NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT **324**

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TRANSPORTATION RESEARCH BOARD
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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST

- Finance
- Environmental Design
- Maintenance
- Human Factors
- (Highway Transportation)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D. C.

DECEMBER 1989

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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FOREWORD

By Staff
Transportation Research Board

The findings of this report will be of interest to state highway officials concerned with the location, planning, design, operation, and maintenance of safety roadside rest areas on the Interstate and rural primary highway systems. The report provides a wealth of up-to-date information on rest area practices, rest area users and use, and benefits and costs of rest areas. Information in the report can be used in a number of ways, for example, recommended spacing for the location of new rest areas, types of services to be added to reconstructed facilities, hours of operation currently expected by travelers, operational problems as a basis for parking area design, security problems and their impact on enforcement needs, cost information for preparation of construction and maintenance budgets and information on benefits to support budget priorities. In summary, the report constitutes a long-needed state of the art on rest areas and provides a tool for analyzing rest area problems and evaluating alternative solutions.

Growth in highway travel has resulted in increased wear and tear on safety roadside rest areas along the nation's highways. The situation requires larger maintenance budgets at a time when states are experiencing a shortfall between highway revenues and needs. Also, many rest areas, built in the early years of Interstate construction, are in need of rehabilitation or reconstruction. In order to justify the need for increased rest area construction and maintenance budgets, highway agencies need data on rest area benefits to the user, to the non-user, to the nearby community, and to the State as a whole.

Under NCHRP Project 2-15, "Identifying, Measuring and Evaluating the Benefits of Safety Roadside Rest Areas," research was undertaken by KLD Associates, Inc., Huntington Station, New York, with the objectives of (1) producing a profile of rest area users and their needs, which can be used to evaluate existing facilities and to plan and design new and reconstructed rest areas; and (2) developing a method for measuring and evaluating the benefits of roadside rest areas.

To accomplish the objectives the research agency performed a comprehensive survey of state agencies, a series of studies including traffic data collection and user interviews at rest areas throughout the United States, and a telephone survey of highway users at large. The data obtained, combined with an extensive literature survey and unpublished study results from a number of states, were used to generate a rest area user profile and to determine rest area benefits and disbenefits. Many of the benefits and disbenefits proved difficult to quantify in monetary terms; hence, a Rest Area Analysis Methodology was developed to analyze benefits and disbenefits using the general principles of decision and utility theory. The research findings, the analysis

methodology, and the results obtained by applying the methodology to an actual case study are presented in this report. Use of the methodology should provide a sound basis for planning and budgeting rest area construction and maintenance and the resulting rest area facilities should better serve the traveling public at the least cost to highway agencies.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 2-15 by KLD Associates, Inc., of Huntington Station, New York. Gerhart F. King, Manager, Transportation and Safety Engineering Projects, KLD Associates, was the Principal Investigator and is also the author of this report.

Edward B Lieberman, President of KLD Associates, acted as Project Manager. Other KLD professional staff members who contributed to the research and to this report included: Dr. Paul Abramson, Senior Statistician; Dr. Chian-Yuan Lin, Transportation Engineer, now of National Chiao-Tung University, Taiwan; Dr. Ajay K. Rathi, Senior Analyst, now of Oak Ridge National Laboratory; and John Incorvaia, Research Assistant, returned to graduate studies.

Dr. Everett C. Carter of the Civil Engineering Department, University of Maryland, acted as a project consultant throughout, concentrating on highway user needs and research methodologies. His contributions to the project are gratefully acknowledged.

The telephone survey of at large drivers throughout the United States was developed by KLD Associates, with the assistance of Dr. Carter, and implemented, under a purchase order, by Schulman, Ronca & Bucuvalas of New York City.

This study could not have been completed without the assistance of engineers, landscape architects and other officials, too numerous to mention, in many state highway agencies throughout the country who freely gave of their time to assemble and furnish data and other information. Special mention is, however, due Mr. Leo Rutledge of the Virginia Department of Transportation and to Mr. Michael Perfater of the Virginia Transportation Research Council who supplied the data and other inputs for the case study described in Appendix B.

EVALUATION OF SAFETY ROADSIDE REST AREAS

SUMMARY

Highway safety rest areas are an integral, necessary element of the rural Interstate and primary highway system in the United States. These facilities are considered, by the vast majority of the public, to be a legitimate public function to be financed from public sources.

The research reported herein was initiated by the need for: (1) an identification and quantification of the benefits and costs of highway rest areas to the public, to state highway agencies, and to others; (2) an updated profile of highway rest area user attributes; and (3) a reliable method of comparing these benefits and costs.

Research methodologies employed included an intensive search for existing data and information, both published and unpublished; a questionnaire survey of U.S. and Canadian state and provincial highway agencies; field data collection at 13 rest areas in five states; a telephone survey of 500 randomly selected U.S. drivers; discussions with cognizant officials and field inspection of rest areas in a number of states; and detailed accident analyses.

Analyses of all the information assembled showed that almost all rural freeway travelers on a long trip (i.e., in excess of 100 miles) are potential users of highway rest areas. More than 95 percent of all drivers have used rest areas, and 60 percent prefer them over other stopping opportunities for nongas, nonrestaurant stops. Demographically, the rest area user population closely approximates the driving population, particularly that engaged in longer trips, with, possibly, a higher participation by older drivers.

The proportion of main-line traffic that enters a given rest area is highly variable—ranging from less than 1 percent to more than 50 percent. The overall average is approximately 10 percent, with the proportion of truck and recreational vehicles entering somewhat higher. There are strong indications that these percentages are increasing over time. Previously developed formulations that predict rest area use may seriously understate actual use.

Most of the benefits of highway rest areas accrue to the traveling public in the form of enhanced comfort and convenience; improvements in highway safety through a reduction in shoulder stops and a reduction in the portion of the driving population that is fatigued; and a reduction in excess travel to search for services. The comfort and convenience benefits are valued by the user public, on a "willingness to pay" basis, at between $0.40 and $1.00 per stop. Benefits to highway and other governmental agencies are of lower magnitude and substantially result from enhanced opportunities to communicate with the driving public. These communication opportunities also may contribute to the state's economy; especially local tourism and travel-related businesses. A benefit-cost analysis restricted to three specific user benefits that could be quantified—comfort and convenience, reduction in excess travel, and reduction in shoulder accidents—yielded a benefit-cost ratio in excess of 3.

Many of the benefits of highway rest areas that have been identified cannot be quantified or expressed in monetary terms, given the current availability, resolution

and accuracy of input data. In recognition of this fact, an analysis methodology has been developed based on the principles of utility or decision theory. This methodology, described in the report and applied to a case study, is able to accommodate both benefits and costs that are intangible or uncostable.

CHAPTER ONE

INTRODUCTION

This report covers all work accomplished, and all findings and conclusions reached under NCHRP Project 2-15. Principal products of the research include: an updated profile of rest area users and use; a description, and quantification to the extent possible, of the benefits of rest areas and of future trends that may affect these benefits; a suggested decision-aiding methodology for the rational analysis of rest area location, design, and operations alternatives; and a case study application of this methodology.

BACKGROUND

Rest areas have been an integral part of the highway system since the first such facility was established in Michigan in 1919. There is general agreement that rest areas enhance highway safety; enhance the comfort and convenience of highway travel; and facilitate the transmission of information to the highway user. The need for these facilities, especially on rural, limited access routes, is recognized by both highway agencies and highway users.

There is, however, a lesser consensus on the optimum spacing and location of such facilities; on the type and extent of services that should be available; and on the factors that should control decisions relative to these aspects. Finally, there exists no rationally based methodology to quantify the need for rest areas and to guide decision-makers in the allocation of resources to a rest area program in competition with other demands.

NCHRP Project 2-15 was initiated to satisfy this need. The project was designed to generate a detailed profile of the current rest area user population; and to define and quantify the benefits accruing to that population, to highway agencies, and to the public at large. These quantified benefits could then serve as the principal input into a cost-benefit based procedure that would constitute a decision-aiding tool for all aspects of rest area location, design, and operation.

OBJECTIVES AND SCOPE

The overall objectives of NCHRP Project 2-15, as stated in the project statement of work, reads as follows:

> Rest areas are very popular with the traveling public. Recent sharp increases have occurred in both construction and operation costs of rest areas, and competition for funding with other highway construction and maintenance programs has become difficult. Therefore, the need is extremely great for a reliable and accepted method of comparing rest area benefits with costs. A study is necessary to identify (1) how state highway agencies benefit from rest areas, (2) users and nonusers and how they benefit, and (3) the value of these benefits and related costs.
>
> A new profile of rest area users and their needs is necessary to properly evaluate existing facilities, and to plan and design new and reconstructed rest areas. The makeup of rest area users today has changed since rest areas were first built. Driving habits are different, motorists' attitudes toward mobility have changed, and there is an increasingly more mobile public, e.g., senior citizens, handicapped, and young families. Furthermore, traffic speeds and conditions have changed, along with vehicle types and sizes.
>
> While rest area benefits are viewed in a variety of ways, safety is typically near the top of the list. Investigation of experience in managing and operating highway systems with rest areas, including those with commercial facilities, and those systems without rest areas may provide useful data on driver fatigue, behavior, and accident patterns.
>
> The objective of this research is to develop a method for measuring and evaluating the benefits of roadside rest areas to result in more cost-effective designs and operations. This research will address both the benefits and disbenefits associated with rest area facilities.

The scope of the research encompassed all rest areas and included facilities located on both the Interstate and rural primary systems. Although empirical field data collection concentrated on Interstate highway facilities, the findings are considered applicable to all rest areas.

RESEARCH APPROACH

Early in the study, it was realized that existing data were inadequate to characterize rest area use and to formulate an accurate profile of rest area users. Data on these topics were therefore collected through an intensive program of studies including a comprehensive survey of state agencies concerned with rest area location, design, operations, and maintenance; a series of empirical studies, including traffic data collection and user interviews, at rest areas throughout the United States; and a telephone survey of highway users at large.

Data so generated, combined with information uncovered through a comprehensive literature survey and unpublished study results furnished by a number of states, were used to generate a rest area user profile and to define rest area benefits and disbenefits. Many of these benefits and disbenefits were found to be nonquantifiable or noncostable.

In order to account for these intangible elements, a method was developed for analysis of rest areas based on the general principles of decision and utility theory. The research findings, the detailed methodology, and the results of applying this methodology to an actual case study are presented in this report.

ORGANIZATION OF REPORT

Chapters Two through Four of this report summarize the research findings pertaining to current rest area practices, rest area user profile, and benefits and costs of rest areas. Most of the detailed data which underlie these findings were included in the project interim report (*1*) and are not repeated here except insofar as necessary to support specific findings.

Chapter Five covers the application of the research findings including summaries of the proposed rest area analysis methodology and its application. The detailed analysis procedures as well as a complete case study are included as appendixes.

The final report section, Chapter Six, discusses the research conclusions and contains recommendations for possible further research on this general topic.

CHAPTER TWO

FINDINGS—CURRENT REST AREA PRACTICES

This summary of current rest area practices is based on a survey (fully documented as Appendix D of Ref. 1) of U.S. and Canadian state and provincial highway agencies; a comprehensive literature survey which examined in excess of 200 references; visits to rest areas in 18 states and discussions with local officials in 10 of these states; and the results of a survey on rest areas/welcome centers made by the AASHTO Subcommittee on Highway Maintenance (*2*).

NUMBER AND SPACING

Every state except Alaska and Hawaii operates one or more Interstate highway safety rest areas; at least 44 of the 50 states also reported operating one or more rest areas on non-Interstate rural primary highways.

Based on the survey results, the estimated number of rest areas in the United States in 1987 was:

	Rest Areas	Welcome Centers	Total
Interstate	1,186	176	1,362
Other rural arterials			
• Total (KLD)	1,321	69	1,390
• Full service (AASHTO)	407	69	476
Total	2,507	245	2,752

The number of rest areas for non-Interstate highways shown as "Total" is taken from the KLD survey (Appendix D of Ref. 1). This number is considerably higher than the total indicated by the AASHTO survey. The KLD survey requested the number of *all* rest areas; the AASHTO survey was restricted to *full service* rest areas.

Thirty states reported that planned Interstate rest area and/or welcome center construction was included in their 5-year (1988–1992) construction program; 15 states are planning this type of work for non-Interstate highways. The aggregate amount of planned construction is:

	Rest Areas	Welcome Centers	Total
Interstate	173 (14.6)	34 (19.3)	207 (15.2)
Other urban arterials	60 (14.7)	14 (20.3)	74 (15.5)
Total	233 (14.6)	48 (19.6)	281 (15.3)

Figures in parentheses in the foregoing table indicate percent of the existing rest area inventory for full service rest areas. No data on construction plans for less than full service facilities are available. The overall compound annual construction rate is 2.9 percent. This figure is identical to the compound annual rate of increase in rural arterial travel (*3*).

Because the implementation of planned construction is dependent on the legislative and budgetary environment, these plans can change rapidly. For instance, in response to the AASHTO survey Virginia indicated that, as of the end of 1987, the Commonwealth had *no* plans for new non-Interstate welcome centers. Less than 3 months later, the Virginia Senate requested a feasibility study for the construction of welcome centers on *all* multilane, non-Interstate arterials crossing the State line. This feasibility study identified 11 potential sites (*4*).

Rest area spacing parameters are given in Table 1. The average

Table 1. Rest area spacing (miles). Note: All parameters are weighted by the number of rest areas in each state.

Average Spacing -	Interstate	Primary
Mean	44.4	30.6
Standard Error of the Mean	0.44	0.67
Median	45	42.5
Mode	35,40,50	50
Maximum	105	150
Minimum	25	10
No. of States Included	43	12
No. of Rest Areas	1296	836
Maximum Spacing -		
Mean	75.3	60.3
Standard Error of the Mean	0.98	1.09
Median	72.5	82.5
Mode	50,100	50
Maximum	200	200
Minimum	40	50
No. of States Included	36	10
No. of Rest Areas	1101	607

Interstate spacing of 44.4 miles is slightly below the currently recommended average spacing of one hour driving time or 50 miles (*5*). This recommended spacing is, however, based on an empirically derived formulation for average rest area use (see Chapter Three, "Predicting Rest Area Use") which may no longer be applicable. Maximum spacing, which averages 105 miles and may reach as high as 200 miles in some states, probably reflects specific local conditions (e.g., high degree of urbanization or a partial implementation of a state's rest area master plan due to budgetary constraints).

The recommended 50-mile spacing represents an apparent increase over previous recommendations. A 1968 AASHTO Design Policy (*6*) stated:

> On a heavily-traveled route with cities close together, at least one [rest area] site on each roadway may be desirable between two sizable cities. Distances between sites may vary from about 20 miles on heavily-traveled Interstate highways in well-developed areas to 30 miles or more on lightly-traveled Interstate highways. Through sparsely settled areas, distances between sites may be longer.

FACILITIES OFFERED

The official definition of a rest area, as adopted by AASHTO (*7*) reads as follows:

> A roadside area with parking facilities separated from the roadway provided for motorists to stop and rest for short periods. It *may* include drinking water, toilets, tables and benches, telephones, information, and other facilities for travelers. (Emphasis added.)

This definition replaces an earlier one, in Ref. 6, which stated that:

> Safety rest areas are off-roadway spaces with provisions for emergency stopping and resting by motorists for short periods. They have freeway-type entrance and exit connections, parking areas, benches and tables and *usually* have toilets and water supply, where proper maintenance and supervision are assured. They *may* be designed for short-time picnic use in addition to parking of vehicles for short periods. (Emphasis added.)

Insofar as the U.S. Government is concerned, Title 23, Highways, Code of Federal Regulations, Part 752.3(a), defines safety rest areas as:

> Safety rest area. A roadside facility safely removed from the traveled way with parking and such facilities for the motorist deemed necessary for his rest, relaxation, comfort and information needs.

In view of these rather broad definitions, and their optional elements, it is not surprising that facilities at individual rest areas range from simple all weather parking lots to full service facilities with manned information centers, playgrounds, and other amenities. The upper end of this range of facilities is constrained by existing legal restrictions on commercial activities on the Interstate right-of-way. Canadian and European rest areas generally include automobile service facilities, convenience and gift shops and quick food and regular restaurants. Some European facilities may even incorporate motels (*8*).

A similar range of services, including commercial activities, can generally be found in rest areas located along toll roads, including those which have been designated as part of the Interstate System. The future of these commercial facilities on roads originally built as toll facilities from which the tolls have been removed, e.g., I-95 in Connecticut, remains undecided.

Detailed examination of the questionnaire responses reveals an interesting pattern in the frequency of available facilities and services.

Percent of All Rest Areas	Facilities Offered
More than 90	Trash disposal
70 to 90	All weather parking Picnic tables—open Drinking water Toilets—flush or chemical type
50 to 70	Segregated parking (trucks, buses) Picnic tables—sheltered Cooking facilities Telephone—all calls Tourist information—unattended, map only Pet exercise area

Furthermore, handicapped access, fixed exterior lighting and heated interior facilities are available at over 50 percent of all rest areas. No facility or service, not listed above, can be found at more than 25 percent of all rest areas.

The facilities listed thus define a model rest area which, by actual observation, represents the most prevalent type of rest area for those located on the Interstate System. While there are considerable differences in architecture, overall layout, landscaping, maintenance status, and parking volume/capacity ratios between the states, and between individual rest areas, almost every rest area visited offered these facilities. There were relatively few instances where additional services or facilities were available.

A number of states have formal or informal policies that allow local civic organizations, or other nonprofit organizations, to dispense coffee, soft drinks and, sometimes, other food items, in highway rest areas by prior arrangement. These items are, ostensibly, available without charge; however, a contribution to the distributing organization is expected. This service is quite popular and state agencies have waiting lists of requests by interested organizations, especially for the more desirable dates (e.g., holiday weekends).

Recent changes in federal highway legislation have somewhat relaxed the prohibition against commercial activities in Inter-

state rest areas. As a result, two types of commercial activities, vending machines and computerized information services, are becoming increasingly popular. Furthermore, a number of states (e.g., California and Michigan) are actively exploring additional private commercial involvement in rest area construction and maintenance. To date, these feasibility studies have concentrated on off-right-of-way facilities which would require an interchange exit maneuver.

HOURS OF OPERATION

In response to the KLD survey, 24 states indicated that there were some temporal limitations on rest area operations, 11 stated explicitly that there were no such limitations and 10 left the question blank, thereby presumably indicating the absence of any limitations. The following types of limitations were cited:

Limitation	No. of States
Seasonal closing of some rest areas	12
Rest areas closed due to snow conditions	1
Seasonal availability of some facilities	2
Seasonal extension of hours of operations	1
Rest area staffed only during part of the day	2
Information center staffed only part of the day	4
Rest area closed part of the day	2

The field investigations of rest areas by the project staff appear to indicate that this listing is incomplete. Seasonal closing of rest areas (winter) and seasonal extensions of hours of operation (summer), especially for staffed facilities, appear to be far more prevalent than indicated by these responses.

This perception is supported by other studies. The AASHTO survey did not address seasonal operations, but it did generate data on hours of operation as follows:

	Number of States Reporting Operations for	
	24 Hours	Less than 24 Hours
Rest area open	42	5
Attendant on duty—rest area	9	35
—welcome center	8	30
Tourist information—manned	2	35

A 1985 survey by Michigan State University (*9*) concerned with rest area operations and management found that only 67.5 percent of responding states kept all rest areas open all year. The corresponding figure for information centers was 64 percent.

OPERATIONAL PROBLEMS AND SECURITY

Highway agencies operating rest areas are faced with a number of problems. Respondents to the survey were asked to rate 26 problem types on a scale ranging from 1 (not at all serious) to 5 (extremely serious). Three of these postulated types, "air pollution," "drag racing," and "entrance/exit accidents," were rated as "not at all serious" by all respondents. The average rating, weighted by the number of rest areas in each state, for the other problem types, is given in Table 2.

Table 2. Rest area problem types—rank order. Note: A rank of 5.0 indicates an "extremely serious" problem; 4.0, a "very serious" problem; 3.0, a "serious" problem; 2.0, a "somewhat serious" problem; and 1.0, "not at all serious."

Rank	Problem Type	Mean Rating
1	Vandalism	2.54
2	Trash Dumping	2.46
3	Moral Offenses	2.36
4	Littering	2.20
5	Facility Overcrowding	2.05
6	Parking Lot Overcrowding	2.03
7	Sanitary Waste Disposal	1.84
8	Overnight/Extended Parking	1.83
9	Other Crimes Against Property	1.74
10	Crimes Against Persons	1.50
11	Alcohol/Drug Offenses	1.46
12	Drinking Water Quality	1.41
13	Unauthorized Commercial Activity	1.24
14	Religious/Political Advocacy	1.23
15	Unauthorized Access	1.11
16	Ground Water Pollution	1.06
17	Parking Lot Accidents	1.05
18	Personal Injury Accidents	1.04
19	Noise Pollution	1.03
20	Fights	1.02
21	Cooking Fires	1.02
22	Carpool Staging	1.01
23	Abandoned Vehicles	1.00

Nine problem types that were rated as "very serious" or "extremely serious" by one or more responding states, are as follows:

Problem Type	States Reporting
Moral offenses	7
Vandalism	6
Littering	4
Parking lot overcrowding	4
Trash dumping	3
Facility overcrowding	2
Other crimes against property	2
Overnight or extended parking	1
Sanitary waste disposal	1

The states were asked if any of these problems had significantly affected rest area use or the utility of the rest areas to the public. A significant or very significant effect on rest area use was cited by 23 states or more than half of the 45 responding states: very significant effect, 11 states; significant effect, 12 states; slightly significant effect, 5 states; no effect (explicit), 12 states; and no response, 5 states.

