7353	15	< .0100
K-S (Lilliefors)	.3667	15	.0000

***REJECT NORMALITY Ho, FOUR OF FIVE UNIQUE VALUES ARE EXTREME VALUES SO THE DISTRIBUTION IS LEPTOKURTIC.

ADD_FUN
By CATEGORY 2.00

	Statistic	df	Significance
Shapiro-Wilks	.7647	15	< .0100
K-S (Lilliefors)	.1419	15	> .2000

***CONFLICTING STATISTICS. NPPLOT SHOWS DECREASING DEVIATIONS WHICH ARE SLIGHTLY SKEWED AWAY FROM ONE EXTREME VALUE (SEE BOXPLOT).

ADD_FUN
By CATEGORY 3.00

	Statistic	df	Significance
Shapiro-Wilks	.6474	15	< .0100
K-S (Lilliefors)	.3158	15	.0003

***REJECT NORMALITY Ho, TWO UNIQUE VALUES {0,1} – NO DISCERNABLE TREND.

ADD_FUN
By CATEGORY 4.00

	Statistic	df	Significance
Shapiro-Wilks	.4995	15	< .0100
K-S (Lilliefors)	.4855	15	.0000

***REJECT NORMALITY Ho, TWO UNIQUE VALUES {0,1} – NO DISCERNABLE TREND.

ADD_FUN
By CATEGORY 5.00

>Note # 17570. Command name: EXAMINE
>The number of unique data values for this cell is equal to one. The cell will be included in any boxplots produced but other output will be omitted.

ADD_FUN
By CATEGORY 6.00

	Statistic	df	Significance
Shapiro-Wilks	.7452	15	< .0100
K-S (Lilliefors)	.3310	15	.0001

***REJECT NORMALITY Ho, THREE UNIQUE VALUES {0,1,2} – INCREASING DEVIATIONS.

ADD_FUN
By CATEGORY 7.00

	Statistic	df	Significance
Shapiro-Wilks	.7582	15	< .0100
K-S (Lilliefors)	.2600	15	.0074

***REJECT NORMALITY Ho, THREE UNIQUE VALUES {0,1,2} – INCREASING DEVIATIONS.

Number of Additional Projects Funded

15 PERCENT ERROR LEVEL

Valid cases: 15.0 **Missing cases:** .0 **Percent missing:** .0

ADD_FUN
By CATEGORY 1.00

	Statistic	df	Significance
Shapiro-Wilks	.7353	15	< .0100
K-S (Lilliefors)	.3667	15	.0000

***REJECT NORMALITY Ho, FOUR OF FIVE UNIQUE VALUES ARE EXTREME VALUES SO THE DISTRIBUTION IS LEPTOKURTIC.

ADD_FUN
By CATEGORY 2.00

	Statistic	df	Significance
Shapiro-Wilks	.7647	15	< .0100
K-S (Lilliefors)	.1419	15	> .2000

***CONFLICTING STATISTICS. NPPLOT SHOWS DECREASING DEVIATIONS WHICH ARE SLIGHTLY SKEWED AWAY FROM ONE EXTREME VALUE (SEE BOXPLOT).

ADD_FUN
By CATEGORY 3.00

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ADD_FUN
By CATEGORY 5.00

>Note # 17570. Command name: EXAMINE
>The number of unique data values for this cell is equal to one. The cell will be included in any boxplots produced but other output will be omitted.

ADD_FUN
By CATEGORY 6.00

	Statistic	df	Significance
Shapiro-Wilks	.7452	15	< .0100
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***REJECT NORMALITY Ho, THREE UNIQUE VALUES {0,1,2} – INCREASING DEVIATIONS.

ADD_FUN
By CATEGORY 7.00

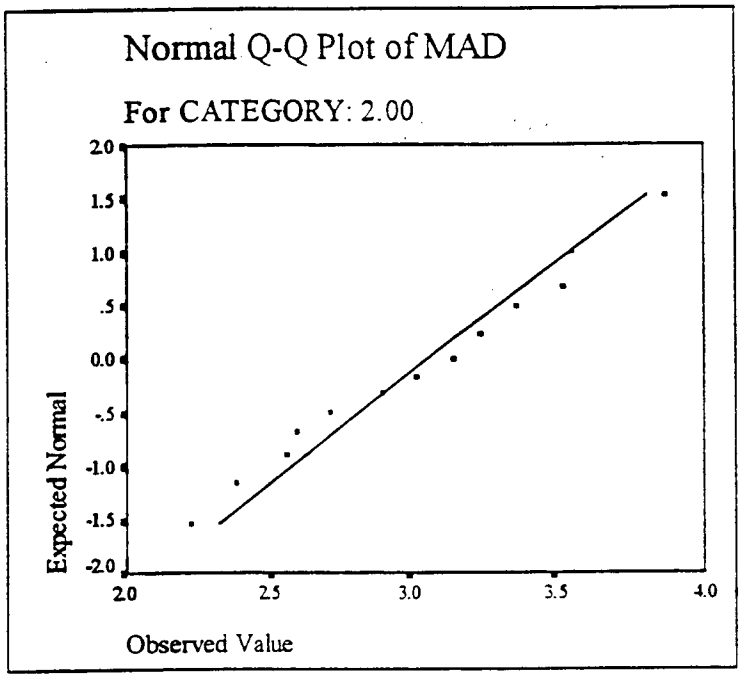
	Statistic	df	Significance
Shapiro-Wilks	.7582	15	< .0100
K-S (Lilliefors)	.2600	15	.0074