The states have different procedures for security enforcement in rest areas. The number of states citing each possible alternative is shown below:

	Police	Highway Dept. Personnel	Others
Permanently stationed	1	18	9
Regular patrols	12	18	3
Irregular (occasional) patrols	31	14	2
On complaint only	10	7	2

Seven states replied that there was no police involvement in rest area security. Five of the problem types given in Table 2 would normally be considered to justify police attention. Three of these, shown in the following listing, were considered "very serious" or "extremely serious" by one or more respondents. For these respondents, the cited degree of police involvement is also shown.

Highest Degree of Police Involvement in Rest Areas	Very Serious and Extremely Serious Problem Types: Vandalism	Crimes Against Property	Moral Offenses
Permanently stationed	0	0	0
Regular patrols	3	0	2
Irregular patrols	2	1	2
Complaint only	1	0	1
None	1	1	1
No response	–	–	1

It appears that states which assert that there are serious problems at rest areas have no more police involvement than those states which do not assert such problems as "serious".

Approximately 38 percent of the states responding indicated that some legal action, against some public agency, had been brought as a result of rest area operations.

PERCEIVED BENEFITS

The principal benefits of highway rest areas which accrue for three defined groups (highway users, highway and other governmental agencies, and all other, e.g., tourism, state economy, local business) in the opinion of the respondents are given in Table 3.

The wording used by the individual respondents has been substantially preserved, leading to some apparent duplication. These duplications may, however, not be real in the eyes of the respondents. For instance, individual responses included "rest/stretch" and "exercise" or "rest/stretch" and "alleviate driver fatigue" as separate benefits.

The overall impression yielded by this tabulation is that the respondents generally consider rest areas to benefit highway users primarily. Governmental agencies and others are seen to benefit to a lesser extent. In fact, except for "public relations" and "boost economy" there appears to be no consensus as to the benefits which accrue to other than highway users.

One of the benefits often alleged as accruing to "other than highway users," the reduction of traffic—especially large trucks—on interchanges, the local street system, and in nearby small municipalities, did not receive any mention. The ability of rest areas to act as refuge in case of severe inclement weather, major accidents, or other reasons for road closure was also not mentioned by any respondent.

The importance of the perceived benefits of rest areas is also indicated by the fact that many states have been subjected to public pressure concerning specific rest area related actions. In a number of cases, such pressure has led to the reversal or easing of decisions concerning rest area closing or limitations on hours of operations.

Most responding states also cited instances of local involvement and public pressure concerning specific rest area locations and the provision of more rest areas in general. There were no reported instances of opposition to the establishment of new rest areas except for directly affected landowners or advocates of a competing location.

Table 3. Benefits of highway rest areas.

Benefit	No. of States Mentioning	No. of Times Mentioned for User	Gov't	Others	All
Rest/Stretch	36	36	6	1	43
Tourist Info./Public Relations	34	4	20	29	53
Safety/Convenience	25	15	11	-	26
Restroom	19	19	2	1	22
Travel/Weather Info.	16	15	1	4	20
Boost Economy	15	-	-	15	15
Picnic Facilities	11	11	-	-	11
Telephone	9	9	1	1	11
Refreshments/Food	7	7	-	-	7
Check/Inspect Vehicle	6	3	3	-	6
Exercise	6	6	-	-	6
Alleviate Driver Fatigue	2	2	-	-	2
Trash Disposal	2	-	2	-	2
Data Collection Point	2	-	2	1	3
Access to Travelers	2	-	-	2	2
Staging Area	1	-	1	-	1
Distribute Literature	1	-	1	-	1
Cooperation with County Conservation Groups	1	-	1	-	1
Revenue for Blind Commission Decreases Hwy. Maintenance Costs	1	-	1	-	1
No. of States Mentioning Any Benefits	42	42	38	37	
Total No. of Benefits Mentioned		127	52	54	

COSTS

Summaries of numerical data on construction and operation and maintenance costs are presented in Chapter Four. It will be seen that these data show extremely high variability. Even when disaggregated into three different rest area levels of service, ratios of high to low cost of 15:1 within states and 60:1 between states for design and construction costs were noted. For maintenance and operation costs, these ratios were 15:1 and 24:1 respectively.

This wide range of costs is due to the interaction of the many factors which affect cost levels. Table 4 gives these factors, as

Table 4. Factors affecting rest area costs.

Factor	No. of Times Mentioned
Location	18
Obtaining Potable Water	11
Sewage Disposal	10
Utilities	9
Amount of Use	9
Labor Costs	8
Size of Area	8
Amount of Parking	7
Access to Highway	7
Types of Facilities Offered	5
Size of Building	4
Terrain	3
Quality/Durability of Features	3
Proportion of Contractor vs. Own Forces Work	3
Architecture	2
Cost of Design Materials	2
Travel Time vs. Resident Custodian	2
Inflation	2
Number of Picnic Shelters	1
Pavement Thickness	1
Inexperienced Management	1
Sanitary Waste Disposal	1
Government Regulations and Codes	1

reported by respondents, together with the number of times each of these was mentioned. Table 4 retains the wording of the respondents. If these 23 individual items are aggregated into broad classes, it can be seen that the distribution is as follows: factors depending on *location,* 51 mentions; factors depending on *size, design,* or *facilities offered,* 53 mentions; and miscellaneous factors, 34 mentions.

Water supply and sewage factors, which depend on location (i.e., independent or municipal system connections) as well as on rest area size and use have been included in both the location and size categories. It can thus be seen that the location of a rest area and its size (a function of expected use) have about equal influence in determining rest area costs. In view of the great diversity in possible rest area location, size, design, and features it is not surprising that the cost figures quoted by the individual responding states show a considerable range.

One method for reducing the burden of paying the costs of a rest area program is through joint use, that is, the accommodation of another public or, more rarely, private function within the physical rest area plant. In response to a question, 40 of the 45 states reported some joint use of rest area. The great majority of these were welcome centers or other facilities for providing tourist information. The entire list of joint uses mentioned is given, as follows, together with the number of states mentioning each:

Joint Use	No. of States
Tourist information center—state gov't	30
Port of entry/welcome center	18
Tourist information—local gov't	13
Truck weighing station	12
Tourist information—commercial	4
Inspection station	3
Private commercial operations	3
Private noncommercial operations	3
Highway police staging area	2
Highway maintenance staging area	1
Other (unspecified) governmental activity	3

Rest area funding is subject to the general, nationwide constraint on infrastructure construction, reconstruction, and operations financing. A question concerning the adequacy of current levels of funding for state rest area programs addressed this point. One state responded that there was no specific funding for the rest area program, another state did not respond to this question. The remaining states characterized current funding levels as follows: comfortable, 8; just adequate, 15; and insufficient, 20.

As a follow-up, a question was posed concerning the priority order of increased expenditures if additional rest area funds would become available. The answers are shown below: a rank of 1 implies "most important," and a rank of 4 implies "least important."

Use	No. of Respondents Ranking 1	2	3	4	Mean Ranking
Reconstruct/upgrade existing rest areas	24	12	4	0	1.5
Improve rest area maintenance and operations	19	6	12	1	1.9
Establish new rest areas	11	11	10	6	2.3
Increase hours of operations	1	3	4	16	3.5

These responses indicate a strong consensus that improvement of existing rest areas and of their maintenance and operations should take precedence over the construction of new rest areas. The low ranking given to the establishment of new rest areas may also reflect the shift in opinion, already noted earlier in this chapter, towards longer average rest area spacing. The high ranking given to reconstruction is, undoubtedly, also a response to the fact that traffic volumes, and therefore rest area use, have increased dramatically over the last 20 years. Furthermore, many rest areas, built near the beginning of the Interstate program, have reached or are approaching the end of their economic life.

CHAPTER THREE

FINDINGS—REST AREA USER PROFILE

This section of the report presents a profile of the users of highway safety rest areas. This profile represents a synthesis of past research and surveys as reported in the literature or as furnished by cooperating agencies; demographic data on and interviews with rest area users in 13 rest areas in five states; and a telephone survey of a randomly selected nationwide sample of 500 drivers.

The rest area interviews and the telephone survey were documented, in detail, in the project interim report. These, and other, data are used to develop the rest area user profile presented in subsequent portions of this chapter. In summary, this profile shows that rest area users represent a random sample of somewhat more than 10 percent of the passing traffic stream with commercial and recreational vehicles somewhat over-represented. Demographically, rest area users are representative of the total population of drivers making trips of 100 miles or more (one way distance) weighted by distance and number of trips.

The time in rest area generally averages between 10 and 15 minutes per vehicle, but is highly variable as a function of vehicle type and time of day. The need for rest and for the satisfaction of bodily needs are the predominant reasons for rest area stops. The only other reason for stopping, for a significant proportion of the user population, is telephone use by business travelers.

REST AREA USE

Anticipated rest area use is a key ingredient in all decisions concerning the location, spacing, and size of rest areas.

Rest Area Use Studies

The last nationwide study of rest area use, conducted in 1971 (*10*), found that the percentage of main-line traffic entering ranged from 1.0 to 27.4 percent. Fifty of the 54 rest areas checked ranged from 3.0 to 14.9 percent with a weighted average of 7.6 percent. Eighty percent of these were passenger cars.

Traffic counts at nine of the rest areas in which field studies were performed during this project showed a range of entering traffic between 5.5 and 17.7 percent with a weighted average of 10.5 percent. Entering percentages by vehicle types are as follows:

	Percent Entering	Percent of Total Entering	Percent of Mainline Traffic
Cars	9.4	76.3	84.5
RV	20.8	10.2	5.1
Trucks	13.8	12.7	9.6
Other	11.8	0.9	0.8

A number of states have published rest area use studies or have made the results of such studies available to the research agency. These results are summarized in Table 5.

The proportions for different vehicle classes entering a rest area can be seen from the KLD data shown above. Supporting data are found in a Virginia study (*12*) which shows, for seven rest areas studied, an average entering proportion of 0.123 for passenger cars and light trucks and an average entering proportion of 0.146 for large trucks, buses, and recreational vehicles. A Nebraska study (*13*) of eight rest areas, however, found the following entering percentages: for cars, pickups, and vans, 11.1 percent; recreational vehicles, 22.5 percent; trucks, 8.5 percent; and buses (including school buses), 3.8 percent.

A seasonal effect on rest area use patterns can be postulated, but is difficult to document, because very few agencies have the resources to study the same rest area more than once in a calendar year. Michigan conducted rest area studies in both winter and summer months, although not at the same locations. The results of these studies appear to indicate a large decrease during the winter months as can be seen from the range of entering percentages between the rest areas studied.

	Winter	Summer
No. of RAs studied	6	7
Percent entering:		
Cars	1.5–6.9	2.9–15.0
Trucks and buses	6.9–18.3	9.6–44.4
Recreational vehicles	4.5–17.8	8.9–31.3
Total	1.8–7.2	3.4–16.2

The percentage of out-of-state vehicles at the rest areas studied by KLD ranged from 16.3 to 79.0 and averaged 32.8. Comparable data for eight rest areas in Nebraska showed that the percentage of out-of-state vehicles ranged from 65.1 to 83.1 percent. The Virginia study reported out-of-state percentages of 61.5 for rest areas and 61.0 for welcome centers. The Virginia results, disaggregated by vehicle type, are shown as follows:

Vehicle Classification	Percent Out-of-State Vehicles Welcome Centers	Rest Areas
Passenger cars	57.5	58.5
Light trucks	40.2	48.5
Tractor-trailers	83.1	74.6
Double trailers	75.0	100.0
Rec. vehicles	90.2	91.4
Buses	46.1	81.8
Motorcycles	61.4	53.3

A Michigan study showed that the percentage of out-of-state vehicles ranged from 5.2 to 27.6 percent in the summer and from 1.0 to 11.3 percent in the winter. This extreme variability in the data, both within and between states, clearly indicates that no generalization on this topic can be made. The proportion of rest area users who are from out of the state is a function of area, route, traffic stream composition and distance to the nearest state line.

Predicting Rest Area Use

As discussed earlier, the proportion of passing traffic that will enter a highway rest area is a function of traffic stream characteristics, such as composition and distribution by trip purpose and by trip length; general area characteristics, especially the frequency, distance to, and accessibility of alternate stopping opportunities; rest area spacing; temporal factors such as season, day of week and hour of the day; weather and other environmental factors; and, probably, many others including the range, appearance, and maintenance status of the services offered. No general model exists which combines these factors to predict rest area use. A model, developed in California (*11*), depends mainly on selecting an existing "comparison" location. The selection of these comparison locations, however, depends on a state-specific area and land use classification, thus making the method incapable of being applied in other locations. A more recent reference (*5*) recommends relating expected use to stopping percentage estimated from usage counts of existing rest areas. The traffic data collected for 10 of the rest areas in the present study indicate that no simple algorithm will explain usage differences between rest areas. The differences between

Table 5. State studies of rest area use.

State	Year	No. of Rest Areas in Sample	Percent Entering	Comments
California	1981	16	2.1 - 21	
Kansas	1983	29	5.6 - 21	
Michigan	1985	7	4.6 - 31	Weekdays
Michigan	1985	7	7.7 - 32	Weekends
Montana	?	16	5 - 50	FAI Routes
Montana	?	16	1 - 25	Non-FAI Routes
Nebraska	1987	8	5.1 - 15	
New York	1980	14	4.9 - 29	I87 only
Utah	1977/78	2	13.8 - 17	Welcome Centers
Virginia	1987	11	8.9 - 35	
Washington	1985	28	0.8 - 12	FAI Routes
Washington	1985	10	2 - 11	Non-FAI Routes

opposite rest areas on I80, in the center of Washington State, and between three adjacent rest areas for traffic in the same direction, on I87 in New York State, suggest that a complex mechanism is at work.

FHWA Technical Advisory T5140.8 (quoted in Ref. 5) gives use percentage figures as a function of route characteristics and rest area spacing. The formulas are: P (interstate) = 0.0024 DSL, P (primary, recreational) = 0.0016 DSL, P (primary rural) = 0.0011 DSL, where P is the proportion of main-line traffic entering the rest area and DSL is the actual distance between rest areas in miles.

Examination of this set of formulas indicates the following imbedded assumptions concerning the proportion of passing traffic, P, that will enter a rest area: (1) It is a function *only* of distance from the last rest area, DSL, and a very general descriptor of overall route characteristics. (2) It defines a straight line through the origin implying that there is neither an upper nor a lower bound on P. (3) It implies that drivers preferences for rest area stops, as against leaving the highway to use competing off-line facilities, do not change as the wait for the next rest area increases. (4) It does not take into account traffic that may have entered the highway at an interchange downstream of the preceding rest area and thus have not been exposed to that stopping opportunity.

Because the maximum distance between adjacent, within state, rest areas on the rural Interstate system is 200 miles and because there are very few, if any, instances of adjacent rest areas without intervening interchanges, these implicit assumptions are somewhat difficult to maintain. Furthermore, the need for periodic stops for fuel and other vehicle services, and for major meals and lodging, which cannot be satisfied at rest areas, places an effective upper bound on successive rest area stops.

The FHWA Technical Advisory proposes different formulas for rural arterials, depending on whether they are primarily recreational or other routes. This distinction is not made for Interstate route. Field data collected for this project showed the following range for variables that may be considered indicative of route attributes and driver characteristics:

Trip purpose, percent business	13.7–84.2
Average trip length, miles	172–493
Percent passenger cars	66.7–89.0
Percent vehicles with children	2.1–33.1

These considerations indicated that a much more complex algorithm is required to predict future rest area use. A sufficiently disaggregated representative data base necessary to derive such an algorithm is, at present, not available. While the format of the FHWA equation cannot thus be checked completely, the explanatory power of that equation, i.e., the appropriateness of the numerical value of the regression parameter, can be tested.

The FHWA formulation was tested against readily available data from 43 rest areas in six states. It was found that, generally, this formulation leads to an underestimation of actual rest area use. The average underestimate was 3.67 percentage points, or 33 percent of the actual value. In only one case, out of 43, did the FHWA formula produce a higher estimate than the actual value.

A regression on these 43 data points produced the following equation:

$$P\ (\text{Interstate}) = 0.020 + 0.0029\ \text{DSL} \quad (1)$$

If the regression is forced through the origin, the resulting equation is:

$$P\ (\text{Interstate}) = 0.035\ \text{DSL} \quad (2)$$

A nonlinear regression through the origin yielded:

$$P\ (\text{Interstate}) = 0.0070\ \text{DSL}^{0.81} \quad (3)$$

Equations 1, 2 and 3, as well as the FHWA equation, are superposed, in Figure 1, on a scatter diagram of the data points used. All three equations represent the data better than does the FHWA formula.

Because it was postulated that driver behavior may change as rest area spacing increases, a two regime model was tried, leading to the following equations:

$$P\ (\text{Interstate}) = 0.023 + 0.0027\ \text{DSL} \quad \text{DSL} \leq 30 \text{ miles} \quad (4)$$

$$P\ (\text{Interstate}) = 0.062 + 0.0019\ \text{DSL} \quad \text{DSL} > 30 \text{ miles} \quad (5)$$

Lack of complete data sets presented a rigorous investigation of additional independent variables. Regression analyses using the additional variables, distance to the nearest downstream rest area, traffic volume levels, and traffic composition, appeared to produce better fitting models. Because of the small sample sizes, however, the coefficients of these additional variables were not statistically significant.

The computational results shown above are indicative only and should not be used for analysis purposes. These regression equations are based on a relatively small opportunity sample which is not internally consistent in terms of data definitions (e.g., different data collection periods). Furthermore, the available data are restricted to a rather small range of possible values. The proportion entering ranged from 0.049 to 0.21, with a mean of 0.111, while the distance to the last rest area ranged from 14 to 64 miles (mean—31.0 miles). Data were available for

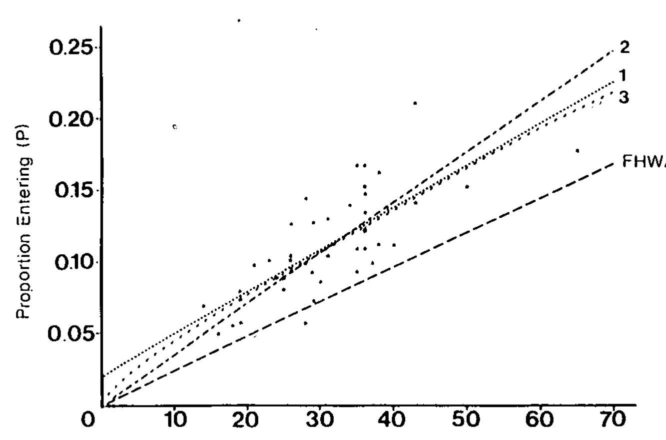

Figure 1. Rest area use as function of rest area spacing. (Note in figure: curve 1. P = 0.020 + 0.0029 DSL; curve 2. P = 0.035 DLL; curve 3. P = 0.698 DSL$^{0.81}$.)

only two rest areas where the distance from the last upstream rest area equaled or exceeded 50 miles.

Qualitative evaluation of the available data base as well as the foregoing computations appear to indicate that: (1) the relationship is not necessarily linear, especially for very small and very large values of DSL; (2) the regression line may not pass through the origin; and (3) other variables affect use pattern—even without the constraint of passing through the origin, the equations derived above accounted only for about 60 percent of the total variance.

Estimated Total Rest Area Use

Several approaches are possible to use these data and the relationships summarized previously to estimate total rest area use.

1. Table 6 shows ADT by highway classification taken from Ref. 14. Using average rest area spacing from the State survey and the FHWA formulas as a lower bound for percentage entering, the expected number of stops for each ADT class has been computed and is shown in the last column of Table 6. The overall estimate for minimum yearly rest area use, for the United States as a whole, is thus, Interstate highways, 368.6×10^6; other primary highways, 202.2×10^6; giving a total of 570.8×10^6.
2. Using data on total annual VMT on long trips (i.e., > 100 miles) from the NPTS data tapes, and data on average distance between stops (138 miles) and preference for rest area stops (59.8 percent) from the telephone survey the expected annual total number of rest area stops can be computed as 648.2 million.

A rough check on these orders of magnitude can be obtained by using data from one state. The State of Washington, in 1985 recorded a total 8,322,602 vehicles entering all of its Interstate rest areas. According to Ref. 4, Washington drivers, in 1985, accumulated a total VMT, on rural Interstate highways, of $2,625 \times 10^6$ miles, or 1.70 percent of the U.S. total. If Washington is considered representative of the United States, extrapolating from the state total, and adjusting for differences in average Interstate rest area spacing (U.S., 44.4 miles; Washington, 35 miles), would yield a national total of 386 million Interstate rest area stops, within 5 percent of the total estimated in (1).

Table 6. Average daily traffic by functional classification—rural highways. (Source: Ref. 14)

ADT Class	Highway Mileage	No. of RA Stops (millions)
Interstate Routes		
< 6000	7833	27.4
6000 - 9999	7348	51.5
10000 - 19999	11757	154.5
≥ 20000	5823	135.2
Other Principal Arterials		
< 1000	4973	1.2
1000 - 1999	15687	11.2
2000 - 2999	13698	16.2
3000 - 9999	37758	116.5
10000 - 14999	4966	29.5
≥ 15000	3637	27.6

DEMOGRAPHIC ATTRIBUTES OF REST AREA USERS

Data on user demographics are not usually collected by states as part of routine rest area studies. Studies which report these data generally rely on postcard or other types of voluntary participation surveys—e.g., Virginia (*12*), Nebraska (*13*). Such self-selected samples are known to be subject to bias. The following summary of rest area user demographics is therefore mainly based on the interviews and visual observations made by KLD personnel at 13 rest areas supplemented by other available data. This data base consists of visual observation of 1,630 rest area users. Of these, 817 were interviewed to obtain additional information.

Vehicle Occupancy

Vehicle occupancy data are based on visual observation of approximately 10,000 vehicles entering the 13 rest areas studied during the periods of data collection. For these vehicles, average occupancy was 2.2, and 32.8 percent of all vehicles observed had only a single occupant. Occupancy data, disaggregated by vehicle type (excluding buses), are given below. High and low values for individual rest areas as well as values for all rest areas are shown.

Vehicle Type	Avg. Vehicle Occupancy			% Single Occupant Range		
	High	*Low*	*Mean*	*High*	*Low*	*Mean*
Passenger car	2.5	1.7	2.3	53.2	12.5	26.6
Recreational vehicle	9.0	2.0	2.8	26.7	0.0	13.2
Truck	1.5	1.0	1.3	100.0	64.3	77.9
Other	4.4	1.4	2:2	68.8	0.0	45.5
All	2.4	1.6	2.2	58.9	12.5	32.8

Comparable Virginia data yield slightly lower occupancy rates:

Vehicle Type	Mean Vehicle Occupancy Rest Areas	Welcome Centers
Passenger cars	1.80	1.90
Light trucks	1.25	1.30
Tractor-trailers	1.05	1.05
Recreational vehicles	2.05	2.10

The Virginia study also noted a seasonal effect on vehicle occupancy. Data collected in the summer months indicated that passenger car occupancy was approximately 12 percent higher than it was in the spring and autumn. This difference, most likely, reflects the larger proportion of recreational, family travel in the summer months.

A difference in traffic stream composition probably accounts for the fact that vehicle occupancy was lower in the nighttime hours as noted in the Nebraska study. While over 24 hours, passenger cars contributed 72.2 percent of all entering traffic, this percentage dropped to 59.5 percent during the 10:00 PM to 6:00 AM period. Overall, the Nebraska 24-hour average

occupancy averaged 2.19 and ranged between 2.10 and 2.26 for the eight rest areas studied. For the 6:00 AM to 10:00 PM period average for all rest areas studied occupancy was 2.27. For the 10:00 PM to 6:00 AM period, this figure dropped to 1.79.

Two percent of all vehicles, and 2.3 percent of all passenger cars observed by KLD, contained persons with apparent ambulatory handicaps. Five percent of all passenger cars contained pets. These percentages, however, varied widely between individual rest areas exhibiting the following ranges: percent vehicles with handicapped, 0 – 4.2; percent vehicles with pets, 0 – 8.9.

The low values for each of these variables were recorded at rest areas on Interstate connectors near large urban aggregations in New York, New Jersey, and Virginia where business travelers predominated.

The responses to the Nebraska postcard survey indicated that 6.0 percent of all vehicles had occupants with ambulatory handicaps. The summary of the survey indicated a total of 149 pets for the 1,139 replies received.

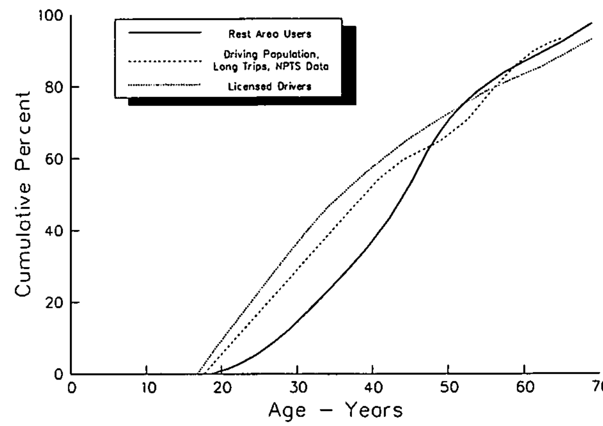

Figure 3. Age—cumulative distribution. (Legend: Solid line on figure designates rest area users; dashed line, driving population, long trips, NPTS data; dotted line, licensed drivers.)

Age and Sex

The distribution of rest area users by age and sex is shown in the histogram of Figure 2. The parameters of this distribution are shown below:

	MALE	FEMALE	ALL
Mean	43.7	41.5	43.0
Median age	43.5	40.0	40.0
Percent > 64 years	8.8	5.8	7.9
Percent > 70 years	3.0	1.8	2.6

Figure 3 shows a cumulative distribution by age. Also shown are comparable cumulative distributions, by age, for all licensed drivers and for the long trip driving population. The close correspondence of these distributions is obvious. It should, however, be noted that drivers under 40 appear to be somewhat underrepresented in the rest area user population.

KLD's observational data showed that the drivers of 71 percent of the vehicles entering rest areas were male. For trips over 100 miles, men drive 74.2 percent of the total mileage on these trips according to NPTS data.

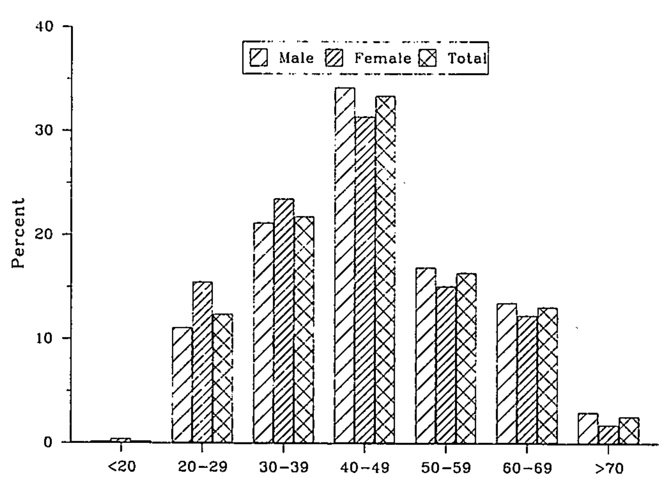

Figure 2. Distribution by age and sex.

Observational data for eight rest areas in Nebraska indicated that 56.2 percent of all rest area users, drivers and vehicle occupants, were male. This percentage was remarkably uniform over the eight locations ranging from 54.2 to 58.2. The same time of day differential previously noted for vehicle occupancy can again be observed. The percent male figure was 55.5 for the 6:00 AM to 10:00 PM period and 61.1 for the 10:00 PM to 6:00 AM interval.

Children, with an apparent age of 12 years or less, were observed in an average of 19.2 percent of all vehicles and 21.5 percent of all passenger cars. The percentage of children in passenger cars, by rest area, ranged from 1.6 to 36.0 percent. The average number of children in vehicles containing any children was 1.8 and ranged from 1.0 to 2.5. These numbers indicate that approximately 15 percent of all rest area users were children.

Travelers interviewed were engaged in trips ranging from 9 to 2,500 miles in length with a mean of 332 miles (median—260 miles).

The number of trips of over 100 miles taken by respondents ranged from one per year to one per day. The median response was:

VEHICLE TYPE	MEDIAN NUMBER OF TRIPS OVER 100 MILES PER YEAR
All	10
Cars	6
RV	5
Trucks	250

The distribution of trip purpose for trips with known purposes is: business, 35 percent; pleasure, 54 percent; and other, 11 percent.

For the 10 rest areas at which this information could be collected from most of the respondents, the proportion of all trips characterized as business trips showed considerable variation. The highest proportion, as expected, was noted near major urban aggregations.

USE OF REST AREA FACILITIES

Rest area facility use, by vehicle class, is given in Table 7. Only seven of the available services and facilities were used by 5 percent or more of the rest area visitors. Differences in use percentage between vehicle classes are minor. Similarly, only small differences can be noted when the data are disaggregated on the basis of sex, age, presence of children or trip purpose. The only significant difference was in telephone use due to a high rate (almost 25 percent) of telephone use by business travelers who were mostly male, relatively young, and unaccompanied by children. Furthermore, most truck drivers were classified as business travelers.

The data shown in Table 7 imply that most rest area users use more than one facility or service during their stop. The principal reason for stopping was identified as either "use toilet" (49.3 percent of users) or "rest/stretch" (32.3 percent of users) by over 80 percent of all users. Only three other reasons were cited as "principal" by more than 2 percent of all rest area users: "use telephone" (4.7 percent of users); "use water fountain" (3.2 percent of users); and "eat" (2.3 percent of users).

Detailed, disaggregate analyses of these data showed the following:

1. There appears to be no major effect of "time since last stop" on rank ordering or on use frequencies. The frequency with which "use telephone" is mentioned appears to be inversely correlated with time since last stop probably because business travelers tend to stop at shorter intervals.
2. There is no significant difference in the distribution of primary stopping reasons between the sexes except for telephone use.
3. Analyses by age group (10-year interval) and by the over/under 65 distribution revealed no significant differences except for higher telephone use by younger travelers.

Table 7. Facility use by vehicle class (from KLD survey). Note: Table entries are percentages of total sample.

	Vehicle Class				
Facility	Passenger Cars	RV	Trucks	Other	All
Use Toilet	87.0	75.5	74.4	84.4	85.1
Rest/Stretch	48.2	54.7	61.5	58.9	50.5
Water Fountain	13.5	15.1	15.9	10.0	13.6
Eat Own Food	9.2	11.3	1.5	2.2	8.0
Use Telephone	5.1	5.7	19.0	14.4	7.2
Car Services	6.7	13.2	5.1	3.3	6.5
Consult Map	5.1	1.9	4.1	7.8	5.0
Exercise Pets	4.1	11.3	0.0	3.3	3.8
Change Drivers	4.1	0.0	0.5	2.2	3.6
Check Load	2.2	3.8	13.3	4.4	3.6
Bought Food/Drink	2.7	1.9	4.6	2.2	2.9
Exercise Child	3.0	7.6	0.0	0.0	2.7
Other Information	1.9	0.0	2.6	0.0	1.8
Change Diapers	1.3	0.0	0.0	0.0	1.1
Sanitary Disposal	1.1	5.7	0.5	0.0	1.1
First Aid/Medical	0.6	0.0	0.0	0.0	0.5
Cooked Food	0.4	0.0	0.0	0.0	0.3

4. The presence of children in a vehicle leads to significantly higher percentages of food-related primary stopping reasons and to significantly lower telephone use.
5. Business travelers, as previously indicated, listed telephone use as the primary reason for stopping to a significantly greater degree than other travelers. Business travelers also cited toilet use as a significantly less important reason for stopping. This may be because of the shorter interval between stops of this type of traveler.
6. Truck occupants showed significantly higher percentages of telephone use and significantly lower percentages for toilet use and for the food and drink related items.

In interpreting the data of Table 7, it should be emphasized that:

1. Data collection, for the most part, was undertaken in the summer, during daylight hours, and under generally good weather conditions. Data collected on the few days with rain and cool weather showed a sharp decrease in the percentage of respondents citing "rest/stretch" as the primary reason for stopping. However, most travelers will take an opportunity to rest even if stopping for other reasons.
2. No data collection was done under extreme climatic conditions such that weather (extreme heat or heavy precipitation), roadway surface, or visibility conditions would be an impetus for stopping.
3. Data on "Food/drink—bought at RA" were constrained by the fact that vending machines, the only legally permissible means of dispensing food and drink in Interstate highway rest areas, were only available at 6 of the 13 areas in which data were collected.

Except for telephone use, the relative ranking of reasons for stopping shown in Table 7 was replicated by the respondents to the telephone survey. This low rate of mention for telephone use as the principal reason for stopping is probably because of the low percentage of business trips included in that sample. Each respondent was asked only about a single (i.e, most recent) trip. There are more business trips than business travelers, because business travelers, including truck drivers, tend to make more frequent trips. The rest area survey, which sampled trips, will, therefore, include more business trips than the telephone survey which sampled travelers.

Nebraska and Virginia data generally show the same rank ordering for facility use and for principal stopping reasons, although there are some differences in the specific proportions. These data are given in Table 8. In comparing survey and observational data, it must be kept in mind that observational data deal with individual rest area users, while survey data refer to the use of a facility by one or more members of a travel party.

The category "rest/stretch" is not included in Part B of Table 8 because it cannot be determined by visual observation (Nebraska data). The mere act of getting out of a vehicle may be for that reason or may be incidental to the use of another facility. Insofar as the Virginia data are concerned, three separate categories (Parking Lot, 16 percent; Paths/Grounds, 7 percent; and Benches, 4 percent) may include "rest/stretch." Because multiple replies were tabulated, i.e., more than one activity per respondent, and because no cross-correlations of the data which could be used to eliminate duplications are available, the overall proportion of "rest/stretch" cannot be determined.

Table 8. Use of rest area facilities—Nebraska and Virginia data.

		Nebraska	Virginia
A.	Principal Reason for Stopping (percent)	(1)	(1)
	Restroom	74	82
	Water Fountain	19	(3)
	Eat	16	2
	Information	12	4
	Telephone	8	2
	Rest, Relax, Stretch	21	7
	Change Drivers	(4)	1
	Miscellaneous/Other	6	2
	Exercise Pet	8	(3)
	Trash Disposal	14	(4)
	Exercise Children	3	(4)
	Car/Truck Trouble	3	(3)
	See Sculpture	2	(5)
	N	1139	1947
B.	Facility Actually Used (percent)	(2)	(1)
	Restroom	74	97
	Water Fountain	12	44
	Eat	9	9
	Information	8	20
	Exercise Children	2	(4)
	Exercise Pets	2	4
	Telephone	2	12
	See Sculpture	2	(5)
	Trash Disposal	(6)	16
	N	8827	1937

Notes:
(1) Survey Data
(2) Observational Data
(3) Less than 1.0 percent
(4) Alternative not included on survey form
(5) Not applicable
(6) Not reported

TIME IN REST AREA

The parameters of the distribution of time spent in rest areas for the two surveys made by KLD are shown below:

	Rest Area Field Surveys	Telephone Survey
No. of rest areas	9	–
No. of data points	2885	447
Mean time in rest area (min)	11.4	19.2
Standard deviation (min)	12.87	26.7
Standard error (min)	0.24	1.27
Median (min)	8	15
Mode (min)	5	15
Minimum	0 hr 01 min	0 hr 02 min
Maximum	3 hr 31 min	6 hr 0 min
Pct. > min in RA	19.0	31.8
Pct. > 30 min in RA	6.8	8.1
Pct. > 60 min in RA	0.9	2.0

Disaggregation of the field survey data by vehicle class is:

Vehicle Class	Time
Cars	11.0
Trucks	12.1
Recreational vehicles	19.5

The dwell times given by the respondents to the telephone survey are significantly higher than those obtained from actual measurements at rest areas. It is probable that the telephone survey data are less reliable because of several factors: (1) they depend on the recollection of the respondents of an event which may be as much as one year in the past; (2) there was a definite tendency to round up to the nearest 5-min or 10-min interval—also 94 percent of all replies were even multiples of 5 min; and (3) there is a possible tendency to report the last "substantive visit" to a rest area and suppress short stops.

The pattern of extended stays in rest areas is detailed in Table 9. Disaggregate analyses yielded the following:

1. The mean dwell time, by rest area, ranged from 9.5 to 14.1 min and the median time ranged from 6 to 9 min.
2. Analysis by vehicle class shows that recreational vehicles stay almost 75 percent longer in rest areas than other vehicle types (19.5 min versus 11.0 min) and also have a two to three times higher probability than passenger cars of a stay exceeding 15 min.
3. The time that a vehicle enters the rest area has a significant effect on the length of stay. There is a pronounced lunch time peak; almost one-third of all vehicles entering between noon and 1 PM stay more than 15 min.
4. There is no significant difference in dwell time between weekday and weekend travelers.
5. There are significant differences between in-state and out-of-state registered vehicles with out-of-state vehicles staying longer.

A number of states have reported time in rest area studies. Among them, data from Nebraska (*13*) are particularly useful because they are disaggregated not only by vehicle type but also by time of day for an entire 24-hour period. These data are shown graphically in Figure 4 and are summarized below.

Time Period	Mean Time in Rest Area (*Minutes*) Vehicle Class			
	Cars	*Trucks*	*RV*	*All*
4AM–10AM	13.8	16.8	16.6	14.7
10AM– 4PM	13.7	18.1	19.6	15.1
4PM–10PM	12.1	22.4	22.0	15.3
10PM– 4AM	33.4	72.6	67.1	47.9
24 Hours	15.5	30.4	23.6	19.3

The Nebraska data appear to show higher dwell times during the day than the KLD data cited earlier. These discrepancies are probably the result of the following factors: (1) pickups are included with cars in the Nebraska data sets; they are considered as trucks in the KLD data; and (2) trip length, trip purpose, and driver demographics differ between the two data sets. For instance, the KLD data included 26 percent out of state registrations; the comparable figure for the Nebraska data is 74 percent.

Table 9. Extended stays in rest areas (KLD field data).

Percent Exceeding Stated Time

Entering Hour	15 min	30 min	60 min
Before 8AM	11.0	3.0	1.0
9AM	16.6	3.7	0.9
10AM	12.4	3.5	0.6
11AM	19.9	6.1	0.7
12 Noon	30.2	14.7	2.3
1PM	20.8	8.3	1.2
2PM	21.3	6.3	0.5
3PM	13.5	5.8	-
4PM	18.5	5.6	0.8
5PM	14.4	4.5	-
After 6PM	9.9	2.0	-

Percent Exceeding Stated Time

Vehicle Class	15 min	30 min	60 min
Cars	17.5	6.3	0.8
RV	45.3	21.1	4.2
Trucks	25.0	5.7	0.4
Other	21.4	-	-

Day	15 min	30 min	60 min
Sat., Sun.	17.6	6.3	0.8
Other	19.6	7.0	0.9

Registration	15 min	30 min	60 min
In-State	16.7	5.7	0.8
Out-of-State	29.2	10.7	0.9

The most striking aspect of the Nebraska data is the long average time for the night hours. These probably reflect substantial sleep stops by a significant proportion of truck and recreational vehicle drivers. Nebraska allows a maximum 5-hour stay in a rest area.

Virginia data are restricted to daylight hours but include repeat measurements, of the same locations, during different seasons. The Virginia sample also included both rest areas and welcome centers.

	Mean Dwell Time in Rest Areas (Minutes)	Mean Dwell Time in Welcome Centers (Minutes)
Fall		
Passenger cars and light trucks	8.8	10.2
Trucks	14.8	11.9
Recreational vehicles	13.9	17.9
Spring		
Passenger cars and light trucks	9.0	11.3
Trucks	18.6	15.1
Recreational vehicles	17.8	18.5
Summer		
Passenger cars and light trucks	10.0	11.8
Trucks	16.6	16.3
Recreational vehicles	16.5	17.0
Total		
Passenger cars and light trucks	9.2	10.9
Trucks	16.5	14.0
Recreational vehicles	14.8	17.9

A seasonal difference can also be seen in Michigan data.

	Winter	Summer
No. of rest areas	6	6
Mean time in rest area:		
Cars and motorcycles	6.7 min	10.1 min
Trucks, busses, and RVs	12.6 min	14.6 min

The differences between vehicle classes, and between winter and summer stops, are striking.

The longer average time in rest areas for trucks and RVs implies a lower turnover rate for parking spaces in the truck lot than in the passenger car lot. This can best be illustrated by the Nebraska data. For the eight rest areas from which data were collected the following aggregates can be computed:

Vehicle Class	Percent of Total Vehicles	Percent of Total Occupancy
Cars	69.9	56.3
Trucks	19.6	30.8
RVs	10.5	12.9

Vehicles using the truck/RV parking lot thus constitute 30 percent of the total number of vehicle traffic streams, but account for almost 44 percent of total occupancy. The effect of this imbalance is confirmed by data which show that design truck parking capacity was exceeded for 28 percent of all hourly observations while the car parking lot never reached capacity. This situation is especially serious during nighttime hours. For the 10PM to 6AM period, cars constituted 60 percent of the traffic stream but contributed only 43 percent of occupancy. During this same interval truck/RV parking lot use was noted to exceed capacity 46 percent of the time. Trucks, other than 2 axle 4 tire, and busses jointly contribute only 19.4 percent of the total rural Interstate VMT (*14*).

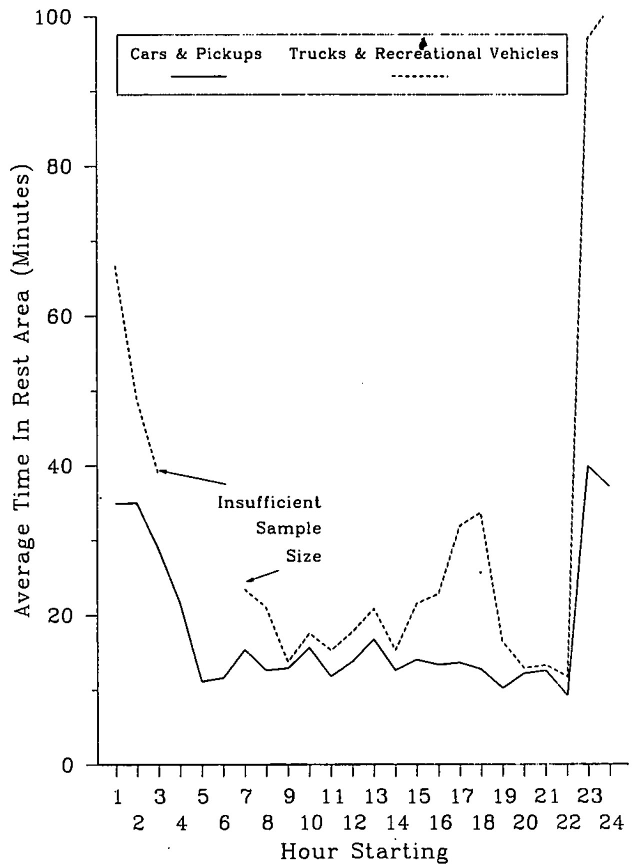

Figure 4. Average time in rest area.

Where parking lot capacity is exceeded, vehicles stop on the approach ramp and even on the main-line deceleration lanes. The accident potential of such stopping, especially during hours of darkness, is obvious.

HIGHWAY TRAVELERS STOPPING BEHAVIOR

The normal average distance, or time, between stops, as indicated by the rest area interviews was 130 miles or 2 hours, 18 minutes, respectively. Significantly lower intervals were noted by business travelers, RV users, and older persons. Truck drivers selected considerably higher intervals. The comparable data from the telephone survey was 138 miles and 2 hours 34 minutes.