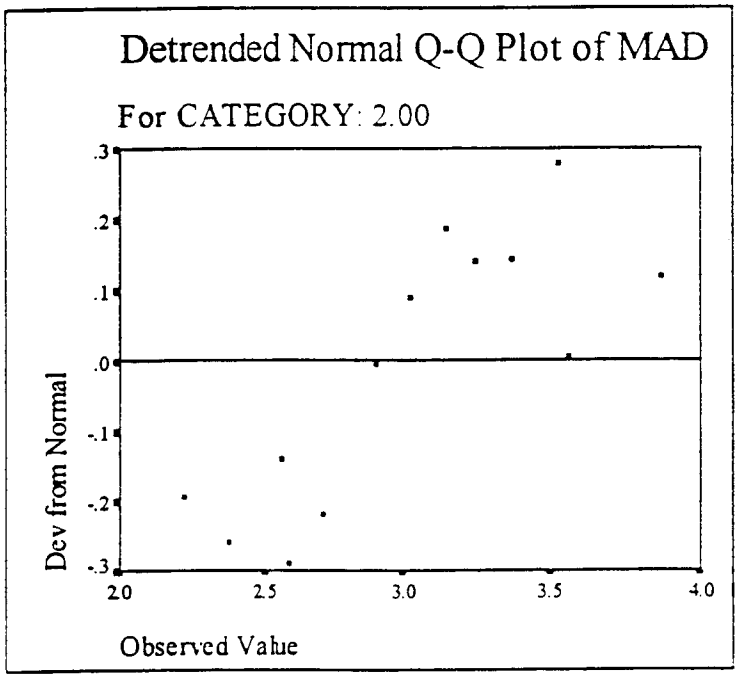
***REJECT NORMALITY Ho, THREE UNIQUE VALUES {0,1,2} – INCREASING DEVIATIONS.

APPENDIX K. SAMPLE NORMAL PROBABILITY PLOTS FOR SUMMARY MEASURES

Figure K-1. *Normally Distributed Example*

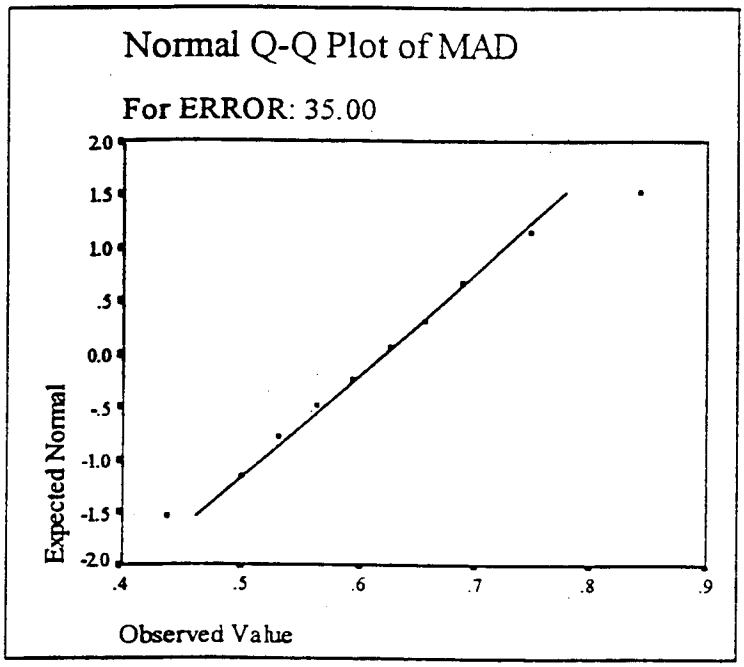
EXAMPLE OF NORMALLY DISTRIBUTED MEASURE

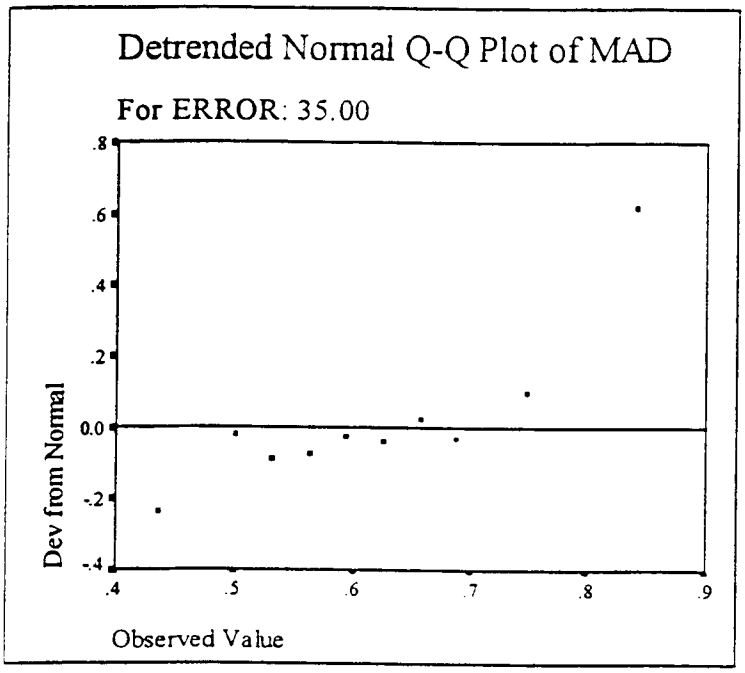




	Statistic	df	Significance	
Shapiro-Wilks	.9672	15	.7755	
K-S (Lilliefors)	.0986	15	> .2000	(sample from 15 percent error level)

Figure K-1 (continued). EXAMPLE OF NORMALLY DISTRIBUTED MEASURE:



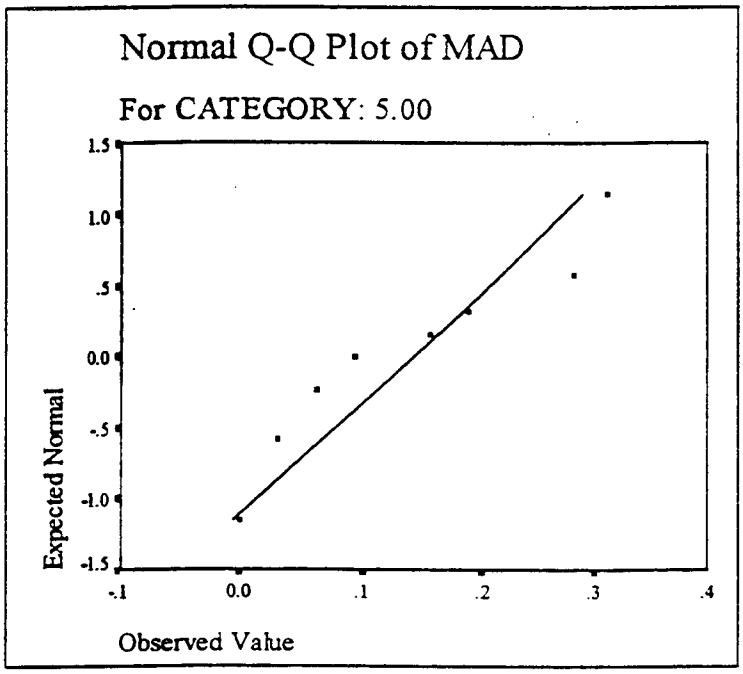


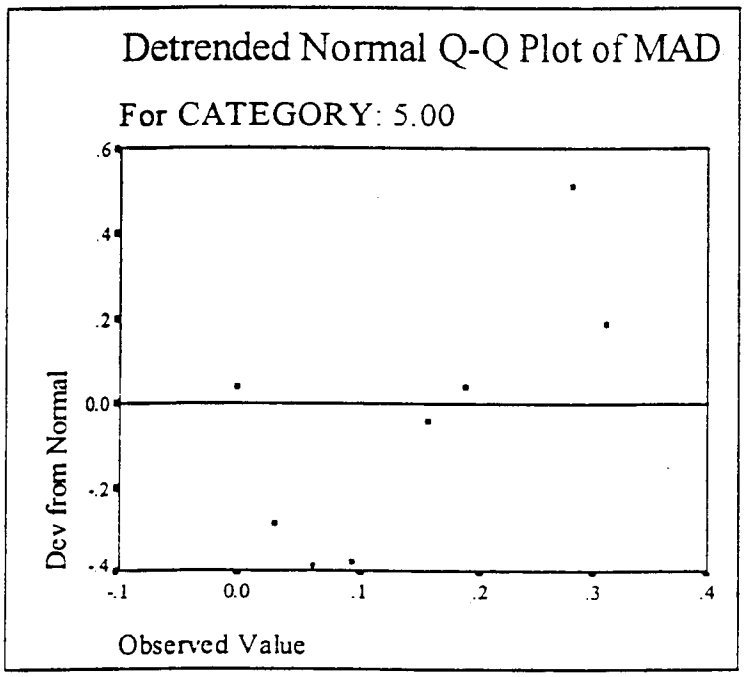
	Statistic	df	Significance
Shapiro-Wilks	.9818	15	.9633
K-S (Lilliefors)	.1265	15	> .2000

(sample from wetlands category)

Figure K-2. "Borderline" Normal Examples

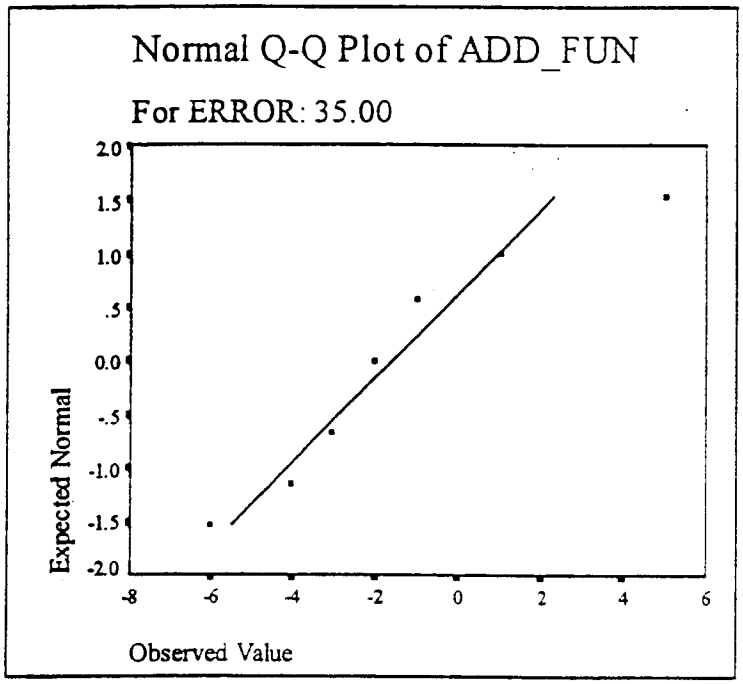
EXAMPLE OF MEASURE DISTRIBUTION THAT IS: "BORDERLINE" NORMAL

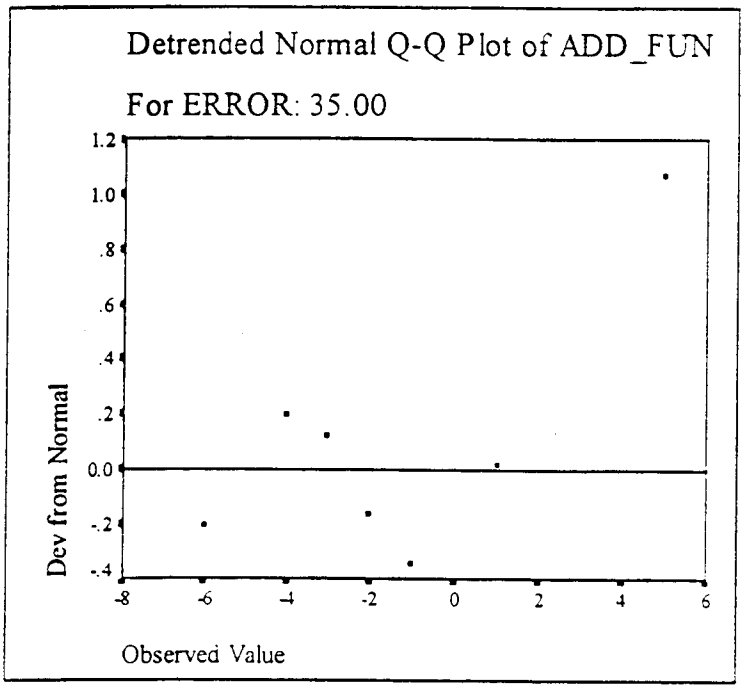




	Statistic	df	Significance	
Shapiro-Wilks	.8447	15	.0148	
K-S (Lilliefors)	.1990	15	.1130	(sample from 10 percent error level)