For the specific trip during which respondents were interviewed, the parameters of the distribution of time since the last stop were:

Mean	2 hours 1 minute
Median	1 hour 30 minutes
Mode	1 hour, 2 hours
Percent 1 hour or less	34.4
Percent 2 hours or less	67.6
Percent 3 hours or less	86.5
Percent 4 hours or less	93.6

The mean elapsed time since the last stop was remarkably uniform across most of the subgroups analyzed. There was a marked difference between pleasure (higher) and business (lower) travelers and recreational vehicles had a generally longer elapsed time than passenger cars. Somewhat surprisingly, both female drivers and travel parties that included children averaged longer intervals than did other demographically defined travel groups.

Analysis of the data concerning the average interval between stops at rest areas showed, for the entire sample, that travelers are more likely to make stopping decisions on the basis of time than on the basis of distance. More than three quarters of all travelers plan to stop at predetermined time intervals; only about 60 percent of travelers consider distance. The modal interval between stops, for those travelers who responded that they have adopted a definite interval, is about 2 hours or about 110 miles or less.

As seen above, the majority of travelers thus appear to stop at fairly regular intervals. A direct question concerning decisions on where to stop elicited the response "convenience" from more than 80 percent of all respondents.

Furthermore, 73 percent of all respondents had already planned their next stop. This percentage was highest for truck drivers and business travelers, and lowest for RV users and pleasure trips.

Respondents to the telephone survey were asked under which conditions they would significantly alter the interval between stops. Responses indicated that the presence of children or pets, or inclement weather, has a significant effect of shortening the distance between stops. No factor has a comparable effect on lengthening the between stop interval.

Telephone survey respondents were also asked for their preference in making discretionary stops when the location of the stop is not constrained by availablitity of services or goods (e.g., stops for gas or buying food). The distribution of responses is shown below:

ACTION	PERCENT
Leave the highway to find a local town	29.0
Wait for the next rest area	59.8
Stop along the shoulder	5.4
Go to the next truck stop/full service area	2.6
Not sure	1.6
Do not stop except for food or gas	1.6

Less than 3 percent of these respondents indicated that they had not stopped, and would not usually stop, at the rest areas. These respondents indicated that they either did not stop at all, except for food and gas, or cited concerns with aspects of personal security.

As a corollary to this question, both groups of respondents were asked what they would do if a rest area were not available. The responses are given in Table 10. Of particular importance is the proportion of persons who would stop on the shoulder. Correcting for "not sure" responses, and weighing each survey by the number of responses, the joint percentage for this reply is 13.4. Among those respondents to the telephone survey who do not prefer rest areas for discretionary stops, 14.6 percent would select a shoulder stop in preference to leaving the route. Furthermore, 22 percent all truck drivers would stop on the shoulder.

Because minimizing potential shoulder stops is one of the major potential safety benefits of highway rest areas (see Chapter Four, "Indirect Safety Benefit Analyses"), a closer analysis of this question was made with the following results:

1. That truckers and RV users are both more likely to stop on the shoulder and less likely to pull off the route than passenger car drivers probably reflects the physical difficulty of navigating local off-system streets and the cost and time penalties of the extra distance traveled. Other data show that approximately 8 percent of all semi- and full-trailer trucks would pull off the interstate route, thereby possibly adding to local traffic problems.

2. There is considerable variability between the responses received to this question at different rest areas. These differences are, to a great extent, explainable by location and other factors. For instance, the average trip distance for respondents indicating "keep going" is 294 miles; for the other three substantive responses, these distances are as follows: go to next rest area 352 miles, pull to side of road—356 miles, and pull off route—343 miles. Also, there is a close correlation between distance to the next rest area and the percentage of respondents who indicated that they would take that action.

3. The proportion of travelers that would stop on the shoulder is independent of the facilities used at the rest area except that persons who stopped to check their vehicles or its load are almost twice as likely to stop on the shoulder if they could not use the rest area.

4. There is no correlation between the probability of stopping on the shoulder and time since last stop or usual distance or time between stops. The probability of going to the next rest area, however, appears to decrease with both increased time since last stop and increased distance or time between stops.

Table 10. Action if rest area not available.

A. Rest Area Interviews

Action	Percent
Keep going non-stop	25.1
Go to next rest area	28.5
Pull to side of road	12.4
Pull off route	28.8
Other	2.2
Don't know	3.1

B. Telephone Survey

Action	Percent
Not stopped at all	17.3
Drive to the next rest area	25.8
Gone to the next full service area	15.1
Looked for a truck stop	5.0
Gone into the next town	19.8
Stopped on the shoulder	14.4
Other	0.6
Don't know	2.1

5. None of the demographic factors investigated appears to have a significant effect on traveler's action if the rest area were not available.

REST AREA USERS ATTITUDES AND OPINIONS

Rest areas are a public service furnished by the government and are ultimately paid for, directly or indirectly, by the users as well as by the population at large. Consequently, rest area users' opinions of, and attitudes towards, rest areas are an important input into the decision process.

Rest Area Quality

Both surveys requested quality ratings of both rest areas in general and of specific rest areas. The specific questions concerned the rest area in which the interview took place or the last rest area visited for the telephone survey. A number of states have elicited such opinions from motorists as part of rest area surveys. Most of these surveys were made at welcome centers, or other fully staffed tourist information facilities, and thus are not strictly comparable. These surveys, as well as the few others made at regular rest areas, resulted in generally favorable ratings with complaints limited to specific perceived defects in maintenance or the absence of specific facilities (e.g., vending machines).

The present study also elicited generally favorable comments. The proportion of all travelers interviewed that gave a specific rest area a positive rating approaches 90 percent for the entire sample. All of the individual rest areas, with one exception, rated 80 percent or higher. There were no differences in these responses among the subgroups analyzed except that business travelers gave the rest areas a somewhat higher, and older drivers a marginally lower, rating than did the average respondent. For the rest area program as a whole, responses generally follow the same pattern except that the individually computed positive rating percentages are generally somewhat lower.

In the telephone survey respondents were asked to rate the last rest area visited on an 11 point scale ranging from very bad (0) to excellent (10). Separate responses were requested for in-state and out-of-state rest areas. The mean ratings, for all respondents, was 7.4 for in-state rest areas and 7.2 for those out-of-state. There is no statistical significant difference between these means. When responses were stratified by census regions, respondents from the Northeast rated their within-state rest areas significantly lower than did respondents from the other three regions.

However, no conclusions should be drawn from this highly subjective process except to note the general overall approval of rest areas. This subjective element is illustrated by the fact that there was no correlation between relative rankings of the five states represented in both samples. In fact, the "best" and "worst" of these five states exchanged places between surveys. Similarly, the rankings of states, on the telephone survey, by in-state and by out-of-state drivers were completely uncorrelated.

Both the Nebraska and Virginia surveys referred to earlier included space for comments. In both cases, the overall approval rating was over 80 percent with isolated adverse comments generally referring to the size and/or cleanliness of bathroom facilities.

Rest Area Frequency and Spacing

The discussion in Chapter Two, under "Number and Spacing," has shown that the existing average spacing for rural Interstate system rest areas is 44.4 miles with the average spacing within individual states ranging from 25 to 105 miles. This average figure is of the same general magnitude as the generally accepted recommended spacing of 40 to 50 miles.

Respondents to the surveys generally tended to agree with these spacing criteria. The cumulative distribution of desired rest area spacing is shown in Figure 5. The parameters of this distribution are given as follows:

		INTERVIEWS	TELEPHONE
Number of responses		778	460
Mean, miles		63	66
Standard error of the mean, miles		1.31	2.14
Median, miles		50	50
Mode, miles		50	50
Maximum, miles		250	300
Minimum, miles		10	5
Pct. less or equal	50 miles	56.7	59.1
	75 miles	71.0	73.3
	100 miles	91.4	91.3

The degree of agreement between the two data sets is striking. The only significant difference between defined subgroups on the interview sample was that RV users were willing to accept a longer rest area spacing. The telephone survey revealed a significant regional difference. Respondents from the Northeast preferred a significantly lower spacing, while respondents from the West preferred longer spacings. These differences can, probably, be attributed to different average trip lengths between these regions.

It would, however, appear to be a mistake to use these data as indicating an optimum rest area spacing for the Interstate System. The responses were made in terms of individual trip-making behavior and indicated the minimum stopping interval of drivers. At currently prevailing highway speeds the preferred distance intervals translate into time intervals of slightly more

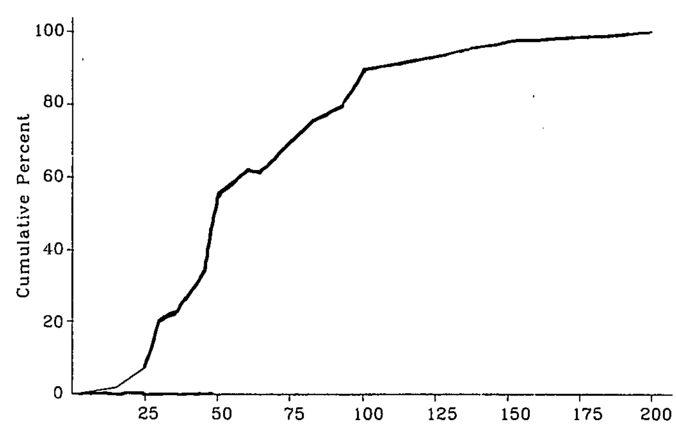

Figure 5. Desired rest area spacing.

than one hour. Any individual driver probably would not like to stop more often.

From another point of view, however, such a spacing would imply a maximum delay of one hour after a decision to stop has been made. Although the question was not posed in these terms, such a delay is probably not acceptable, especially when the principal reason for rest area stops is considered and in view of the fact that over 80 percent of respondents indicated that decisions on where to stop were made on the basis of convenience.

To a question on the adequacy of the current number of rest areas respondents replied as follows: too few, 41.9 percent; about right, 54.0 percent; too many, 0.5 percent; no opinion, 3.7 percent.

In general, truck drivers and RV users, business travelers, and older persons would like more rest areas.

Perceived Personal Security

As indicated earlier in this chapter, the results of every survey examined shows an extremely high positive opinion of rest areas in general. Adverse comments are generally restricted to capacity or maintenance problems of specific facilities, e.g., toilets; or the lack of some desired service, e.g., vending machines. However, users' attitudes concerning perceived personal security are somewhat more negative.

Although 99 percent of all respondents indicated that they felt safe and secure during daylight hours, only slightly more than half expressed no reservations about stopping at night. The percentage that definitely feel safe at night ranged from 42 to 62 among the 13 rest areas. In three rest areas, one each in Michigan, New York, and Virginia, less than half of the respondents felt safe. Particularly low percentages were recorded, as could be expected, by older travelers (34 percent) and by women (43 percent), while high percentages were registered by truck drivers (66 percent) and business travelers (68 percent).

A further analysis relating vehicle occupancy to perceived personal security showed the following percentages (eliminating no opinion responses) of respondents who felt *unsafe* or *insecure.*

Respondent Group	All Respondents		Women Only	
	N	%	*N*	%
Single adult/no children	271	31.4	39	57.1
Single adult with children	16	53.8	5	100.0
More than one adult	530	43.5	160	49.3

Although these perceived security problems may not correspond to actual conditions (see the discussion of rest area problems and security in Chapter Two, under "Operational Problems and Security"), the fact that these perceptions exist does act as a deterrent to rest area users. A perceived problem may thus turn into a real one if needed rest area stops, to combat fatigue at night, are not made.

Private Business Involvement

The previously referenced AASHTO survey of state highway agencies indicated the following range of responses to the question, "Does your state favor commercial development of rest areas/welcome centers?": yes, 24 percent; no, 22 percent; maybe 48 percent; no opinion, 6 percent.

Table 11 summarizes the attitudes of respondents to both surveys to six different types of private business activities in highway rest areas. There were no significant departures from these percentages for any demographic disaggregation of the data. The difference between the two response sets is striking and difficult to explain.

The only difference was the relative placement of this question within each of the two surveys. For the interviews, the question was asked before the topic of rest area financing was introduced; in the telephone survey, this order was reversed. Another possible explanation is that there may have been some confusion, in the minds of telephone survey respondents, between highway rest areas and toll road service plazas.

The telephone survey added vending machines to the list of potential private business involvement with the following results: vending machines—food and drink, 86.0 percent approval; vending machines—other items, 58.8 percent approval.

This question was not asked during the interviews because the presence of existing vending machines in some, but not all, of the rest areas would have biased the results.

A question, in the Virginia study concerning additional amenities desired, showed that well over 50 percent of the respondents in rest areas that did not have vending machines would like to have this service.

The opposition to commercial business activities in rest areas noted in the interview survey parallels the results of a California survey made in 1972 (*15*). That survey showed 44 percent of the motorists interviewed were opposed to such activities. Reasons for opposition included the opinion that there are enough commercial stopping opportunities (30 to 40 percent), fear that commercial businesses would lead to overcrowding (30 percent), dislike of the commercial atmosphere (20 percent), and a preference for a park-like environment (20 percent).

Of the 39 percent of the motorists in that survey who favored commercial development at rest areas 64 percent desired the presence of restaurants (or the availability of food and snacks), 46 percent wanted gas stations, 13 percent wanted motels/hotels, and 2 percent wanted gift shops.

In 1984, Caltrans and the California Transportation Commission requested comments from the members of 13 traveler-related organizations regarding rest areas (*16*). Seven of the organizations provided 1,200 completed questionnaires. Of the respondents, 86 percent favored commercial development at a

Table 11. Private business activities in rest areas.

Business Type	Interviews Yes	Interviews No	Interviews Uncertain	Telephone Services Yes	Telephone Services No	Telephone Services Uncertain
Restaurant - Fast Food	30.8	61.6	7.6	56.6	42.0	1.4
Restaurant - Sit Down	29.9	62.4	7.7	50.8	47.8	1.4
Gas & Other Automotive Services	30.1	61.4	7.8	67.8	31.0	1.2
Shopping - Travel Related Goods	28.0	63.9	8.1	47.5	50.1	2.4
Shopping - Local Handicrafts & Souvenirs	27.4	64.8	7.8	41.4	57.5	1.4
Advance Hotel Reservations	29.3	62.7	8.0	57.3	39.5	3.2

rest area. Of these, 80 percent wanted gas and automobile service stations, 76 percent wanted take-out restaurants, 66 percent wanted sit-down restaurants, 58 percent wanted vending machines, 30 percent wanted motels, 30 percent wanted gift shops, and 26 percent wanted catering trucks.

It must be pointed out that the sponsoring organization did not have control over the sampling process. The resulting sample, which may have been self-selected, could therefore have been biased. The bulk of the responses was, apparently, received from one organization representing recreational vehicle owners.

Paying for Rest Areas

Many benefits that have been postulated for highway safety rest areas, especially those concerning highway users comfort and convenience, are not quantifiable in monetary terms. A standard economic methodology to assess the impact and importance of this class of benefits is to determine the willingness on the part of potential beneficiaries to pay for the services being considered. Questions dealing with this topic were therefore included in the surveys.

A general question (asked only on the telephone survey) on whether tax revenues should be used to construct and operate rest areas elicitated the following responses: yes, 93.8 percent; no, 4.4 percent; not sure, 1.8 percent.

More specific questions, covering different possible financing mechanisms, however, did not result in such near unanimous agreement. The percent *positive* responses were as follows (responses of "not sure" or "uncertain" omitted):

	Interviews	Telephone Survey
Increase in general taxes	60.4	53.2
Increase in vehicle or gas taxes or fees	60.0	47.6
Purchase of an annual user pass	–	38.2
User fee for each visit	38.8	50.1

A possible explanation for the differences in response percentages between the two surveys is the distinction between an actual and a hypothetical experience. Persons interviewed had actually stopped at a rest area and used one or more of the facilities available; respondents to the telephone survey, interviewed at home, had to think in terms of a somewhat remote past or future rest area stop.

Respondents generally were in favor of increasing taxes as an alternative to the closing of rest areas. There were no significant differences between the two types of taxation except in Michigan, with a sharp preference for general taxes and in Virginia where the opposite was the case. Because taxes are paid by state residents, the analysis was repeated limited to in state vehicles only. Somewhat surprisingly, these in-state percentages were somewhat higher, considerably so in the case of motor vehicle taxes in Virginia.

Analysis by trip and demographic stratification variables for the interview survey yielded the following results:

1. Truckers were significantly less inclined, while RV users were somewhat more inclined, than the average to increased taxes. Both truckers and RV users were less inclined than the average, towards user fees.

2. There are no significant differences of opinion for any of the other stratifications investigated except that older drivers and single adults with children were the only groups in which majorities favored user fees.

3. Almost 62 percent of all respondents were willing to pay one of the two types of taxes mentioned.

4. Less frequent travelers were more willing to pay extra taxes, as can be seen from the table below, which shows the average number of trips per year for the entire sample stratified by willingness to pay.

	Avg. Number of 100 Mile Trips Per Year	
	Willing to Pay	*Unwilling to Pay*
Mean	52	76
Median	8	12
Mode	2	250

These figures reflect the large percentage of "unwilling to pay" among responses from truckers.

5. Among those respondents indicating that they would be willing to pay a user fee, about 73 percent preferred a flat fee (per visit) to fees for individual services.

A key, follow-up question, asked all respondents to indicate the amount they would be willing to pay. The wording of the question was slightly different on the two surveys: In the rest area interviews, respondents were asked to indicate the maximum amount that they would pay from a preselected list (ranging from $0.25 to more than $3.00); in the telephone survey, respondents were asked to name an amount without any guidance or constraint.

Although only 39 and 50 percent, respectively, of the respondents had indicated that they were willing to pay a user fee to prevent rest area closings, 46 and 84 percent, respectively, indicated that they would pay some fee if such a fee was actually imposed. The average maximum amount that respondents would be willing to pay, together with the standard error of that average, is shown below. In computing these parameters, respondents who did not answer, who indicated that they were not sure, or who stated the amount would depend on the services offered, or on other factors, have been omitted. These parameters were computed in two separate ways—once for all respondents and once only for those who gave a definite nonzero response.

	Number	Mean	Standard Error
Telephone Survey:			
All responses	440	$0.82	$0.047
Nonzero amount only	368	$0.98	$0.052
Rest Area Interviews:			
All responses	587	$0.36	$0.026
Nonzero amount only	269	$0.78	$0.044

There were some differences in these amounts between demographically defined subgroups. These, however, were relatively small and not consistent between the two surveys. It is worth noting, however, that the interview data show that travelers with children were willing to pay significantly higher amounts. Although a smaller percentage of truckers named a definite amount (30 percent as against 46 percent for the whole sample), the average amount for those that did, was considerably higher. There were no significant differences when these data were stratified on the basis of the principal reason for stopping. Persons who had indicated a willingness to pay extra taxes also named higher maximum user fees, although the proportion naming nonzero amounts was somewhat smaller.

The differences between the surveys, in both the proportion that would pay a user fee and in the amount of that fee, are probably correlated with the difference between the two samples in the willingness to pay taxes. It is possible that the rest area users, who were in a facility clearly identified as a government function, believed that the user fees would be imposed as an addition, and not as an alternate, to taxes.

It is also likely that the proportion of all travelers who would actually refuse to use a rest area if a nominal fee were imposed will be considerably smaller than that which responded to this hypothetical question. However, that is not the point. The questions were asked not to decide what the maximum fee the "market would bear" but rather as a surrogate for the value, in monetary terms, of the rest area to the traveling public. Depending on how these data are interpreted this value probably lies somewhere in the range of $0.40 to $1.00 per visit.

FUTURE TRENDS

Overall rest area use and the types of services desired and used are a function of a number of variables including traffic volume and traffic stream composition; driver and vehicle population characteristics; route, abutting land use, and general area characteristics; trip length and trip purpose distributions; frequency, characteristics, and accessibility of competing stopping opportunities; rest area spacing, location, characteristics and time of operations; and miscellaneous social and economic factors.

Changes in any of these can be expected to have an effect on rest area use patterns and rest area user attributes. The remainder of this chapter will be devoted to a discussion of some trends in the factors mentioned above that have been documented or postulated, including an attempt to assess the effect of these trends on the use of highway rest areas.

Traffic Volumes and Composition

Despite 4 years of almost constant, or slightly decreasing, highway travel because of the energy crises of 1974 to 1975 and 1979 to 1982, the average annual rate growth in total highway travel since 1970 has been 3.3 percent. Since 1982 the compound rate of increase has been 3.8 percent. The growth of rural arterial highway travel has been somewhat slower, increasing at an average rate of 2.8 percent between 1982 and 1987. The contribution of commercial traffic to this total has, however, increased at a considerably faster rate. Between 1970 and 1987 heavy truck traffic, i.e., other than 2 axle 4 tire, on rural Interstate and primary highways increased at a compound annual rate of 4.9 percent (*14, 17, 18*).

There is no reason to believe that these trends will not continue in the future, barring another energy crisis or similar event. A continuing increase in total rest area use, and in the proportion of that use represented by trucks, can therefore be expected.

Driver and Vehicle Population Characteristics

The changing nature of the U.S. population, especially insofar as the distribution by age is concerned, is a well known fact. Between 1960 and 1987 the proportion of the U.S. population 65 years old or older increased from 9.2 percent to 12.3 percent. By the year 2010 it is expected to reach 13.9 percent (*19*).

This shift, by itself, would have an effect on rest area patronage; its effect is, however, amplified by a number of other factors. The older portion of the population is both healthier and wealthier than in the past. This trend can be expected to lead to an increase in discretionary travel. The second factor is that the generation now approaching retirement age is the first one that participated, as adults, in the explosive growth of motorization that took place after World War II. This trend is strikingly illustrated by the following data (*20, 21, 22*):

Year	Percent of: All Licenses Held by Persons Over 64	Percent of: Population Over 64 Licensed to Drive
1940	1.7	N.A.
1969	8.0	43.0
1977	9.9	55.0
1983	11.1	62.3
1986	11.9	64.6

The composition of the vehicle population has also been changing. Between 1970 and 1987 the proportion of trucks to total vehicle registration (privately owned, excluding buses) increased from 16.7 to 22.4 percent (*22*).

While trucks are getting bigger, passenger cars are getting smaller and fuel consumption rates have improved dramatically. As the distance that a vehicle can travel on a full tank of gasoline increases, the probability that a desired stop (for rest or other purposes) coincides with a required stop (for gasoline) decreases. These changes in vehicle population are all likely to increase the demand for rest areas.

Trip Length and Trip Purpose Distributions

Little information is available to quantify possible future changes in the distribution of either trip length or trip purpose. There are, however, a number of indications that longer trips are likely to increase. For example, continuing reductions in interurban passenger rail service and reductions in scheduled air service to smaller communities may lead to an increasing proportion of interurban automobile travel; and increased leisure time, stable energy prices, and the increase in the number of households without small children combined with international exchange rates that inhibit foreign travel may all lead to more driving vacation or weekend recreational trips.

Commercial Traffic

Anticipated increases in commercial traffic, in terms of both VMT and traffic stream composition, have already been mentioned. There are a number of other trends, which may have an effect on rest area use.

In recent years, because of the general climate of deregulation, there have been changes in the organization of the trucking industry. One of the results of these changes is an increase in the number of individual owner-operators and of small trucking firms. These operators and small firms, often operating on the economic margin of the industry, are under great pressure to maximize productivity and may thus be less likely to accept the

time penalty of leaving a limited access facility for a rest stop. Furthermore, these individual and small operators do not have the support infrastructure of the large trucking firms including depots in, or on the outskirts of, larger cities. Increasing use of rest areas on the approaches to medium and large urban aggregations as truck staging areas, especially in the early morning hours, has been noted. In a number of cases, such use has exceeded truck parking capacity leading to unsafe parking in the approach roadways and on highway shoulders.

Recent legislation mandates that all states permit the operation of longer vehicles including double and triple trailers on Interstate highways and most other primary arterials. Not only do trucks use rest areas with greater frequency than do passenger cars, but also trailer trucks and other long vehicles may, in some locations, be de facto constrained to Interstate and other limited access routes because they are banned from significant portions of the conventional road system, and they may also encounter physical difficulties in navigating part of that system and, thus, may be unable to reach alternative off-line facilities.

Finally, the increasing popularity of two-person crews and of sleeper cab truck configurations increases the probability that a rest area stop will be substituted for an off highway extended rest stop. It should be noted that, according to Part 395 of the Federal Motor Carrier Safety Regulations (*23*), sleeper berth rest times is not credited against hours of service unless a total of 8 hours are accumulated in not more than two separate intervals. The Regulations also provide that neither of these two intervals can be less than 2 hours. To comply with the Regulations, a driver who takes a 2-hour rest in one rest area would have to spend 6 hours in another rest area. The possibility of splitting off-duty time into two periods of 4 hours each is considered by the American Trucking Association (ATA) to be generally advantageous. Many states do not currently permit a vehicle to remain in a rest area for 4 hours.

There is considerable pressure by interested parties, such as the American Trucking Association, to have a parking time limit, in all states, of no less than 4 hours. The ATA believes that enforcement of truck parking limits of less than 4 hours will force drivers to violate the hours-of-service regulations and will also lead to forcing fatigued drivers back onto the road, which is likely to result in an increase in fatigue-related accidents.

If this change is implemented, there will be an increase in the average time in rest areas for trucks, especially at night, and a consequent increase in the demand for parking spaces in those states which currently have a parking time limit of less than 4 hours.

Land Use and Competing Stopping Opportunities

While the long term land use trend is directed towards an increased degree of urbanization, it is unlikely that this trend will, in the near future, affect the demand for rest areas. It is possible that a few rest areas, located near urban aggregations, will face increasing competition from alternate stopping opportunities as the metropolitan borders expand. However, the current rest area location policies of many states require that rest areas not be located near large population centers.

Another development, documented by a number of researchers (e.g., *24*), may have greater impact in increasing the availability of alternate stopping opportunities. It has been noted that purely rural Interstate highway interchanges are acting as nuclei for local development, including such transportation-related activities as service stations, restaurants and motels. On the same topic, California is actively investigating the feasibility of joint development that is combining highway rest areas with this type of interchange development (e.g., *25, 26*). A similar type of investigation is about to begin in Michigan.

The degree to which such competing opportunities will attract potential rest area users depends not only on the character and accessibility of that alternate, but also on the attractiveness of the rest area and on the information available to the driver about both of these opportunities.

Other Factors

Rest area use is a function of highway traffic volumes and composition which, in turn, is affected by the demand for and supply of transportation services by all modes in the United States. For instance, Ref. 26 speculates about the effect of the opening of a proposed high speed rail connection between Los Angeles and Las Vegas on the demand for rest area services in Southern California.

Transportation supply and demand are a reflection, although sometimes with considerable time lag, of the social and economic aspects of society. Demographic and social changes, preceded or followed by technological advances, may thus affect transportation as a whole and rest area use in particular. A number of such possibilities have been mentioned in the preceding sections. A number of others deserve mention.

Teleconferencing and other advances in communications techniques may reduce the demand for face-to-face business conferences and, as a consequence, the demand for business travel. The heavy rest area use by business travelers because of the need to use a telephone has been noted. Advances in in-vehicle cellular telephone availability may reduce this need in the relatively near future. It should be noted, however, that the spread of cellular telephone availability into the more rural areas where most rest areas are located will probably have to await the initiation of satellite transmissions. However, one cellular telephone company is currently advertising the availability of continuous cellular telephone use in the 200-mile corridor from Hartford, Connecticut, to Wilmington, Delaware.

The large increase in truck traffic in recent years is the result of the fact that the current technological, regulatory, and economic environment gives truck transportation a definite advantage over the competing air, rail, and water routes. A change in this environment, such as the development of "lifting hooks" technology, may, for instance, give the air transportation mode a cost, time, and capacity advantage over long haul trucking.

Other, and more speculative, instances of such factors could be cited. However, given the time lags involved, it is not believed that any of these will play a significant role in the 20 to 25 year time frame for which most rest area-related decisions are made.

Summary

The effect of all of the factors discussed above cannot be reliably quantified and their interactions remain to be investi-

gated. It appears highly likely that the growth in rest area use and the demand for rest area services will exceed that which could be anticipated on the basis of the secular growth in highway traffic alone.

The fact that this projected trend is recognized, at least to a certain extent, is shown by the responses of the State survey. The Interstate rest area system is scheduled to expand, by adding new rest areas, at an average annual rate of 3.3 percent, slightly above the anticipated rate of increase in rural VMT. Furthermore, an average of 8.6 percent of all Interstate rest areas are scheduled to be "reconstructed" or "upgraded" annually. In many cases, such activities include expansion of facilities and/or parking lot capacity.

On the other hand, similar data for the non-interstate portions of the rural primary system appear to indicate that the rate of growth, and of modernization, will not keep pace with projected increases in demand.

CHAPTER FOUR

FINDINGS—BENEFITS AND COSTS OF REST AREAS

This chapter discusses the benefits of rest areas that have been identified. A taxonomy of the benefits of rest areas is shown in Table 12. The final part of the chapter presents a brief discussion of the cost elements involved in the establishment and operation of rest areas.

SAFETY BENEFITS

A 1973 study of rest areas (*27*) stated that "Rest areas are now an integral element of limited-access and other highways to provide motorists a *greater measure of safety* and comfort." Similarly, the introduction to the major AASHTO publication on this subject (*6*) states that "*In the interest of safety* and convenience to the motoring public, safety rest areas are necessary." This opinion is repeated in the most recent AASHTO set of policies (*7*). "Safety rest areas, information centers, and scenic overlooks are functional and desirable elements of the complete highway development and are provided for the *safety* and convenience of the highway user." (Note: emphasis added in the foregoing quotations.) Enhanced highway safety is thus a prime consideration in establishing a highway safety rest area program as explicitly stated in a report from Michigan (*8*), a State that established the first right-of-way roadside rest areas in 1919: "... the basic service of the rest areas, or safety stops as they are sometimes called, is *accident prevention.* ..." (Emphasis added.)

Although there is general agreement that the establishment of a highway rest area has a beneficial effect on highway safety, little supporting empirical evidence can be found in the literature. Similarly, there have been few reports on theoretical or conceptual investigations designed to study the causal chain that relates rest areas to accident reduction. A recent Australian study (*29*) states "Despite the potential importance of rest areas in highway safety little research has been conducted on such micro environments."

Conceptual Analysis

A brief conceptual analysis of the possible causal chain between highway rest areas and highway safety, which may involve a number of separate mechanisms, is presented in the following paragraphs.

Driver Fatigue and Discomfort. The effect of driver fatigue as a contributory cause of highway accidents is well documented both in the United States (e.g., *30, 31*) and abroad (e.g., *32*). This effect extends far beyond the "driver asleep" type of accident and encompasses a wide range of impairments in the perceptual, cognitive, and motor skills necessary for safe driving.

The extent and potential consequences of these impairments have been thoroughly studied (e.g., *33, 34*). An analysis of the 1982 accident file assembled as part of the National Accident Sampling System (NASS) concluded that 9 percent of this accident sample could be attributed to fatigue (summarized in *35*). Kishida (*36*) points out that careless driving behavior, such as looking aside, are often listed as accident causes but should more properly be listed as a subsidiary behavior compensating for fatigue. Kishida suggests that the actual percentage of accidents attributable to fatigue is still unknown but is expected to be higher than currently quoted estimates. A California study (*37*) concluded that, for a number of reasons, the inclusion or omission in police accident reports of fatigue, as an accident causation element, is not reliable.

These reasons include the fact that the definition and determination of fatigue, as a general concept as opposed to the specific "driver asleep," is a highly subjective process. Furthermore, as well documented in the literature, fatigue is not only a continuous variable but also one whose level, in any specific driver, can change from moment to moment in response to external stimuli and to physiological changes.

While the only certain way to overcome the effects of fatigue is to take a nap (*38*), most researchers agree that these adverse effects can be lessened by periodic rest, exercise, and the moderate use of mild stimulants such as caffeine. For instance, Clark

Table 12. Taxonomy of rest area benefits.

1. User Benefits
   - 1.1 Comfort & Convenience
     - 1.1.1 Access to Services
     - 1.1.2 Rest/Stretch
     - 1.1.3 Exercise Pets
     - 1.1.4 Trip Planning Opportunity
   - 1.2 Safety
     - 1.2.1 Fatigue Related Accidents
     - 1.2.2 Shoulder Stop Related Accidents
     - 1.2.3 Other
   - 1.3 Reduction in Excess Travel
   - 1.4 Commercial Vehicle Scheduling and Staging
   - 1.5 Refuge for Adverse Driving Conditions
   - 1.6 Opportunity for Vehicle and Load Checking and Minor Maintenance Work
2. Government Agency Benefits
   - 2.1 Highway Safety
   - 2.2 Highway Operations and Maintenance
     - 2.2.1 Reduction in Cross Street and Ramp Volume
     - 2.2.2 Reduced Wear and Tear on Highway Shoulders
     - 2.2.3 Reduced Litter Pickup on Highway ROW
   - 2.3 Direct Monetary Benefits
     - 2.3.1 Commissions on Hotel Reservations
     - 2.3.2 Franchise Fees and Revenues
   - 2.4 Information Interchange with Highway Users
3. External Benefits
   - 3.1 Specific Economic Impact - Tourism
   - 3.2 General Economic Impact
   - 3.3 Societal Costs of Accidents
   - 3.4 Diversion and Segregation of Commercial Traffic
   - 3.5 Telephone Company Revenues
   - 3.6 Commercial Enterprise Profits

(*39*) recommends 10-minute stops every hour. Stave (*40*) reported a significant positive correlation between the frequency of performance lapses and subject fatigue and stated that a 4-minute rest period would restore proficiency beyond the point of significant error. Drory (*41*) replicated these findings and showed that a 30-minute rest period provided even greater improvement. However, a Swedish study (*42*) has shown that one half-hour rest after 6 hours of driving, within an 11-hour driving cycle (i.e., the limits allowed by Swedish regulations) was insufficient to prevent serious deterioration in performance.

In a simulation study of driving performance, Suhr (*43*) determined that work decrement begins within the first 2 hours of simulated automobile driving; a pause for refreshments (tea) prolongs the onset of fatigue and reduces the work decrement resulting from a prolonged period of simulated automobile driving.

Rest areas will thus have a beneficial effect on highway safety to the extent that they offer an opportunity for rest, for exercise, and sometimes for having a cup of coffee.

If rest areas are not available, drivers have three alternate courses of action: (1) Exit the limited access highway on which they are traveling and find the required facilities off-line. This may add considerably to the length and duration of a trip, increase the possibility of getting lost, and may lead to real or imagined safety and security problems. This extra driving also increases accident exposure. (2) Defer a necessary rest stop past the start of diminished driving performance, thereby increasing the accident potential. Such a deferral can also be due to perceived security problems associated with off-line facilities. (3) Stop on a highway shoulder, or in some other unsafe location, thereby leading to a different type of accident potential as discussed below.

Shoulder Stops. Drivers will stop on the shoulders of a highway for a number of reasons. These stops may be forced or voluntary. A forced stop is one which is caused by police action, by accident involvement, by an impairment of the vehicle or of the driver, or by highway surface or visibility conditions that make further progress impossible or excessively hazardous. Because such forced stops cannot generally be avoided, they are not considered further. The role of preventive maintenance in reducing the frequency of such stops is discussed later.

Voluntary or discretionary shoulder stops are made for any number of reasons and usually outnumber forced stops. Table 13, taken from a study of shoulder stops in South Dakota (*44*), illustrates the variety of reasons and the distribution of such stops. A similar distribution was reported from a pilot study in the Washington, D.C., area except that, in this metropolitan area, map reading was of considerably less importance (*45*).

Shoulder stops have also been investigated in a number of other locations including New York, New Jersey, and Oregon (summarized in *46* and *47*). The frequency of discretionary shoulder stops, computed in these studies, ranged from one for every 980 vehicle-miles of travel to one for every 2,800 VMT.

Vehicles parked on shoulders, especially on high speed facilities, create an accident hazard. For instance, an FHWA Bureau of Motor Carrier Safety Study (*48*) indicated that approximately 3 percent of all accidents involved vehicles parked on shoulders; and of these, 21 percent were classified as due to nonemergency parking.

Interestingly, the same study found that the proximate cause in more than half of these accidents involved "drivers dozing at the wheel and allowing their vehicle to travel onto the paved shoulder."

Table 13. Number of shoulder stops classified by type and purpose of stop. Note: Stops due to accident involvement or due to police action are not included. (Source: Ref. 44)

Type of Stop	Purpose	No.	Percent of Class	Percent of Total
Involuntary	Flat tire	33	23	9
	Out of gas	28	19	7
	Mechanical failure	80	56	22
	Other	3	2	1
	Subtotal	144	100	39
Voluntary	Rest and leisure			
	Rest or sleep	12	11	3
	Checking map	54	50	15
	Changing drivers	13	12	4
	Eating in vehicle	8	7	2
	Car sickness	3	3	1
	Visiting	7	7	2
	Latrine	6	5	2
	Other rest or leisure	6	5	2
	Subtotal	109	100	31
	Business			
	Inspecting utilities	4	80	1
	Other business	1	20	0
	Subtotal	5	100	1
	Other voluntary			
	Assisting another vehicle	8	8	2
	Checking vehicle or load	46	45	13
	Minor mechanical trouble	35	34	10
	Unclassified	14	13	4
	Subtotal	103	100	29
	TOTAL	362	-	100

The severity of these accidents is indicated by California data for 1984 (*49*), which showed that 42 fatal accidents resulted from vehicles being struck while stopped on freeway shoulders. In exactly half of these accidents the parked vehicle was a truck. These numbers, however, grossly understate the number of fatal accidents caused by shoulder stops. A significant proportion of other accident classes must be added because: (1) some proportion of the fatal accidents involving 19 dismounted motorists on shoulders, and 44 dismounted motorists in the traveled way, were undoubtedly preceded by a shoulder stop; and (2) some of the 18 fatal moving vehicle accidents classified as sideswipes and 90 fatal accidents classified as rear end could have involved vehicles entering or leaving shoulders.

Summaries of existing shoulder stop–accident correlations are also included in Refs. 45 and 50. This subject is further explored in this chapter, under "Indirect Safety Benefit Analyses."

Preventive Maintenance. Most vehicle failures do not require an immediate stop. Vehicles can be driven considerable distances with low tire pressures, engine or exhaust system problems, exterior lighting failures, or similar malfunctions. Very often a driver will continue his trip, especially at night, in an unfamiliar area or in an apparently hazardous location, after becoming aware of such a malfunction. The trip is continued in the hope that the destination, or another convenient safe location, can be reached before the vehicle condition deteriorates further.

If such a location is not reached in time, an involuntary emergency stop will be necessary. Furthermore, continuing to drive a defective vehicle, especially if the defect affects acceleration or braking ability, steering control, driver visibility, or front or rear lighting, by itself creates an accident hazard.

Table 13 indicates that 23 percent of all shoulders stops were for the purpose of "checking vehicle or load" or "minor mechanical trouble." These stops could be made more safely and conveniently in a highway rest area. It is also probable that the number of stops for "flat tire" and for "mechanical failure" would be reduced if there had been an earlier opportunity to make a convenient "checking vehicle" stop. In fact, the mere act of stopping and starting a vehicle, or of leaving and entering that vehicle, may often give the first indication of an incipient mechanical or tire failure.

It is thus extremely likely that the existence of a system of highway rest areas of appropriate spacing will reduce the frequency of shoulder stops because of vehicle maintenance reasons and may also reduce the total exposure of vehicles with safety-related defects. Both factors will tend to reduce the incidence of highway accidents.

Miscellaneous. A number of other causal mechanisms that relate highway rest area use to highway safety improvements have been postulated. These are listed and briefly described below. These items, however, are almost impossible to verify empirically or to quantify.

1. A rest area can serve as a safe refuge whenever weather, visibility, or roadway conditions make further driving hazardous. The rest area not only serves as a safe alternative to a shoulder stop under these conditions, but the presence of the rest area may also influence a driver to stop rather than to continue.

2. A rest area can serve as a safe location to recover from the effects of alcohol consumption; time is needed to metabolize the alcohol in the system. Admittedly, no driver should be on the road in a condition where he feels it necessary to stop for this reason. However, because alcohol very often has a delayed effect, a driver may not become aware of his relative incapacity until after he starts on his trip.

3. Rest areas represent a major interface at which highway authorities can communicate with the motoring public. The survey summarized in Chapter Two indicated that weather, road and traffic information is available at 22 percent of all rest areas. Possession of such information by the driver is likely to lead to safer route selection and driving. This role of rest areas is much more prevalent in Europe than in the United States.

4. A contributing factor in highway accidents may be driver distraction because of an unruly child or pet in the vehicle or because of driver or passenger discomfort. Such distractions are likely to be reduced by appropriately spaced stops in rest areas.

Summary. The preceding analysis of the effects of highway rest areas on highway safety has shown that these effects operate through different mechanisms including: reduction in driver fatigue and other adverse physiological effects; reduction in voluntary shoulder stops; some reduction in involuntary stops and in vehicle-miles of travel by defective vehicles and impaired drivers; reduction of driver or passenger discomfort or other sources of driver distraction; transmission of safety-related information to drivers; and reduction of driving under hazardous weather, roadway and visibility conditions.

The evaluation of the safety effects of highway rest areas represents a complex problem involving two major factors:

1. The *existence* of a highway rest area will not directly affect accidents except for the potentially adverse effects of additional merging and lane-changing near the rest area entrances and exits. Any effect on accidents will arise from the *use* of a rest area. In this respect, rest areas are somewhat analogous to seat belts: the *installation* of seat belts affects highway safety only to the extent that they are *used.*

2. Unlike seat belts, there is no direct causal connection between the use of a rest area and the occurrence or severity of highway accidents. Any such connection is indirect. Actual or planned rest area use may affect driver actions or performance which, in turn, are potential contributing causes to accidents. Similarly, a defensive driving course does not directly affect highway safety: it is the consequent potential changes in driver attitudes and behavior that may have that effect.

Detailed Accident Analyses

Many researchers have tried to derive quantitative relationships between highway safety, expressed in terms of some parameter(s) of the distribution of accident occurrence, type or severity, and the existence, use pattern or other attributes of highway rest areas. In almost every case, these efforts have failed because of a number of factors: (1) Shoulder stops and driver fatigue have been postulated as being affected by rest area location, spacing, and use. Generally, less than 5 percent of all limited access highway fatal accidents involve a vehicle parked on the shoulder (e.g., *49*). State accident summaries show that usually less than 3 percent of accidents are attributed to "driver asleep." With such small proportions, the effect of any rest area on accidents is almost impossible to quantify, given the normal variability of the accident distribution. (2) Although a vehicle

stopped on the shoulder is likely to be so identified in a police accident report, the same usually does not apply to vehicles entering or leaving the shoulder. Furthermore, "driver asleep" or "driver fatigued" observations are, in most cases, self-reported evaluations by the involved driver (possibly biased) or rather uncertain inferences by the investigating officer.

These considerations together with other accident data problems led one researcher (*37*) working with accident data of above-average quality (California) to conclude:

> The accident data do not demonstrate the safety benefits of rest stops but a sensitivity analysis shows that a significant benefit may indeed exist without being discoverable. *In short, neither the existence or nonexistence of safety benefits of rest stops can be proved using the available accident reports.* (Original emphasis)

It, thus, does not appear to be feasible to develop statistics that can be reliably used as inputs into benefit-cost analyses given the inherent accuracy and variability of the accident data base.

Nevertheless, the research agency devoted considerable effort to detailed analyses of accident data drawn from the records of a number of cooperating states. The initial effort was focused on micro-analysis; individual accidents were coded in terms of their distances to the nearest upstream and downstream rest areas and an attempt was made to correlate these distances to accident frequency. No significant relationships could be developed.