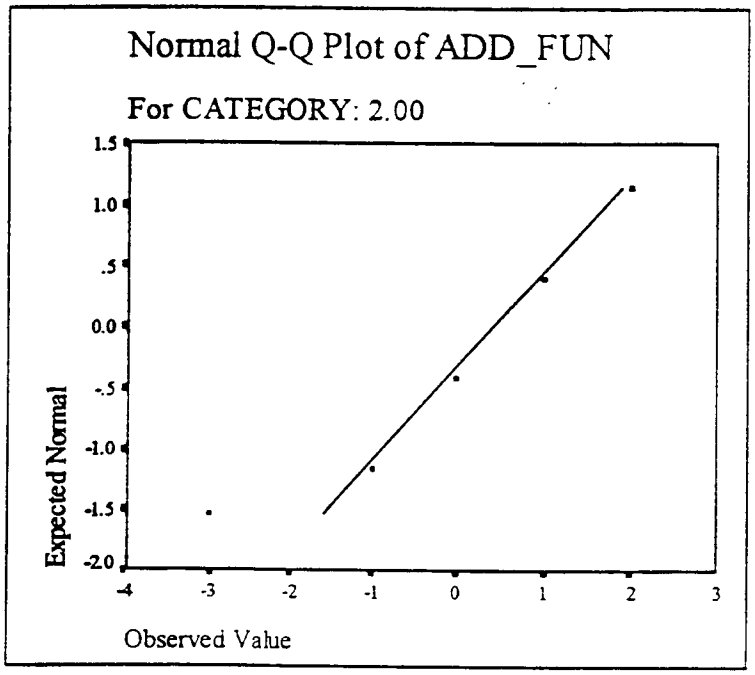
Figure K-2 (continued). EXAMPLE OF NORMALLY DISTRIBUTED MEASURE WHERE: NPPLOTS support Shapiro-Wilks statistic, because they show only one extreme deviation.

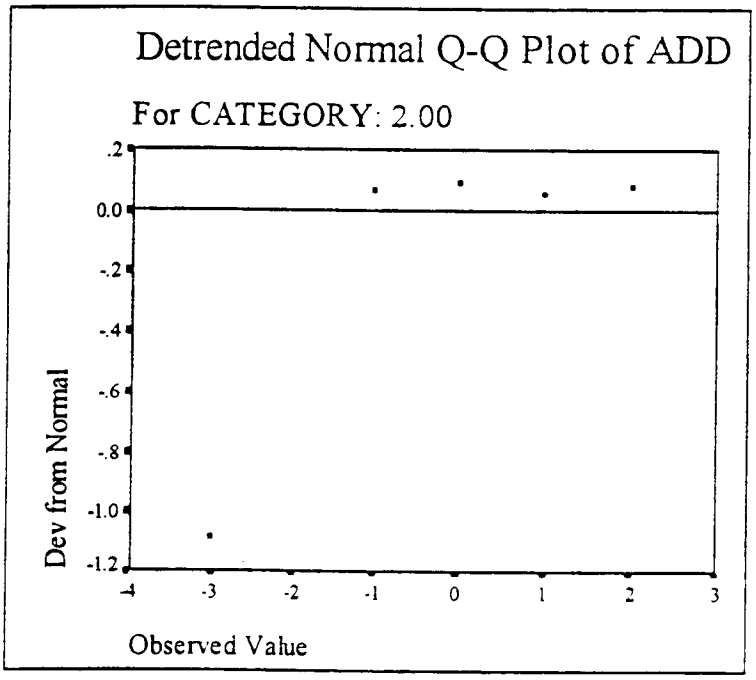




	Statistic	df	Significance	
Shapiro-Wilks	.8942	15	.0829	
K-S (Lilliefors)	.2295	15	.0325	(sample from community support category)

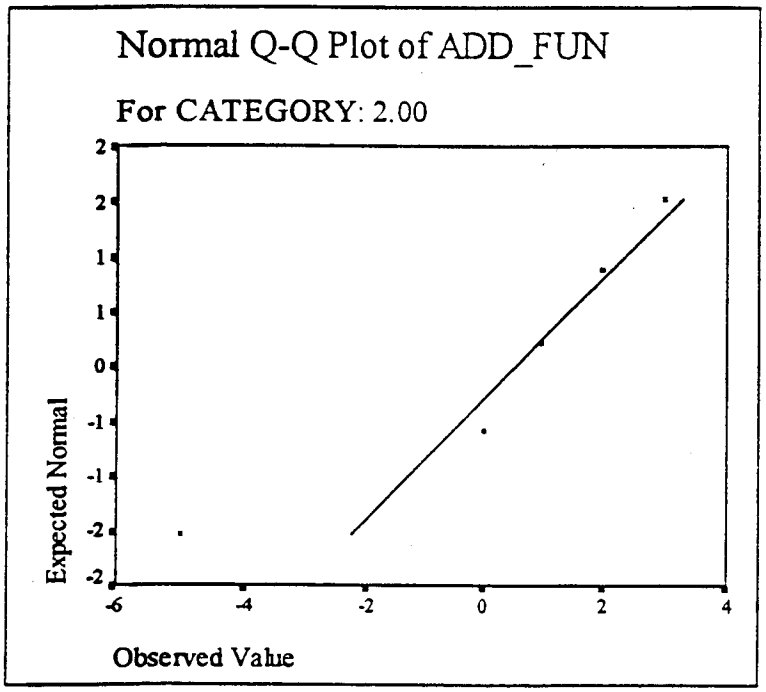
Figure K-2 (continued).
EXAMPLE OF "CONFLICTING STATISTICS/BORDERLINE NORMAL" WHERE:
NPPLOTS show one extreme deviation from normal (in direction of the skew).