A macro-analysis was implemented to look for a correlation between accident frequencies and average rest area spacing for rather long (100 miles or more) rural highway segments.

This analysis was constrained by two factors: (1) the available data base included very few sections of 100 miles or more which did not contain an urban aggregation or major freeway to freeway interchanges; and (2) accurate traffic volume, traffic stream composition, and topographic data were not available for most of the highway sections for which accident data had been obtained.

Preliminary analyses of these data gave some indications that accident frequency may decrease with decreased rest area spacing until that spacing reached approximately 50 miles. Shorter spacing had no apparent effect. However, no statistically valid, quantifiable safety benefit of highway rest areas could be demonstrated.

Indirect Safety Benefit Analyses

The available accident data base reflects traffic operations on a rural highway system which, for many years, has been provided with relatively frequent highway safety rest areas. The overall safety effect of rest areas is therefore already subsumed in the accident data and, given the relatively small proportion of all accidents which may be affected by rest area location, the effect of differences in rest area spacing on accident frequency or on the distribution of accidents by type or severity is probably not strong enough to yield statistically significant results.

The use of a rest area will affect some aspect of driver attitudes, behavior, or condition and this change, in turn, may affect accident occurrence. The two aspects that have been best documented by past research, by the empirical studies made as a part of the present research effort, and by conceptual analyses of the problem are: (1) the existence and use of a rest area will tend to reduce the number of shoulder stops; and (2) the existence and use of a rest area will tend to reduce the proportion of drivers in the traffic stream whose abilities are impaired by fatigue and, possibly, by other causes.

The safety benefit of rest areas can thus be estimated by a 4-step procedure:

1. Define a functional relationship between driver performance attributes and the occurrence of highway accidents.
2. Quantify the "base" levels of the pertinent driver performance attributes.
3. Quantify the change in these attributes as a result of the existence and use of highway rest areas.
4. Apply the functional relationship of (1) to the quantitative relationships of (2) and (3), using appropriate mathematical techniques, to quantify the effect of rest areas on the occurrence of highway accidents.

This procedure can be illustrated with a well-known example. If the probability of a single vehicle accident resulting in a fatality is two times higher if the driver does not wear seat belts (step 1), increasing the rate at which seat belts are worn from 20 percent (step 2) to 40 percent (step 3) will decrease the single vehicle fatal accident rate by 11.1 percent (step 4). The computational procedure is illustrated as follows:

$$\begin{aligned} TAR(B) &= SBAR \times PSB(B) + 2 \cdot SBAR \times (1-PSB(B)) \\ &= SBAR \cdot (2-PSB(B)) \\ TAR(A) &= SBAR \times PSB(A) + 2 \cdot SBAR \times (1-PSB(A)) \\ &= SBAR \cdot (2-PSB(A)) \end{aligned}$$

where TAR = total accident rate, SBAR = seat belt accident rate, PSB = proportion of driving using seat belts, and (B) and (A) = before and after.

The percent reduction in accident rates is then given by:

$$100 \cdot (TAR(B) - TAR(A))/TAR(B) \text{ or}$$
$$100 \cdot [SBAR(2 - PSB(B)) - SBAR(2 - PSB(A))]/[SBAR(2 - PSB(B))] \text{ or}$$
$$100 \cdot (PSB(A) - PSB(B))/(2-PSB(B))$$

Substituting the appropriate numerical values, percent reduction in accident rate = 100 (0.4−0.2)/(2−0.2) = 11.1 percent.

Analogous procedures for the two specific factors considered are summarized below.

Shoulder Stops. The analysis of the effect of rest areas on shoulder stops, and, therefore, on the frequency of accidents involving such shoulder stops, is based on: (1) data on the frequency of shoulder stops and on the estimated rate of accidents involving vehicles stopped on shoulders assembled by Hauer (*50*); (2) data on the number of shoulder stops prevented by rest areas derived from the surveys made as part of this project (see Table 10); (3) estimates (see Chapter Three, under "Rest Area Use") of rest area use; (4) disaggregated data on VMT published by FHWA (*14*).

The analysis, detailed in Appendix C, shows that, in the absence of rest areas, an increase of approximately 52 percent in shoulder stop related accidents can be expected. The estimated number of such accidents prevented by rest areas is fatal acci-

dents, 200; nonfatal injury accidents, 3,200; property damage only accidents, 4,500; total accidents, 7,900.

Using unit accident cost data for rural accidents developed by Rollins and McFarland (*53*), updated to 1987 by applying appropriate economic indices (*54*), the total cost of this accident total is estimated at approximately 297 million dollars. The average cost for each of these prevented accidents is almost $38,000 because of their extremely high average severity. This figure is 44 percent higher than the average cost of rural accidents computed by Rollins and McFarland.

The AASHTO survey (*2*) estimated the total annual maintenance cost of the entire U.S. Interstate rest area/welcome center system to be 93.4 million dollars and its replacement cost to be 2.4 billion dollars. If the life of a rest area is taken at 25 years and equivalent interest rates at 7.5 percent (a representative rate for tax free bonds), these figures translate into Uniform Annual Costs of approximately 309 million dollars. It can thus be seen that, for Interstate highways, the estimated total costs of shoulder stop accidents prevented by rest areas is almost equal to the total cost of the rest area system.

The preceding analysis was based on the entire rest area system. The same procedure can be used for individual state rest area systems and possibly for individual rest areas by using local traffic volume and proportion entering data and only considering the segment of road to the next downstream rest area. The use of nationwide data on shoulder stop frequency for individual, specific locations may, however, be questionable because the factors affecting shoulder stop frequency are not fully understood and, also, as cited earlier in this chapter under "Conceptual Analysis," there are considerable regional differences in that frequency.

The procedure used to derive the estimated reduction in accidents reductions implies that these costs are insensitive to distance between rest areas if the FHWA formula (see Figure 1), or any other formula specifying a straight line through the origin, is used. However intuition, conceptual analysis, as well as the partial data quoted earlier indicate that this formula is not always realistic. It is unlikely that rest area use is a linear function of distance between rest areas, alone. As this distance increases, motorists will start to seek other stopping opportunities resulting in an increasing proportion of shoulder stops or travel to off-line facilities.

Fatigue. Theoretically, the same type of analysis can be applied to other elements of the accident occurrence causal chain including driver fatigue. A number of references (e.g., *35, 36*) have cited data, or other information, to the effect that fatigue may be the main cause, or a contributing element, directly or indirectly, in 10 percent or more of all highway accidents. The opportunity for rest afforded by highway rest areas should contribute significantly to the alleviation of fatigue in the driving population and, therefore, to a reduction in fatigue-related highway accidents. The quantification of this effect is, however, impossible at the present time.

Existing data will allow inferences concerning the effect of rest areas on driver fatigue. Detailed analysis of state historical accident data may permit quantifying the role of fatigue in highway accidents. Difficulties in defining and determinating fatigue, as discussed in this chapter under "Conceptual Analysis," makes this task far more difficult than the relatively easy task of the definite physical event of the presence of a vehicle on a highway shoulder. However, there is no existing data base that defines the distribution of fatigue in the driving population. There is also no general agreement on a metric for delineating fatigue which, as well documented in the literature, is a continuous variable.

Even though quantification is not possible, a parametric study can indicate the order of magnitude of this effect. The 1982 NASS file indicated that at least 9 percent of the accidents sampled had been caused by fatigue. Specifically, 9 percent of the drivers involved in an accident exhibited factors attributable to fatigue. As previously discussed, this figure probably represents a lower bound on fatigue-related accidents.

During the rest area interviews, approximately one-third of all users indicated that rest was the primary reason for stopping; another third used the opportunity to rest even though the stop was made for a different primary reason. In response to a direct question, almost 28 percent of all persons interviewed at rest areas indicated that they felt fatigued before entering the rest area.

An in-depth analysis of the interview responses, concentrating on such items as somatic complaints associated with fatigue (*55*), boredom and monotony (*42, 56*), and the time elapsed since the last stop (*40*), indicates that an additional 4 percent are also fatigued. Data shown in Figure 1 indicate that, given an average rest area spacing of 44 miles, 14 percent of all passing traffic will enter a rest area.

Drivers who are fatigued *and* who enter a rest area thus represent an estimated total of $100\,(0.32 \times 0.14) = 4.5$ percent of the traffic stream. If it is assumed that these drivers are no longer fatigued when they leave the rest area, it would be possible to calculate the reduction in fatigue-related accidents if the proportion of fatigued drivers in the traffic stream was known. This is, however, not the case. Given the present state of the art and available data, only a parametric study is possible.

Let Af = accident rate–fatigued drivers, Anf = accident rate–nonfatigued drivers, Pf = proportion of all drivers who are fatigued, and Cfe = change in proportion fatigued due to rest area. Then:

$$\text{Accident rate with no rest areas} = Af \cdot Pf + Anf \cdot (1 - Pf) \qquad (5)$$

$$\text{Accident rate with rest areas} = Af \cdot (Pf - Cfe) + Anf(1 - Pf + Cfe) \qquad (6)$$

By subtraction:

$$\text{Change in accident rate} = Cfe\,(Af - Anf) \qquad (7)$$

The total accident rate cannot be disaggregated into a fatigued and a nonfatigued component because the relative size of these two populations is not known. However, if the proportion of all accidents involving fatigue can be ascertained from accident data files, assuming per person VMT is equal for the two population components, one can write

$$Af = \frac{AC \cdot Paf}{Pop \cdot Pf} = \frac{\text{No. of accidents involving fatigue}}{\text{Population of fatigued drivers}} \qquad (8)$$

$$Anf = \frac{AC \cdot (1 - Paf)}{Pop \cdot (1 - Pf)} = \frac{\text{No. of accidents not involving fatigue}}{\text{Population of nonfatigued drivers}} \qquad (9)$$

where AC = total number of accidents, Pop = driving population, and Paf = proportion of all accidents involving fatigue.

Substituting Eq. 8 and Eq. 9 into Eq. 7 and simplifying yields:

$$\text{Reduction in accident rate} = \frac{\text{Cfe(Paf}-\text{Pf)}}{\text{Pf}(1-\text{Pf})}\cdot\frac{\text{AC}}{\text{Pop}} \qquad (10)$$

If fatigue is a causal factor in accidents, as is generally accepted, the proportion of accidents involving fatigued drivers, Paf, should exceed the proportion of drivers who are fatigued, Pf. Thus, only positive values of the above equation (indicating a *reduction* in accident rate) are of interest.

Equation 10 gives the absolute reduction in accident rate. Dividing Eq. 10 by the overall accident rate, AC/Pop, yields an expression for the relative reduction in that rate:

$$\text{Percent reduction in accident rate} = 100 \times \frac{\text{Cfe(Paf}-\text{Pf)}}{\text{Pf}(1-\text{Pf})} \qquad (11)$$

Equation 11 is plotted parametrically in Figure 6 using the value of 4.5 for Cfe derived from the rest area field studies. The parameter Cfe in Eq. 11 is the product of the proportion of drivers who enter the rest area and the proportion of entering drivers who are fatigued.

It is seen that the greater the influence of fatigue on accident causation (i.e., the greater the difference, Paf−Pf), the greater the potential for rest areas to provide a reduction in accident rate.

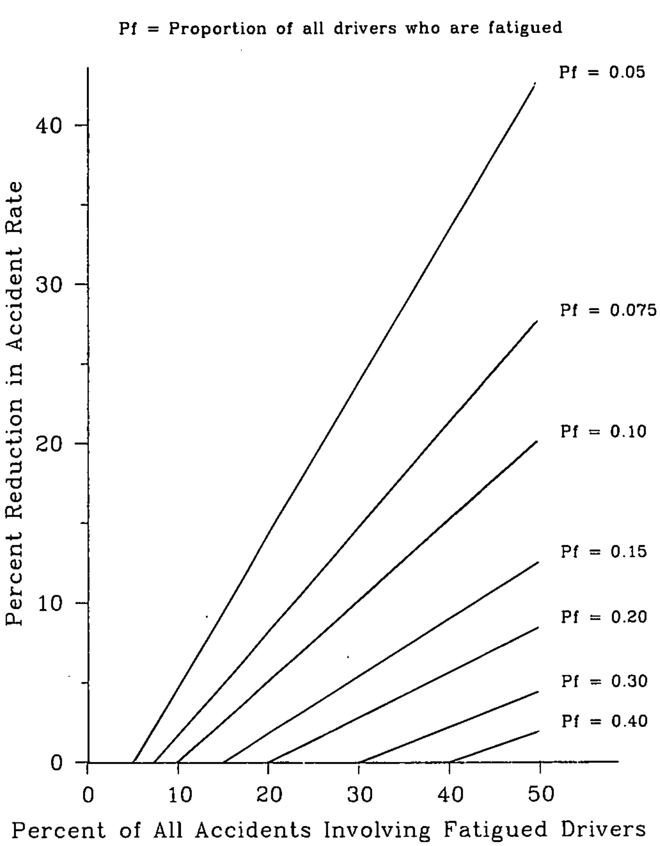

Figure 6. Possible reduction in accident rates (parametric study).

The economic significance of this reduction in accident rates can be illustrated by an example. If it is assumed that half of all fatigued drivers will enter a rest area, the population fatigue level, Pf, will be given by 2 × (Proportion Entering) × (Proportion Entering who are Fatigued) or, using the data cited earlier, 2 × 0.14 × 0.32 = 0.09. If it is now assumed that the true proportion of all accidents which involve fatigue is 0.15, i.e., approximately 50 percent higher than the lower bound cited previously, the reduction in accident rates due to the rest area is 3.7 percent.

The total economic loss due to accidents on the rural Interstate system has been estimated to exceed 4 billion dollars annually. A reduction in accident rates by 3.7 percent because of the existence of rest areas would thus represent a benefit to society of 148 million dollars per year under the conservative assumption that the severity distribution of accidents involving fatigue is the same as that for all accidents. This amount represents approximately 50 percent of the annualized cost of the U.S. Interstate rest area system.

Other Causal Factors. Other accident causation elements which might be mediated by highway rest areas, preventive maintenance, improved trip planning, and driving under adverse conditions, fall into the same general category as fatigue. A recent study (*57*) has estimated that excess driving, the distance driven while drivers are lost or are following a less than optimum route, is responsible for accidents with a total economic loss of 4.4 billion dollars nationwide. This total might be higher if the opportunity to consult maps, and plan subsequent trip segments, offered by rest areas were not available. Existing data, which delineate the population distribution of these factors, are insufficient to allow the beneficial effects of rest areas to be quantified.

COMFORT AND CONVENIENCE

There is general agreement that, apart from improvements in highway safety, enhancement of the comfort and convenience of the motoring public is the principal reason for the existence of rest areas. Convenience and the availability of restrooms and picnic facilities occupied three of the five top places in a ranking of the benefits of rest areas to highway users (Chapter Two, under "Perceived Benefits"). There is general agreement that comfort and convenience are broad, intangible, and subjective concepts incapable of being directly quantified or expressed in monetary terms.

The need to select an appropriate methodology of accounting for such intangibles, or noneconomic goods, in decisions concerning the expenditure of public funds has received considerable attention in recent years often in connection with the question of providing support for cultural or recreational facilities (e.g., Ref. 58). One of the frequently advocated methods, if an equivalent economic good with a known price cannot be identified, is willingness to pay. This method, essentially, consists of asking the potential user or beneficiary of the facility being considered "What is it worth to you?"

Both KLD surveys included a series of questions which explored "willingness to pay" in terms of both amount and modality. The responses to these questions have been summarized in Chapter Three, "Paying for Rest Areas".

Depending on how these data are interpreted the perceived value of comfort and convenience probably lies in the range of

$0.40 to $1.00 per entering vehicle. Total annual rest area use has been estimated (see Chapter Three, "Rest Area Use") as more than 600 million vehicles. The total "comfort and convenience" benefit can, therefore, be estimated to be in the $240 to $600 million range with a midpoint of $420 million. This total is somewhat higher than the estimated savings in the costs of accidents involving shoulder stop.

This type of analysis can be done for individual rest areas using local data for ADT, composition of the traffic stream and proportion entering by vehicle class. For instance, assume an ADT of 7,500, the 1987 average unidirectional ADT per mile for the U.S. Interstate System. Also assume that 10 percent of all passenger cars and 15 percent of all trucks on the main line enter the rest area and that trucks constitute 14 percent of the traffic stream. The annual main line volume would then be approximately 2.7 million vehicles (ignoring weekday-weekend differentials). Further assume that automobile travelers would pay $0.76 and truck drivers $0.82 per visit. These amounts were computed by the assumption that half of all respondents who indicated that they would not pay would change their mind if a fee was actually imposed.

Annual rest area use would thus consist of 219,000 passenger cars and 77,000 trucks.

Based on the willingness to pay approach the benefit of enhanced comfort and convenience to a rest area would be valued at approximately $230,000. This amount is approximately equal to the estimated Uniform Annual Cost of constructing, operating, and maintaining one rest area (AASHTO data).

OTHER USER BENEFITS

Highway safety, and driver comfort and convenience, discussed in preceding sections, represent the major benefits of rest areas accruing to highway users. While enhanced comfort and convenience benefits only the actual rest area user, potential accidents averted by a preceding rest area stop could benefit other drivers who had not used a rest area. The taxonomy of Table 12 gives a number of other possible benefits of highway rest areas. These are briefly discussed below.

Reduction in Excess Travel

Data summarized in Table 10 indicate that approximately 30 percent of all drivers would leave the highway if a rest area were not available. If there were *no* rest areas available, this percentage would increase to 43 percent because a proportion of those drivers who would travel to the *next* rest area would also divert off the route.

If it is assumed that the services required (e.g., toilet, telephone, safe stopping place, etc.) are available within 5 miles of the next interchange and the return can be made using that same interchange, every such detour would involve an extra 10 miles. Applying this figure to the estimated total rest area use of 600 million vehicles results in extra driving of about 2.5 billion miles. The Automobile Manufacturers Association (*22*) estimates that variable (out of pocket) driving costs, for automobiles, are about 7.6 cents per mile. Operating costs for trucks, because of higher fuel consumption, higher tire costs, and mileage based taxes, are much higher but exact figures are not readily available. A composite rate of 10 cents per mile for the entire traffic stream appears to be conservative. At this rate, the estimated excess driving distance would result in extra costs to the public exceeding $250 million for the entire rest area system.

In addition to these excess operating costs, the detour will also consume time. If an average detour speed of 30 mph is assumed, this extra time will be 20 min for each detour or a total of about 85 million hours. As part of a recently completed research project (*57*), KLD derived data on the average value of time for passenger cars as follows: work trips, $8.50 per hour; other trips, $6.50 per hour.

Personal business travel, from NPTS data, amounts to about 7.5 percent of VMT for trips over 150 miles. Truck business travel can be computed, from data in Ref. 14, as 24 percent of all VMT if it is assumed that 50 percent of all VMT by 2 axle, 4 tire trucks (e.g., vans, pick-ups and other small trucks) are nonbusiness related. If it is further assumed that vehicle occupancy is 1.4 for business travel and 2.1 (adults) for other travel, the total cost of this excess time can be estimated as in excess of one billion dollars. The value of time, especially of small increments of time, is an extremely controversial aspect of highway economic analysis; this estimate should therefore be considered with caution.

For individual rest areas the analysis can be made more precisely because the location of the alternate stopping places in relation to the nearest interchange, and the excess distances so generated, are known or can be ascertained in the field. Other required input data, such as expected rest area use, can also be determined more accurately.

Commercial Vehicle Scheduling and Staging

A considerable proportion of all interurban goods transports are made by trucks using Interstate and other primary rural routes. Much of this driving is done at night, especially with the increasing use of large trailer-truck combinations with two-person crews. It has been stated that the objective in using a two-person sleeper team is to keep the truck rolling for 20 out of 24 hours. Deliveries, however, are usually restricted to normal business hours. Because of heavy CBD traffic, some localities restrict deliveries or pickups to the hours following the end of the morning rush hour.

Consequently, trucks frequently use rest areas as staging areas, especially near large urban aggregations. Intense truck activity in rest areas in the early morning hours was noted during the rest area field studies and confirmed during discussions with highway officials in a number of states. A progress report of the Virginia rest area study, previously mentioned, stated that: "In early morning, many tractor-trailers were found to frequently exceed the two-hour parking limit; some were seen parked along entrance and exit ramps when truck parking lots were full."

This use of rest areas represents a definite benefit to truck drivers and truck operators by allowing more convenient scheduling. Although this type of behavior has been noted qualitatively in many areas of the country, no quantitative data base exists to define its extent. Furthermore the unit benefits, that is, the value of this type of scheduling to the individual truck driver and truck operator, are unknown.

The parking of large trucks on rest area entrance and exit ramps represents a definite hazard and increases accident po-

tential to other highway users. It should be noted, however, that the problem type "entrance/exit accidents" was rated "not at all serious" by every respondent to the State survey.

Commercial vehicles frequently encroach onto passenger car parking facilities. This activity represents a disbenefit to "normal" rest area users, generates additional maintenance costs, and may force the development of additional capacity. In fact, one state has opened additional rest areas close to existing ones for the sole use of trucks.

Refuge for Adverse Driving Conditions

Most rural limited access facilities experience occasional roadway, weather, or visibility conditions which make driving extremely hazardous, if not impossible. Drivers on the road when these conditions materialize are faced with the alternatives of leaving the highway, making a shoulder stop, or entering a rest area. Drivers may be quite averse to leaving the highway especially in an unknown location and under adverse driving conditions. The normal hazard of a shoulder stop is magnified under adverse visibility or weather conditions. Furthermore, such a stop occurring, for instance, in severe winter weather may lead to hypothermia or carbon monoxide poisoning.

Highway rest areas represent safe and convenient locations to "wait it out." They also represent the best opportunity for the highway authorities to communicate with motorists to advise them of current conditions and to recommend appropriate actions.

GOVERNMENTAL AGENCY BENEFITS

A number of potential benefits accruing to highway department and other government agencies are given in Table 12. The responses to the State survey on this topic were shown in Table 3. Examination of this table leads to some interesting inferences:

1. Respondents generally consider rest areas to benefit highway users primarily. Governmental agencies and others are seen to benefit to a lesser extent.
2. Only two benefits to public agencies received more than occasional mention: tourist information/public relations and safety/convenience.
3. Both of these benefits received more mentions when applied to other affected groups. Thus, safety/convenience is mentioned more often in relation to highway users and tourist information/public relations is mentioned more frequently for "all others."

Reductions in accident rates will also result in both direct and indirect benefits to public agencies. Direct benefits include the reduction in costs of responding to and managing accidents (e.g., police, ambulance, fire department, clean up, and traffic control). These cost elements are part of the overall unit accident costs used in the analysis discussed earlier in this chapter under "Detailed Accident Analyses." These unit cost figures also include, in a category denoted as societal costs of accidents, part of the indirect costs such as lost tax revenues due to incapacitating injuries and fatalities and public financing of medical facilities.

A number of other potential benefits deserve a brief discussion even though they were not explicitly included in the responses given in Table 3.

Highway Operations and Maintenance

A reduction in the frequency of shoulder stops, especially by heavy trucks, will result in less wear on the shoulders and a consequent reduction in shoulder maintenance costs. These reductions may be considerable, especially in areas where shoulders are built to lower design standards than through lanes or in cases where vehicles stopping on the shoulder encroach beyond the pavement. Although individual states may be able to disaggregate this cost category, there are no data available to estimate these costs for the nation as a whole.

A reduction in excess travel will decrease costs for maintenance and traffic control on the affected portions of the conventional road system. This decrease in costs may be substantial if an appreciable number of heavy trucks are deterred from using narrow, flexible pavement, secondary rural roads whose geometry, cross section and pavement design are inadequate for this type of vehicle.

Trash receptacles are an almost universal feature of highway rest areas. A large proportion of the trash deposited there would otherwise be disposed of on or near the highway adding to the already large highway clean-up costs. A reduction in shoulder stops, by itself, will lead to a reduction of highway trash.

Trash containers in rest areas usually fill up rapidly; in fact a number of rest areas are equipped with large dumpsters to handle this demand. In personal conversations, members of the research staff were informed that, in some instances, the rest area trash disposal is replacing local garbage collections. Some people will drive to the nearest rest area to dispose of the household's trash. One state highway department representative asserted that his agency had become the largest garbage collector in the state.

Direct Monetary Benefits

Apart from telephones and vending machines, the only commercially sponsored activities permitted in highway rest areas on the Interstate System are privately operated information services. These services, operated by commercial enterprises for profit, may operate fully staffed information centers (New York) or elaborate displays (California, Oregon) featuring local attractions and travelers services. The operating firms derive their income from the firms that are listed in these displays. Part of these revenues accrue to the highway agency in the form of franchise or lease fees, profit sharing arrangements and/or participation in the cost of maintaining and operating the rest area.

A number of state tourism agencies maintain a hotel reservation service as part of their welcome centers or staffed information centers. This service is rendered at no cost to the traveler. However, in some states, the agency may receive standard agency commissions on all reservations made.

Summary

This coverage of potential governmental agency benefits from rest areas represents the results of repeated discussions with

state officials and from the results of the state survey. Highway rest areas represent a service furnished by the appropriate governmental agency primarily for the benefit of the driving public. Any benefits accruing to governmental agencies are incidental to that main function. For this reason, the benefits discussed are rather ill defined and, for the most part, unquantifiable.

EXTERNAL BENEFITS

External benefits from highway rest areas are those that accrue to other, nonuser groups, as discussed below.

Economic Impact

The area in which external benefits are most often mentioned is the positive impact of rest areas on the state's economy, primarily on its tourism industry. This impact includes: (1) enhancement of the state's image through a favorable impression made by rest areas and welcome centers; (2) traveler decisions to extend their stay in the state as a result of information received at welcome or information centers; (3) traveler decisions to make future trips to a state because of information received or because of generally favorable impression; and (4) decisions to purchase goods or services, and to visit attractions not previously planned, as a result of information received in the rest area.

These claims are not strongly substantiated by data. In the few instances that data are available, these usually consist of inferences drawn from responses to questionnaires distributed in, or administered at, welcome centers.

The research agency requested all state tourism agencies to provide any information concerning the impact of highway rest areas on the state's economy and on tourism. Less than half of these agencies reported. Almost all responses indicated a strong belief that the rest area/welcome center system had a definite impact on the state's tourism industry; very few of these gave monetary estimates. Excerpts from typical responses appear in Table 14.

Examination of Table 14 indicates that an adequate data base for the quantitative determination of the impact of rest areas and welcome centers does not exist. Only four states provided overall monetary estimates; these do not appear to be based on a consistent set of criteria and assumptions.

Another question must be addressed in considering the impact of rest areas on tourism. For the nation as a whole, any positive impact can only exist if there is elasticity of demand for tourism services. To the extent that such elasticity does not exist, i.e., the total amount of time and funds devoted to tourism is fixed, any benefits accruing to one state are not newly generated but rather are taken from another state. Some of the trends discussed in Chapter Three, under "Future Trends," such as increased leisure time, more travel by older (retired) persons, and a reduction in foreign travel, indicate that there may be increasing elasticity in the demand for tourist services.

Traffic Diversion

One of the alternatives to a rest area stop is a departure from the route and a search for the desired services in some nearby locality. The impact of this diversion on highway maintenance and operations agencies has already been discussed. There are also impacts on local inhabitants and business enterprises. There will be a beneficial effect on the local economy because of traveler needs for goods and services. This impact may extend beyond these specific items if the travelers are exposed to services and attractions of which they would otherwise not have been aware.

Disbenefits will accrue in the form of increased congestion and consequent increases in air and noise pollution and in accident potential. Local facilities (e.g., parking) may be overtaxed and traffic controls, designed for local traffic volumes, may become inadequate. The net impact on a community cannot be determined generally and will depend on site-specific conditions.

Specific Business Enterprises

Some specific commercial enterprises are likely to benefit from rest areas. For example, telephone companies will obtain additional revenue from rest area operations as will vending machine operators; contract operators of computerized and other types of rest area tourist information systems also expect to profit from this type of enterprise as do the participating advertisers; and operators of tourist attraction and travelers' services can be expected to obtain additional revenues from the distribution of promotional literature in highway rest area information centers. On the other hand, some private enterprises located near interchanges that serve the through-traveler may lose some business.

Joint Use

While most joint uses of highway rest areas involve other governmental functions, there are some that involve commercial operators. A current California program studying the feasibility of developing rest areas, outside the highway ROW, in conjunction with private developers may indicate a possible future direction (*25, 26*).

COSTS

The subject of costs in economic analysis usually considers three separate aspects: (1) direct costs—the cost of providing, maintaining, and operating the facility; (2) external costs—costs incurred by other than the provider or direct user of the facility; and (3) disbenefits—reductions in benefits to one or more affected groups because of benefits accruing to another group.

The distinctions among these three cost categories, while somewhat artificial, have a significant effect in some formulations of cost-benefit analysis. For instance, in the computation of a benefit-cost ratio, different numerical results will be obtained if a given item is treated as a disbenefit, i.e., subtracted from the numerator rather than as a cost, i.e., added to the denominator.

Direct Costs

The following discussion of costs is based on: (1) responses to the KLD survey from 46 states; (2) amplification of these

Table 14. Rest area impacts on tourism—selected state comments.

California	"We do not have any estimate of the economic impact of rest stops."
Colorado	"There is no available data regarding the economic impact of information centers on Colorado vacationers. We have researched the economic impact of TICs in other states with similar programs and are applying our findings to the Colorado Department of Highways 1984 traffic figures using AAA's most recent figure of $111/day (meals and lodging only) for two adults. 1.4% of the Directional Average Daily Traffic (DADT) extended their stay an average of 2.4 days. (15% of the DADT stop and 9% of this 15% extend their stay by 2.4 days.) Our estimate of generated revenue from the Grand Junction and Burlington TICs is $5,014,347."
Florida	"During the four quarters of 1985 about four out of every five visitors to the Welcome Centers read, saw, or picked up information about attractions, activities and/or destinations of which they report they were not previously aware. Due to the information obtained at the Welcome Centers about one out of four added one or more days to their trip. While about half of these went to new or different attractions, about one in three went to either a new or different destination or a new or different historic site. One out of every five changed their plans in some other way. Overall, due to the information obtained at the Welcome Centers about three out of every four visitors surveyed either extended their stay by one or more days or went to a new or different attraction, destination, historic site or changed their plans otherwise."
Iowa	"The estimated economic impact of the travelers stopping at the Welcome Centers is determined by expanding the average party spending and length of stay in Iowa to all registered parties and applying multipliers. Because the factors used were up, the 1985 estimated economic impact of $46,054,970 for interstate travelers is 20.8 percent higher than the 1984 estimated impact of $38,117,346."

Table 14. Continued

Kansas	"As a result of no public advertising in rest areas, Tourist Information Centers or roadside parks and the recent implementation of private advertising in the Tourist Information Centers only, monetary benefits accrued to the State through rest areas that revenues generated by travelers across the state are substantial. Kansas roadside rest areas and parks serve a variety of purposes, all of which impact Kansas travelers and tourists. The existence of roadside rest areas have a positive impact and fulfill many intangible needs, many of which are very basic to Kansas tourism."
Kentucky	"Travelers who stopped and registered at the four welcome centers were responsible for a $59.1 million infusion into the Kentucky economy in 1983. This spending occurred as a result of their travels in and through Kentucky. Over $7.4 million of the expenditures were by tourists who stated that their decisions to travel in Kentucky were influenced by the information obtained at these information centers. The travelers who stated that they were influenced by the information spent nearly $364,000 on Kentucky's state parks. Tax revenues generated by the expenditures of those who were influenced by the information amounted to over $514,000. State government received over $414,000 of these tax revenues. Total revenues received by state government from the spending of travelers who were influenced by the information totaled over $778,000. This includes both state tax revenues and expenditures on state parks. The cost to the agency of operating the four welcome centers was $195,000. Thus, the revenues received by state government as a direct result of operating these centers exceeded the cost by $583,000."

Table 14. Continued

Louisiana	"We cannot put a dollar value to the benefits of the rest areas in Louisiana. However, conversely, if not properly maintained, the negative impact might by more significant. A state's "image" is reflected by those aspects touched by the traveling public, and the rest areas are a very visible part of the traveling public's view. Litter, vandalized rest rooms, uncut grass, and other unsightly parts of a rest area can have a very significant impact upon one's overall impression of a state or region."
Maryland	"It would be difficult to estimate the monetary benefits of information centers to the State. The most obvious benefits are the promotional and the hospitality benefits. We know that it retains the travel in our State, but how much of a monetary value this produces we do not know."
Michigan	"Although monetary benefits are hard to quantify for our rest area/travel information center system, an interesting study has been recently conducted by this Department and I am pleased to send you some preliminary information that has just become available. This can be found on the attached sheet entitled, "Economic Impact of Michigan Welcome Centers". Basically, the study showed that our 11 travel information centers counseled 1,800,000 people and because of their counseling efforts, were successful in convincing 9 percent of travelers to stay an additional 4.02 days in Michigan, the direct economic impact to the State was $41,679,360. We are advised that using a 1.78 multiplier (dollars generating additional dollars) and recognizing that 8.2 percent of the tourism dollars results in tax revenue, we find that $6,083,519 was tax generated. These are excellent economic returns from 11 travel information centers. We have not been able to quantify the economic benefits of rest areas without manned travel information centers but our feeling is they do have considerable positive economic impact on tourism in Michigan."

Table 14. Continued

North Carolina	"Monetary Benefits: We make thousands of hotel/motel reservations during the year. This brings in several hundred thousand dollars to these organizations. Through our promotion of the state, tourists stop at attractions, historic sites, restaurants, and also to tour and buy. Many areas have a hotel/motel room tax. The money resulting from this is pumped back into the area. We handled over 5 1/2 million visitors through centers in 1985."
Ohio	"In 1985, Ohio experienced its most successful tourist season. That success cannot be solely attributed to capturing motorist at the gates of Ohio. However, the TIC's convenient distribution of information and new appearance played a role in having people return to Ohio."
Utah	"While the majority of center visitors claims their trip plans would not be changed as a result of their visit to the center, a large group indicated change would occur. Expressed changes in plans were particularly evident among St. George Visitor Center visitors where nearly 20 percent said they would stay longer in Utah and 15 percent would visit unplanned attractions. If it were assumed that this 35 percent spent at least an extra one-half night in Utah than they had originally planned, the St. George Visitor Center alone may have accounted for an additional expenditure of $650,000 in Utah."
Vermont	"We believe vital, active rest areas, appropriately staffed, would strengthen the state's image and provide additional assistance to travelers. We currently have sign plazas at these facilities as part of a state sign system which is publicized through state literature. Also, contractual distribution of travel business literature is permitted at these areas. Any estimates on the monetary benefits would be a wild guesstimate, but under proper guidance, could generate some $100 million in additional traveler spending and upward to $10 million in state and local tax revenues. While much of this is under certain assumptions, we have a strong sense of the value to be gained from a fully staffed operation, particularly since Vermont is a rural state and presumed access to travel information is limited."

data in discussions with a number of state representatives, and (3) data assembled by the Roadside Task Force of the AASHTO Subcommittee on Highway Maintenance.

The KLD survey requested a range of costs for three types of rest areas (LOS = high, average, low) and for three cost categories (right-of-way (ROW), design and construction, operations and maintenance).

Unfortunately, less than 20 percent of the responding states furnished all the information requested. Many states furnished a single number instead or a range of numbers for each cost element-LOS combination. Four states furnished figures for operations and maintenance that were so high, $500,000 and more, that it was extremely unlikely that they represented yearly maintenance and operations costs for a single rest area.

These survey data were interpreted as follows: single values were considered to represent average costs for that cost element-LOS combination, for a range of costs, the midpoint was taken as the average cost; and obvious outliers were discarded.

Discussions with state personnel confirmed that historical cost data were incomplete. These discussions also confirmed both the high variability of individual cost elements and the wide differences between the cost accounting systems of the individual states.

The construction of rest areas on rural primary highways started more than 50 years ago and received its main impetus with the opening of major sections of the Interstate System in the early 1960s and with the passage of the Highway Beautification Act in 1965. The survey may thus include cost data for ROW, design, and construction elements, for rest areas originally built 20 or more years ago. It is not known whether respondents updated their figures to reflect current price levels. Construction cost indices (e.g., FHWA, *Engineering News Record*) generally show increases of 400 percent or more since 1955.

ROW, design and construction costs presented and discussed below may therefore be understated. Operations and maintenance costs are usually recomputed yearly and are, therefore, probably current.

Cost Element	Average Cost Estimates ($1000) Level of Service		
	High	*Average*	*Low*
ROW	52	35	16
Design and construction	1635	1208	542
Operations and maintenance (annual)	81	56	26
Annual costs (see below)	230	166	75

Annual costs were computed under the following assumptions:

Cost Element	Useful Life
ROW	50 years
Physical plant (i.e., design and construction):	
10 percent (e.g., site preparation, grading, etc.)	40 years
90 percent (all else)	25 years
Equivalent interest rate	7.5 percent

Table 15 shows the wide range that individual cost elements can assume. The range between states (based on average costs for each state), the range within states for those states which gave a range of costs, and the absolute range (i.e., highest high to lowest low) are shown.

Interestingly, annual operation and maintenance expenses are approximately 35 percent of the total annual costs for all three levels of service.

An analysis of the annual costs (operations and maintenance) of three states which furnished detailed data yielded the following percentage distribution:

State	Labor	Material	Equipment	Other
1. (South)	79.2	17.0	3.8	—
2. (West)	46.7	8.7	12.0	32.6
3. (South)	65.8	10.5	3.4	20.3

The category "other" is explicitly designated as contractual services for State 2 and presumably represents these services also for State 3. Because contractual services are, usually, manpower intensive, it can be seen that labor costs account for almost 80 percent of total annual operations and maintenance costs.

Extreme variability in cost levels is also indicated by the AASHTO survey which is summarized below:

Type	Rest Area Costs From AASHTO Survey ($1000)		
	Average Costs	*Range Low*	*Range High*
Rest area construction costs: Pair	3,590	600	9,000
Single	1,810	300	5,000
Rest area operating costs: Pair	126	50	300
Single	66	6	275
Welcome center const. costs: FAI	2,060 (FAI and Other)	270	4,500
Other		170	4,500
Welcome center operating costs: FAI	99.8 (FAI and Other)	34	1,000
Other		6	275

Obvious outliers were omitted from this tabulation. For instance, one state reported construction costs of $28.1 million for a rest area pair. Another reported rest area operating costs of $450 per year. It was not possible to determine from the welcome center cost data furnished whether these data covered total costs, costs to the State agency (omitting local contributions), or incremental costs of a "welcome center" over those of a rest area.

Some of the reasons for this wide dispersion of reported costs were discussed in Chapter Two, under "Costs."

Table 15. Range of costs. Note: Table entries are ratios of high to low.

LOS-Cost Element	Between States	Within State	Absolute
High - ROW	160.0:1	42.5:1	240.0:1
High - Design & Construction	18.0:1	4.0:1	20.0:1
High - Maintenance & Operations	5.4:1	2.7:1	9.1:1
Average - ROW	150.0:1	2.8:1	150.0:1
Average - Design & Construction	25.3:1	2.0:1	53.3:1
Average - Maintenance & Operations	6.4:1	15.0:1	24.1:1
Low - ROW	50.0:1	2.0:1	50.0:1
Low - Design & Construction	40.0:1	5.0:1	60.0:1
Low - Maintenance & Operations	12.7:1	4.0:1	15.2:1

External Costs and Disbenefits

External costs and disbenefits can arise from many factors, including air pollution, noise pollution, ground water contamination, interference with surface runoff, destruction of existing vegetation, interference with the habitat of the local animal population, removal of arable land from agricultural use, and adverse aesthetic elements.

None of these potential impacts is considered to be serious. All of them are usually avoided or minimized by appropriate rest area location, design and construction policies. The results of the survey, inspection of existing rest areas, and examination of the rest area literature revealed few instances of adverse environmental impact. There are isolated instances of ground or surface water contamination duc to poorly designed, overused, temporarily malfunctioning or vandalized sanitary waste treatment and disposal systems. Several instances of adverse aesthetic impact due to poor maintenance or unrepaired damage, usually because of vandalism, were noted during the study.

The establishment of a rest area prevents the use of that land for alternative purposes. The joint development study in Ref. 25 devoted considerable attention to whether a highway rest area represented the "highest and best" use for the specific site being considered and the impact that it would have on future land use development in the immediately adjacent area.

Entrances and exits of rest areas, however well-designed and lighted, will create some additional traffic stream turbulence. Aside from the specific problem of overflow truck parking, the interaction of through, entering, and exiting traffic will tend to increase the variance of the spot-speed distribution at these locations, a cause for increased accident potential. Proper advance signing, in addition to correct design (e.g. appropriate acceleration and deceleration lanes) and appropriate location (e.g., clear sight distance on the approach), can minimize these adverse effects.

As noted earlier, the establishment of rest areas will, in some instances, have an adverse effect on some local travel-related establishments. While travelers still leave the highway in order to buy gasoline or food, or to find lodging, other needs, especially short rests or use of a toilet or telephone, can be satisfied in a rest area.

In a number of instances, rest areas have become the focus for socially undesirable behavior including prostitution, homosexual activities, and drug sales and use. This pattern places an extra burden on already extended police forces.

With few exceptions, these external costs should, even for a worst case scenario, have no significant effect on a decision to establish or continue a rest area as long as it is properly located, designed, operated, and policed.

CHAPTER FIVE

APPLICATION OF RESEARCH FINDINGS

NCHRP Project 2-15 had three major objectives: (1) develop an updated profile of rest area use and users; (2) define the benefits of rest areas to highway users, to governmental agencies, and to others; and (3) develop a methodology for evaluating the benefits of rest areas in relation to their costs so as to facilitate national rest areas decision-making.

The research findings are discussed in terms of these objectives.

REST AREA USER PROFILE

On the basis of the findings presented in Chapter Three, the following generalizations can be made about rest area users:

1. Almost every rural freeway user on a trip in excess of 100 miles is a potential user of highway rest areas.
2. Over 95 percent of all drivers have used rest areas and 60 percent prefer them over other stopping opportunities for nongas, nonrestaurant stops. Almost one passenger car in every eight and one truck in every five would stop on the shoulder if a rest area were not available.
3. Drivers stop at average intervals of about 130 miles or somewhat more than 2 hours and would prefer rest areas to be spaced about 50 miles apart.
4. Demographically, the rest area user population closely approximates the driving population, especially those engaged in longer trips with, possibly, a higher participation by older drivers.
5. The proportion of main-line traffic that enters a given rest area ranges widely, depending on traffic stream, driver, trip and area characteristics, and on competing stopping opportunities. This proportion may range from less than 1 percent to almost 50 percent. The overall average is about 10 percent; the proportions of trucks and recreational vehicles entering rest areas are generally significantly higher. Current formulations to compute expected rest area use as a function of rest area spacing, based on data almost 20 years old, may seriously understate actual use.
6. Approximately 20 percent of all vehicles entering rest areas contain children; 2 percent include visibly ambulatory handicapped occupants; and 4 percent of all travelers are accompanied by pets. The average occupancy of passenger vehicles entering rest areas is 2.3.
7. The average time spent in rest areas ranges from 8 to 15 min per vehicle with a significant increase for vehicles that enter

the rest area at night. Trucks and recreational vehicles generally remain for significantly longer time periods than do passenger cars.