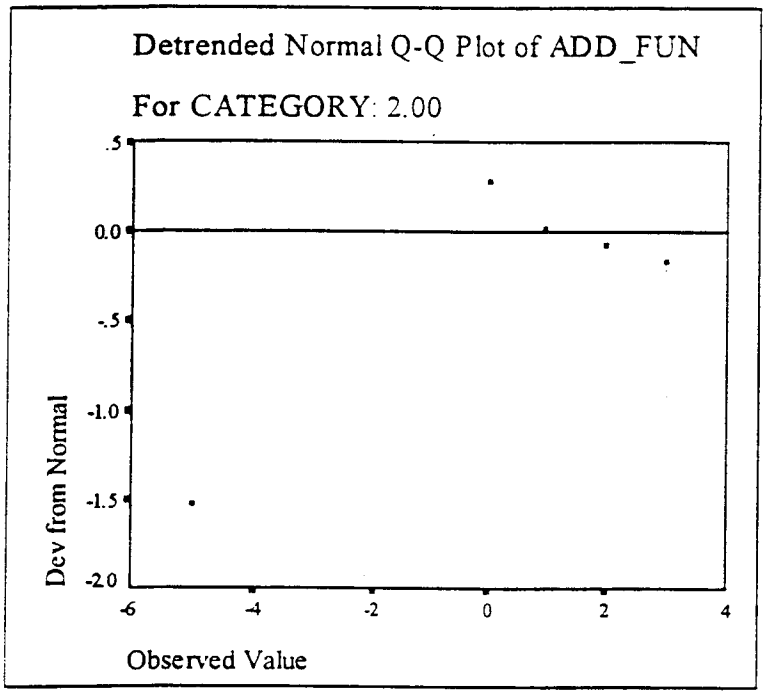




	Statistic	df	Significance
Shapiro-Wilks	.8648	15	.0313
K-S (Lilliefors)	.1543	15	> .2000 (sample from 10 percent error level)

Figure K-2 (continued). EXAMPLE OF CONFLICTING STATISTICS WHERE: NPPLOT shows decreasing deviations which are slightly skewed away from one extreme value.



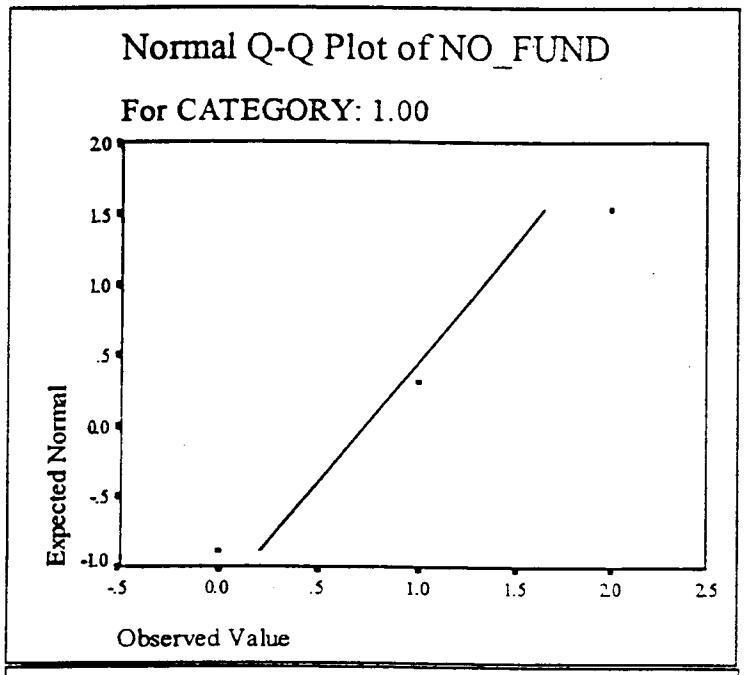


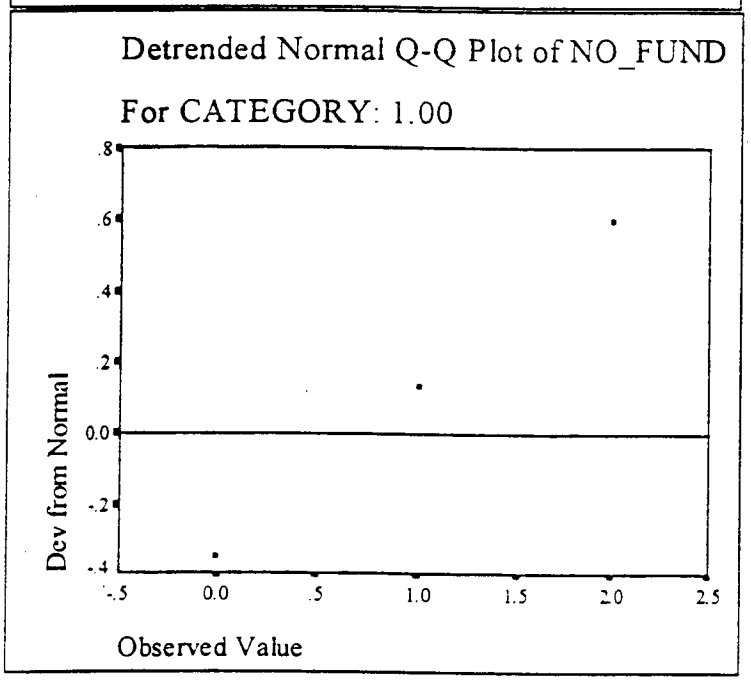
	Statistic	df	Significance
Shapiro-Wilks	.7647	15	< .0100
K-S (Lilliefors)	.1419	15	> .2000

(sample taken from 15 percent error level).

Figure K-3. Non-Normal Distribution Examples

EXAMPLE OF NON-NORMALITY WHERE:
Only three unique values {0,1,2} and NPPLOTS show increasing deviations from normal.



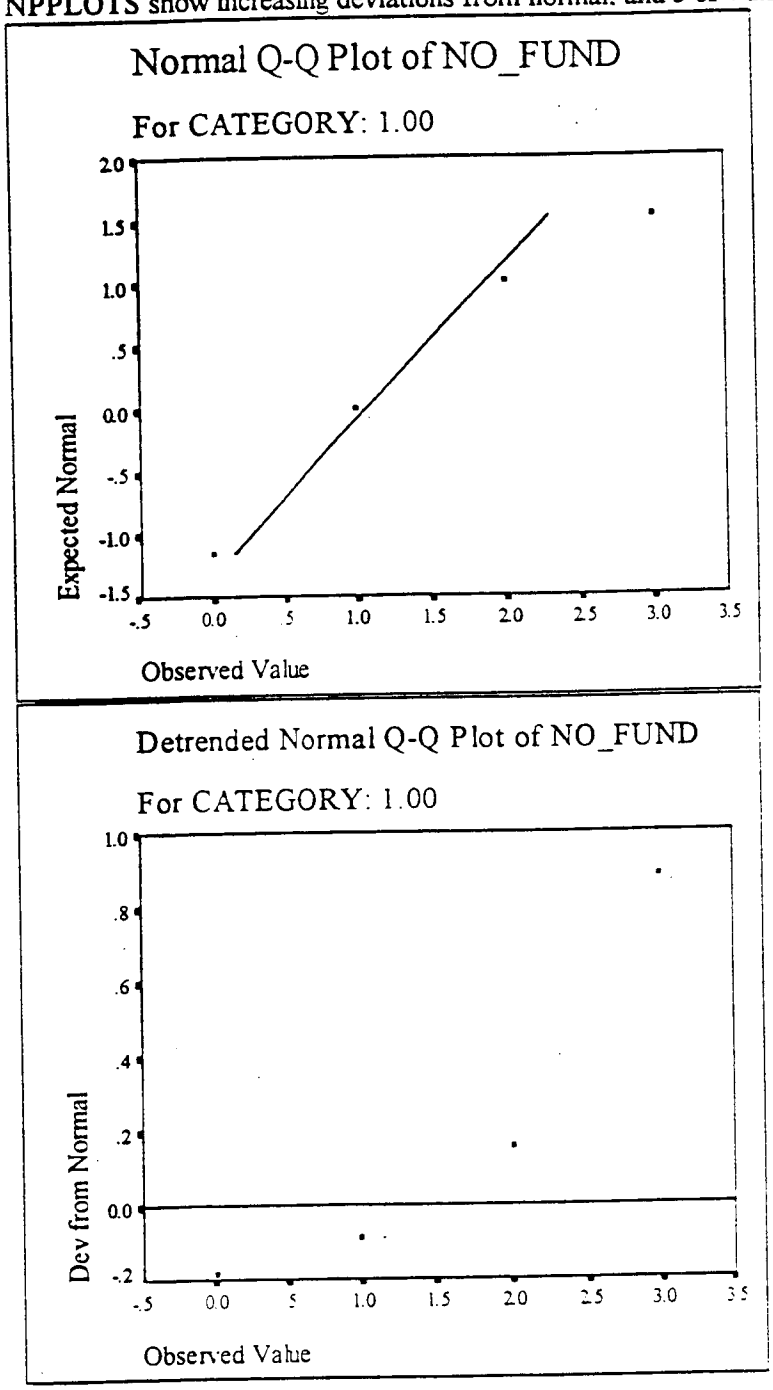


	Statistic	df	Significance
Shapiro-Wilks	.7582	15	< .0100
K-S (Lilliefors)	.2600	15	.0074

(sample from 10 percent error level)

Figure K-3 (continued). Non-Normal Distribution Examples

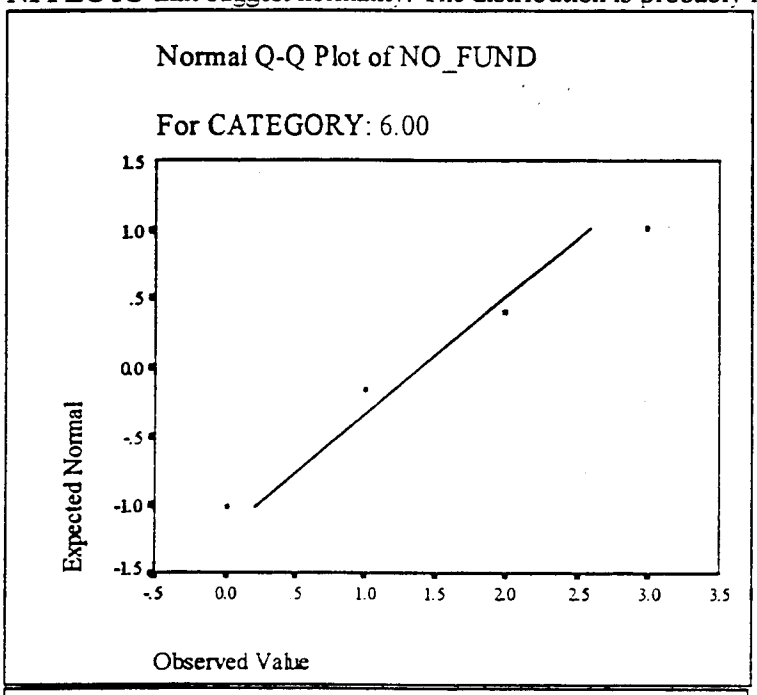
EXAMPLE OF NON-NORMAL LEPTOKURTIC DISTRIBUTION WHERE:
NPPLOTS show increasing deviations from normal, and 3 of 4 unique values are extremes.

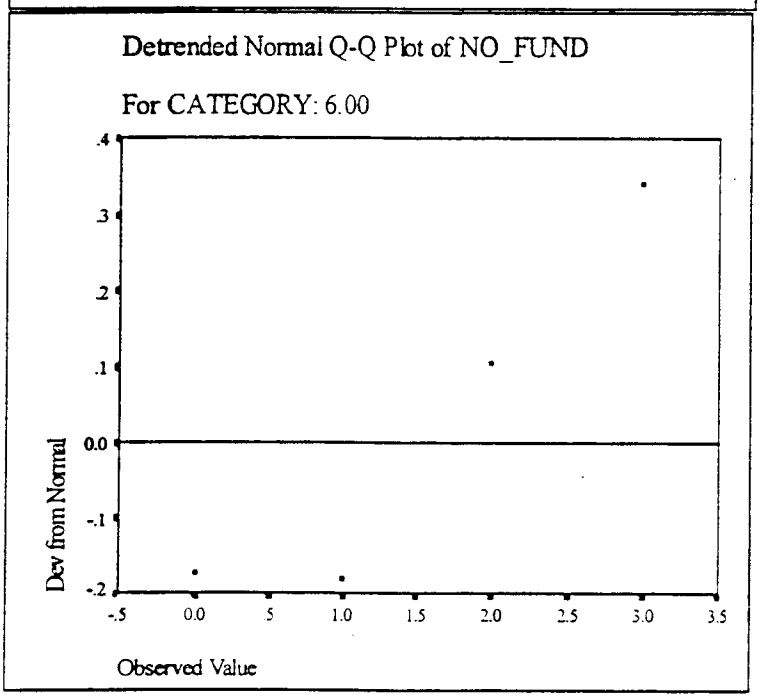


	Statistic	df	Significance
Shapiro-Wilks	.8174	15	< .0100
K-S (Lilliefors)	.3333	15	0001

Figure K-3 (continued). *Non-Normal Distribution Examples*

EXAMPLE OF STATISTICS THAT REJECT NORMALITY Ho, AND NPPLOTS that suggest normality. The distribution is probably leptokurtic about the median (=1).

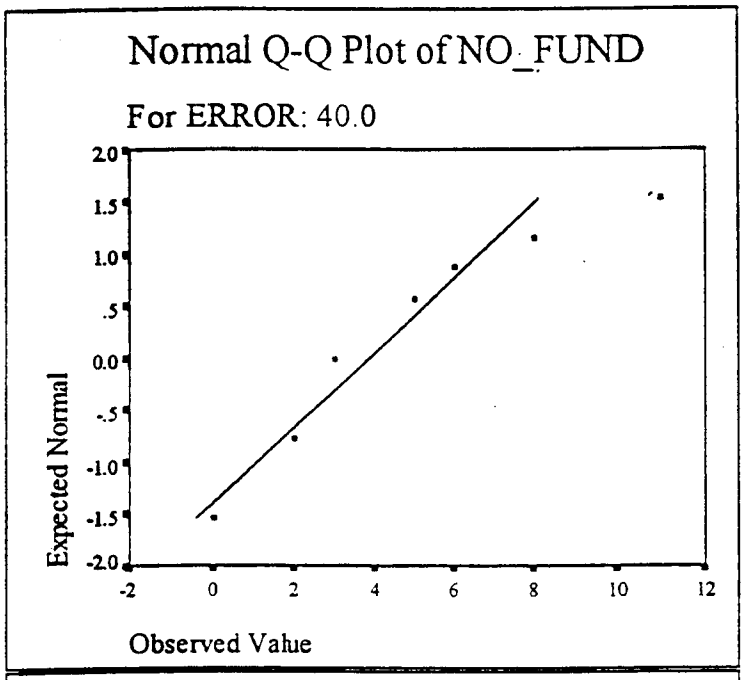


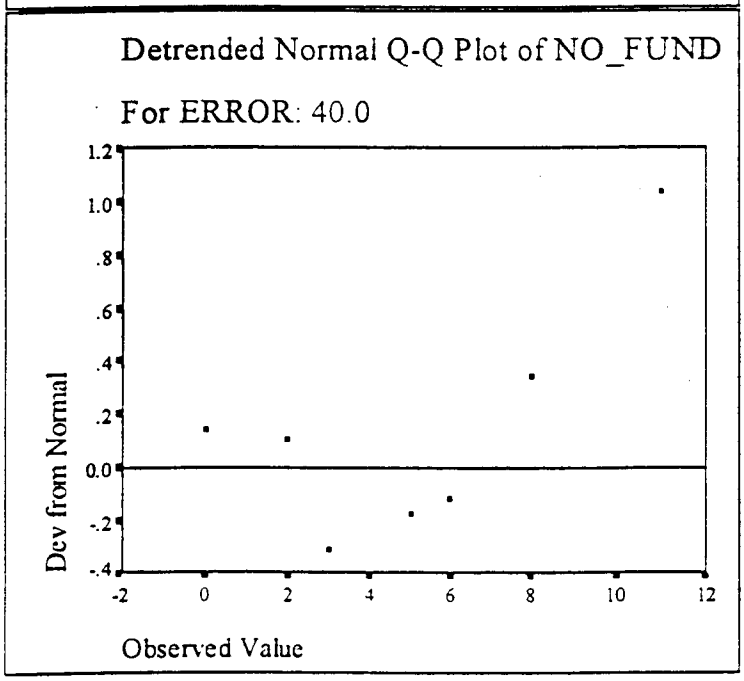


	Statistic	df	Significance	
Shapiro-Wilks	.8493	15	.0172	
K-S (Lilliefors)	.2323	15	.0286	(sample taken from 30 percent error level).

Figure K-3 (continued). Non-Normal Distribution Examples

EXAMPLE OF NON-NORMALITY WHERE:
Distribution could be platykurtic because of outliers seen in boxplot (see summary statistics).





	Statistic	df	Significance	
Shapiro-Wilks	.8570	15	.0223	
K-S (Lilliefors)	.2893	15	.0014	(sample taken from cost-efficiency category).

APPENDIX L. PRELIMINARY SIMULATION RESULTS FROM URBAN SUB-PROGRAM

Contents:

Simulation output charts for error applied in two criteria categories:

1. Cost-efficiency.
2. Community support.

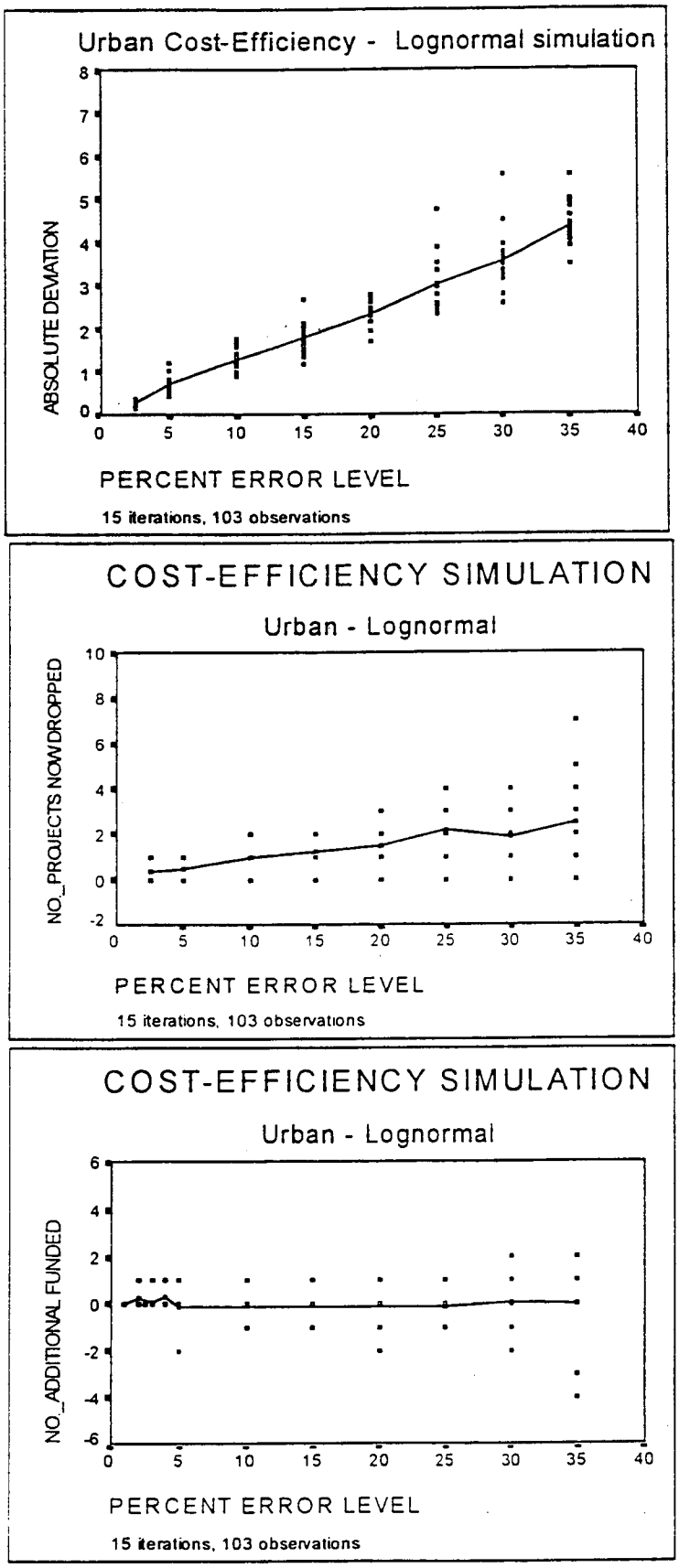
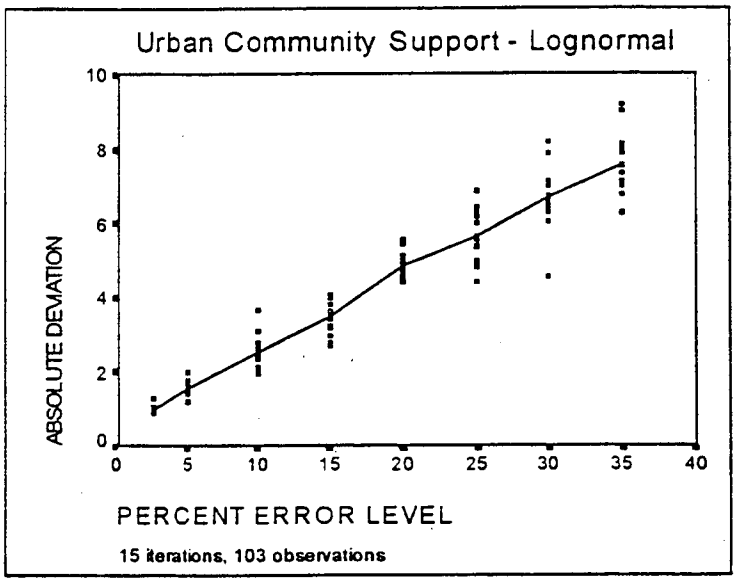
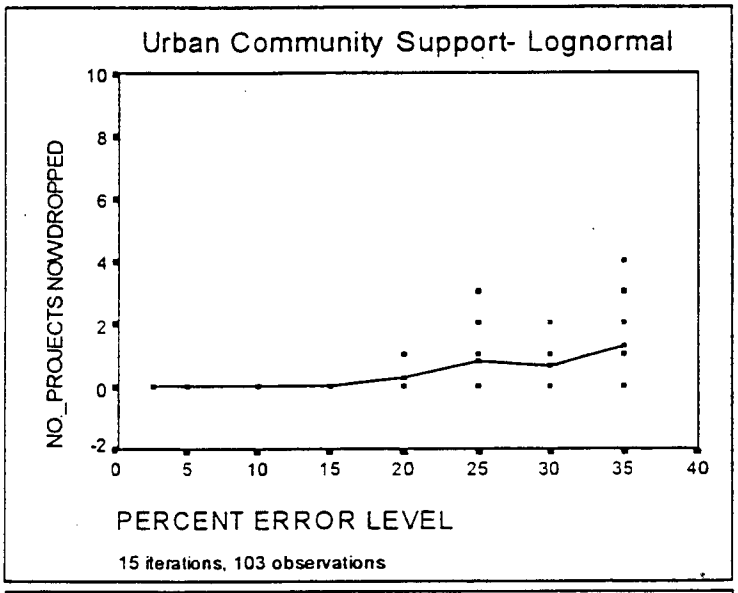


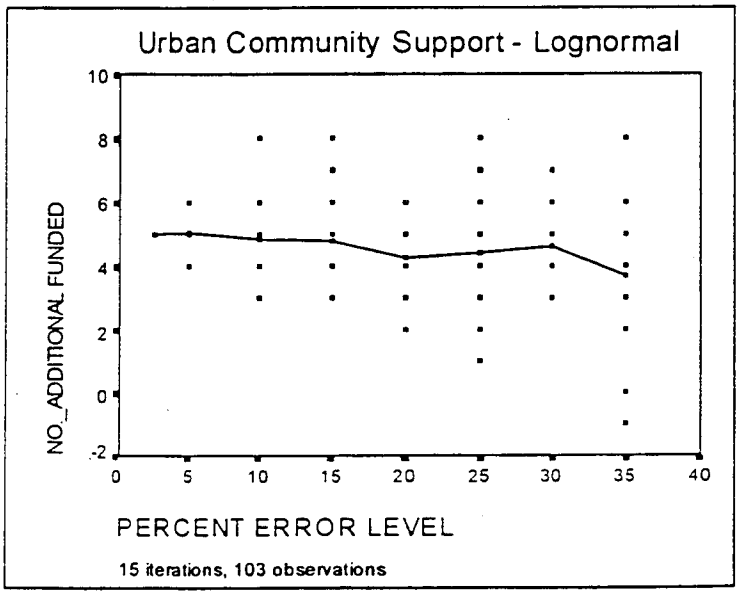
Figure L-1. Urban Cost-Efficiency Result Series



A.



B.



C.

Figure L-2. Urban Community Support Result Series