8. Use of toilet facilities and rest/stretch/exercise are, by far, the dominant reasons for stopping at rest areas. Considerably smaller, but still significant, proportions of entering traffic do so to eat or drink; use the telephone (primarily business travelers); check or repair their vehicle; or consult a map. No other rest area service or facility is used by more than 5 percent of entering traffic.

9. An overwhelming majority of all rest area users believe that these facilities represent a valid public service that should be financed by public funds. There were, however, considerable differences of opinion whether private business, even if travel related, should be allowed in rest areas.

10. Based on a "willingness to pay" approach, the value of each rest area visit to the traveling public appears to lie somewhere between $0.40 and $1.00.

11. Rest area use, as a function of passing traffic, can reasonably be expected to increase at a somewhat faster rate than the growth in traffic volumes and in vehicle-miles of traffic. This rate of increase may be larger for commercial traffic than for passenger vehicles.

BENEFITS OF HIGHWAY SAFETY REST AREAS

The major benefits from the establishment and operation of highway rest areas accrue to the *motoring public.* Three classes of benefits appear to dominate: (1) user comfort and convenience—mainly the opportunity to rest, stretch, and satisfy bodily needs; (2) improvements in highway safety—reduction in hazardous shoulder stops, reduction in the proportion of the traffic stream whose drivers are fatigued or otherwise impaired, opportunity for vehicle and load checking and minor preventive maintenance, and refuge from hazardous driving conditions; and (3) reduction of excess travel to search for services.

Benefits to highway and other governmental agencies are of a lower order of magnitude except, possibly, for the opportunities that rest areas present to communicate with the driving public.

One of the major benefits claimed for highway rest areas, especially when these are combined with welcome centers or other staffed information facilities, is an enhancement of the State's economy. This enhancement is attributed to two mechanisms: (1) increased attendance at local tourist attractions and increased use of local commercial establishments, especially travel-related ones, as a result of information displayed or distributed in rest areas; and (2) an overall increase in a State's tourism-related revenues because of both the good image created by the rest area and the information made available there on the State's attractions.

While such claims appear to be plausible, evidence in support of them is mostly anecdotal with little, if any, hard data in support. Local business undoubtedly benefits from such additional publicity channels; however, the incremental effort of rest area information over that transmitted by other means, e.g., logo signing, standard outdoor advertising, hard copy handouts in motels and restaurants, etc., cannot be assessed.

The effect is probably strongest in such states (e.g., Vermont) with strict control over other advertising channels. Increased use of rest areas to transmit information on travel-related goods and services and on tourist attractions has been proposed as a replacement for outdoor advertising (*59*).

REST AREA COSTS

Available data on rest area construction and operation costs were presented in Chapter Four, under "Costs." Generalizations concerning these data show extremely high variability in all cost elements both between and within states. Furthermore, considerable differences exist in cost accounting practices between the states, which make it difficult to isolate comparable cost elements or, in some instances, to assign costs to specific rest areas.

APPLICABILITY OF COST/BENEFIT METHODOLOGY

One of the principal objectives of NCHRP Project 2-15 was the development of an analysis procedure which could serve as the basis for decisions concerning such aspects of both existing and proposed new highway rest areas as their location, design (i.e., facilities to be included), and hours of operation, among others. For existing rest areas, this procedure would also apply to support decisions concerning reconstruction, closing, relocation, etc. An extension of such a procedure would allow for the comparative evaluation of proposed improvements to the rest area system with improvements to other portions of the highway system.

The original intent of the research agency, as formulated in the approved Working Plan, was to base this procedure on a classical cost-benefit approach following the general approach of the AASHTO "Manual on Road User Benefit Analysis" (*60*). This approach would quantify the anticipated incremental changes in safety and in other benefits of a proposed alternative and relate these to the costs of that alternative.

An alternative methodology was developed when it became apparent during the research effort that such a cost-benefit approach was not feasible. The underlying factors, documented in earlier parts of this report, primarily in Chapter Four, are summarized in the following.

Safety Benefits

Detailed analyses of a large accident data base drawn from the historical records of six cooperating states have shown that the safety effect of an individual rest area (the accident reduction due to the presence of a specific rest area) cannot be completely quantified, given the accuracy and resolution of currently available accident data. There is no assurance, given the stochastic nature of accident occurrence, that such quantification will be possible even with a larger, improved data base.

Other Benefits

Other benefits, most of which accrue to highway users, are known to exist. However, no reliable data are available to quantify these benefits or to express them in monetary terms. Data on how much rest area users are "willing to pay," a standard

economic method to estimate the monetary value of intangibles, has been developed. Transforming these data into a quantitative benefit for a specific rest area alternative presents serious methodological problems.

Costs

Some of the uncertainties regarding the assignment of anticipated costs, both initial and recurring, to the alternatives to be considered have already been discussed. However, one other important point needs to be made in this connection.

One of the major determinants of rest area costs is the size of the rest area. This size depends on its anticipated maximum use over its design life. Data and procedures have been published to estimate the expected use of an average rest area as a function of ADT, traffic composition, and general route and area characteristics.

The data assembled during this project cast serious doubts on the applicability of these prediction algorithms, some of which are based on data almost 20 years old. Even if a more accurate prediction procedure, using current data, would be developed to predict the expected use of an average rest area, application of these procedures, even if updated and improved, to specific rest area alternatives would still entail a considerable amount of uncertainty, particularly if the alternatives include changes in existing rest area spacing.

As discussed in Chapter Three, under "Future Trends," highway travel and the stopping behavior of highway users are affected by long-term economic, social, and demographic trends. There is considerable uncertainty involved in projecting these trends over an analysis period that may extend over the 20+ year economic life of a proposed rest area improvement alternative. This difficulty in predicting overall future trends is exacerbated in the case of individual rest area locations that are subject to the influence of local changes in economic activity, land use, and highway system configuration. For these reasons forecasts of future rest area use, and consequent rest area size requirements, should be made with extreme caution and explicitly recognize these uncertainties (e.g., the possibility of reduced effective service life because of larger than anticipated usage growth).

Cost/Benefit Estimates

Even though most of the benefits identified cannot be expressed in monetary terms using classical valuation approaches, an approximate estimate can be made. Comparing the estimated magnitude of quantifiable benefits to the average annual costs of highway rest areas leaves little doubt that the rest area system as a whole can be justified using classical benefit-cost approaches.

The AASHTO (*2*) survey showed, for the entire Interstate rest area system of 1,362 full service rest areas and welcome centers:

Replacement Costs	$ 2.4 billion
Annual Maintenance Costs	$93.4 million

Assuming an average rest area effective life of 25 years and an equivalent interest rate of 7.5 percent results in uniform annual costs of 309 million dollars. As part of the current research, quantitative estimates for three separate user benefits were derived:

Reduction in Shoulder Stop Accidents (Chapter 4, "Indirect Safety Benefit Analyses")	$297 million
Reduction in Out-of-Pocket Costs of Excess Driving (Chapter Four, "Reduction in Excess Travel")	$258 million
Increase in User Comfort and Convenience (Chapter Four, "Comfort and Convenience")	$420 million

These three items together thus yield a total user benefit of approximately $975 million or a benefit-cost ratio of 3.2.

Decisions on the location, size, number and type of facilities to be included, reconstruction or upgrading of a specific rest area require more comprehensive and specific information on costs and potential benefits.

PROPOSED ANALYSIS METHODOLOGY

An analysis procedure was developed to satisfy the research objectives and meet the needs of the user population. This procedure is designed to satisfy the following requirements: (1) include significant costs and benefit elements, even though some of these cannot be expressed accurately in monetary terms; (2) incorporate the probabilistic nature of anticipated rest area use and of different cost and benefit elements; and (3) be responsive to the fact that different agencies may have different preferences concerning the relative importance of some benefits, or costs (disbenefits), which can only be expressed on an ordinal scale.

Conceptual Approach

The foregoing three requirements all necessitate the incorporation of judgment-based, subjective factors into the analysis process. The application of judgment to identify, scale, rank and weight benefit and cost elements is an integral part of the procedure. This approach is consistent with the concept that "... the individual (or decision maker) is an integral and indispensable component in the process of evaluation, since we require his value judgments in order to help him resolve his indecision or find a solution to his problem " (*61*).

The procedure represents an adaptation of a standard class of methodologies, collectively referred to as value or decision theory, to the specific problem of rest area evaluation. These methodologies are based on the general concept of relative value or utility.

Decision theory is a familiar tool in transportation planning, especially for major decisions involving intermodal choice or corridor selection. This approach has also been used for more narrowly defined aspects of highway engineering including the selection of a testing method for asphaltic pavement (*62*) and the feasibility of constructing a pedestrian overpass (*63*). The original intent to follow the approach of the AASHTO Manual (*60*) has been retained—that publication states:

> ... could utilize several different analytical approaches to take noncostable effects into account. In order of increasing complexity, sophistication, and cost, the leading candidates are probably expert judgment, cost-effectiveness analysis, scoring or

weighting methods, and decision analysis. The choice of an evaluation approach should take into account both the nature of the problem and the needs, aims, and capabilities of the decision maker that it serves. It is felt that cost-effectiveness approach is generally desirable and is adequate for evaluating highway and transit improvements. In cases entailing important and complex impacts on diverse interest groups, however, either (1) scoring methods that involve interest groups in assigning weights or (2) decision analysis (which accomplishes the same result in a more rigorous manner) may be worth the added time and cost required.

The basic conceptual framework of the proposed methodology is as follows:

1. The analyst can identify a number of alternatives, usually including the "do nothing" alternative.
2. The consequences of selecting any one of these alternatives must be evaluated for a number of different effects impacting different groups and using different evaluation criteria.
3. The relative magnitudes of most consequences are located within probability distributions.
4. The relative importance of each decision criterion, or type of consequence, is neither equal nor fixed but must be redefined for each decision process.
5. The consequences to be evaluated for any decision problem are one of the following: (a) quantifiable on a defined interval scale—some of these scales may be translatable into monetary units and others may not; (b) expressed on an ordinal scale—these ordinal scales are, generally, not translatable into monetary terms; and (c) dichotomous—a given consequence may, or may not, result from the selection of a given alternative.
6. Each consequence for each alternative can be associated with a specific utility by the application of a suitable measurement scale or mapping function.

Utility-based evaluations generally rest on the assumption that utilities are additive. The basic mathematical formulation, as expressed by Lin and Hoehl (64), is:

$$U_i = \sum_j W_j U(S_{ij}) \qquad (12)$$

in which U_i = utility of plan "i" as compared with other plans; S_{ij} = outcome state of plan "i" in "j"th category of consequences; $U(S_{ij})$ = utility of outcome state S_{ij} as compared with other outcome states in the same category of consequences; and W_j = weight to be attached to the utility of "j"th category of consequences as compared with other categories.

A modification of this formulation to incorporate a probabilistic element leads to the following:

$$U_i = \sum_j W_j \sum_k p_{jk} U(S_{ijk}) \qquad (13)$$

where p_{jk} is the probability of realizing outcome state S_{ijk} and $\sum_{j,k} p_{jk} = 1.0$.

Development of a Rest Area Analysis Procedure

Based on this conceptual approach, the decision or analysis process consists of the following steps:

1. Select the alternatives to be considered. This does not imply that all possible alternatives should be investigated. The analyst will be able to reject a considerable proportion of these a priori on the basis of his experience and on such constraints as legal requirements, existing policies, bounds on available funds, or patent infeasibility. However, a fairly large set of alternatives should be included at the outset.
2. Perform a preliminary screening of this initial set of alternatives by making qualitative estimates of the probable overall consequences of each alternative in each of eight major categories: costs; highway safety; highway user consequences; institutional consequences; environmental consequences; economic and social consequences; implementation effects; and system effects. This screening is designed to identify those consequence categories for which major effects (positive or adverse) can be expected and whether any of the adverse effects are so severe that a specific alternative should be eliminated from future consideration.
3. Select the consequences to be considered. At a minimum these consequences will include initial and recurring costs, highway safety, and user comfort and convenience. Local factors and policies will indicate which additional consequences are to be included. For instance, environmental consequences should be included for an ecologically sensitive area; different consequences for an area that is largely tourist oriented. Any consequence category for which major effects were postulated in step 2 must be included.
4. Decide which metric is most applicable to each consequence selected: interval scale in monetary terms, interval scale in terms of a nonmonetary variable, ordinal scale (semantic descriptors), and dichotomy—a dichotomous outcome is a limiting case of an ordinal scale constrained to two levels.
5. Determine which exogenous set of conditions will affect the magnitude of each consequence. For most consequences these conditions will be some measure of future traffic volumes and rest area use. Other conditions may also apply. For instance, cost levels may depend on future interest rates or price levels; consequences to surface runoff or ground water may depend on rainfall patterns. Rest area use, and parking lot turnover, may depend on future changes in administrative regulations defining the maximum length of stay.
6. Develop a limited set of each of these conditions (probably not more than three—high, average, and low) together with a probability of occurrence for each of these.
7. Assign relative "importance" weights to each category of consequences.
8. Compute or estimate the level for each category of consequences for each scenario and for each alternative in terms of the metric selected in step (4).
9. Define, for each consequence metric, a suitable transformation or mapping function that will convert the consequence level into a utility value bounded by ±1.0.
10. Determine the utility associated with each probability level of each consequence for each alternative using the function defined in step (9).
11. Determine the total utility of each alternative in accordance with Eq. 13.

This procedure will provide a rank ordering of all alternatives in terms of the totality of the consequences included in the analysis and in accordance with the weighting and value as-

signment structure adopted. The selection of weights as well as the assignment of utility values in cases where quantitative measures cannot be determined incorporates subjective inputs. It is thus appropriate, before basing a decision of recommendation on the output of step 11 to perform a sensitivity analysis. This analysis will demonstrate the robustness of the relative merits of each alternative to: (1) changes in relative weights; (2) basing the decision process on only one of the possible subsets of all the consequences identified (i.e., assigning a weight of zero to some of these consequences); (3) changes in the probability distribution association with each consequence (the possibility that these distributions will change over time should also be considered at this point—this possibility applies especially to forecasts of changes in traffic volumes, driver population, traffic stream characteristics and rest area use patterns over the ânticipated effective life of the alternative being considered); and (4) changes in the relative utilities assigned to consequences classified as incommensurable or intangible.

The procedure outlined above can apply to all rest area related decisions. However, it need not be implemented for every decision. If the preliminary screening of step 1 results in only one viable alternative, the remaining steps in the analysis are superfluous. Also, if all benefit and cost elements identified as pertinent to the decision are expressed in monetary terms, the standard methods of cost-benefit analysis apply. A repair-reconstruct-replace decision for a sanitary waste treatment facility at an existing rest area may represent a good example of this.

Although the 11-step procedure outlined previously applies to decisions concerning a single existing or proposed rest area system, consideration must play an important role in the decision process. An obvious example is a decision whether to establish a new rest area within an existing rest area system. Projected use patterns for the proposed rest area will affect, and be affected by, usage patterns at the two adjacent existing rest areas. Within the context of the proposed methodology, these system effects can be incorporated by considering all affected rest areas and assigning utilities to individual consequences for each of these. Some consequences (e.g., alleviation of recurring parking lot overcrowding) may only apply to the adjoining rest areas and not to the one being specifically considered.

The determination of levels of consequences in step 8 can be done in either absolute or relative, as referred to existing or some other base condition, terms. These approaches may both be used within the same analysis as long as a consistent method is applied to every category of consequences.

A detailed procedure manual for implementing the procedures outlined above has been developed and is included herein as Appendix A. Appendix B includes a completely worked out case study using these procedures.

Extensions to the Methodology

Several extensions to the basic methodology, including the implementation of cost-utility and weighted ranking approaches are detailed in Appendix A. Under certain defined conditions, these extensions may be computationally simpler and/or less data demanding than the basic analysis methodology.

The outline of the proposed analysis methodology in this section as well as its detailing in Appendix A and its case study application in Appendix B have been presented in the context of deciding between a set of alternatives, all of which are concerned with rest area improvements. This methodology has, however, been kept sufficiently general so that it can be applied to many other decision processes commonly faced by highway agencies. Specifically, this includes comparisons between proposed rest area work and competing proposals for work on other parts of the highway system.

Detailed examination of the proposed methodology shows that it can be used to evaluate any set of alternatives which meets the following conditions: (1) all alternatives to be considered can be clearly and completely defined; and (2) the effects, if implemented, of all alternatives, can be estimated in terms of a common set of consequences.

The second requirement above does not imply that all the alternatives considered must have an effect in each consequence category. For instance, consider a comparative evaluation of a number of different proposed rest area rehabilitation projects and a number of different proposed projects to install or rehabilitate guardrail. These alternatives will have effects, which can be estimated, in at least two common consequence categories: cost and highway safety. There may also be effects, for each of these, in other categories such as implement effects (e.g., differences in lead time) or institutional effects (e.g., different future maintenance work load). Other consequence categories, especially user effects and economic and social effects, will be mainly applicable to the alternatives involving rest areas. The level of these consequences should, therefore, be set at zero (if quantitative) or at "no effect" (if qualitative) for the guardrail alternatives.

Factors affecting occurrence probabilities are also likely to differ between the two classes of alternatives. There will be some common elements, such as anticipated traffic volumes and traffic stream composition, applicable to all alternatives. Others, such as highway user demographics, will only apply to one of the classes of alternatives. This dichotomy can be handled by increasing the number of future scenarios and holding consequence levels constant between scenarios for those alternatives not affected.

Similarly, difference in economic or effective service life between the different types of alternatives can be accommodated by defining an additional consequence category. This category would contain an estimate of the value or utility remaining, for each alternative, at the end of a defined time period. This time period should be set equal, or shorter, than the shortest estimated service life for any alternative.

The methodology detailed in Appendix A can use a "paper and pencil" approach and hand calculations. Initial work has been completed on converting this methodology to an interactive PC-based computer program using expert system approaches. Figures 7 through 11 illustrate typical screen images for such a computerized approach.

```
WELCOME TO
RAAMSYS

R est
A rea
A nalysis
M ethodology
S YStem

KLD Associates Inc.
January 1988

Press any key to continue ...
```

```
This System, or Advisor, is designed to assist you in
implementing the RAAM procedures.
You may input up to 25 alternatives in one analysis case.

Please follow the instructions presented on the screen.

Press any key to continue ...
```

Figure 7. Typical screen images—computerized analysis methodology.

```
Main Menu

==> 1. Begin a new analysis
    2. Continue an existing analysis
    3. Quit (Leave the system)

Select a menu item by using space-bar to move
arrow, then press ENTER key.
```

```
Outline of RAAM Procedure

Step 1 : Define your set of selected Alternatives
Step 2 : Conduct initial screening of these Alternatives
Step 3 : Define your set of Consequences, by category

Press any key to continue ...
```

Figure 8. Typical screen images—computerized analysis methodology.

```
                 Screening Matrix Entries
                 ========================
                                                   Safety
. No.                  Title                    Consequence
-----     ------------------------------------  ---------------
1         alt 1                                       +
2         alt 2

L e g e n d
-----------
Enter a blank (spacebar), +, -, or X.
Blank : No significant impact on the indicated consequence
  +   : Significant positive impact on the indicated consequence
  -   : Significant negative impact on the indicated consequence
  X   : Alternative is not viable due to unacceptable negative
        impact on the indicated consequence
```

```
Preliminary Ranking of Alternatives

               No. of Indicated Entries
Alternative    +     blank    -     Score   Ranking
-----------  -----   -----  -----   -----   -------
     1         2       6      0       2        1
     2         0       6      2      -2        2

Do you want to eliminate an Alternative ? (Y/N)
```

Figure 9. Typical screen images—computerized analysis methodology.

```
Do you want to conduct the RAAM procedure for
this set of Alternatives ? (Y/N)
```

```
Major Consequence Category List

1. Cost
2. Safety
3. User
4. Institutional
5. Environmental
6. Economic and Social
7. Implementation
8. System
9. Other Consequences
```

Figure 10. Typical screen images—computerized analysis methodology.

```
Please enter Name of Alternative  1, then depress ENTER key.
(Must be 40 characters or less)

==>  alt 1

Do you wish to define additional alternatives ? (Y/N)

Please enter Name of Alternative  2, then depress ENTER key.
(Must be 40 characters or less)

==>  alt 2

Do you wish to define additional alternatives ? (Y/N)
```

Figure 11. Typical screen images—computerized analysis methodology.

CHAPTER SIX

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

The analysis of the data assembled during the course of the research effort, and its synthesis with the existing state of the art, leads to the following general conclusions:

1. Highway safety rest areas are an integral, necessary element of the rural Interstate and primary highway system in the United States. They are considered, by the vast majority of the public, to be a legitimate public function to be financed with public revenues.
2. Quantifiable benefits for the U.S. Interstate rest area system include a reduction in shoulder stop accidents, the perceived value of user comfort and convenience, and the reduction in excess travel to obtain services. These benefits are estimated to range between 1 and 2 billion dollars a year. The annual costs of this system, including replacement costs based on a 25-year useful life, are estimated to range between 270 and 309 million dollars per year. The resulting systemwide benefit-cost ratio thus lies between 3.2 and 7.4.
3. On average, approximately 10 to 15 percent of passing traffic will enter a rest area. The entering percentages are generally higher for trucks and recreational vehicles than they are for passenger cars. The exact percentage depends on traffic stream composition, route and area characteristics, season, and time of day. There are indications that this percentage has increased over time and can be expected to increase in the future.
4. Currently used methods to estimate future rest area use appear to lead, in many cases, to a serious underestimation of this use. A more accurate methodology, explicitly including other factors in addition to main line traffic volumes, is needed.

More specific conclusions are listed as follows.

Benefits of Highway Safety Rest Areas

1. The benefits of highway rest areas accrue primarily to the highway user population with lesser benefits to the operating governmental agencies and to other public and private organizations.
2. User benefits consist mostly of increased highway safety, user comfort and convenience, and reduction in excess travel.
3. Benefits to others include the opportunity of highway operating agencies to communicate with motorists and potential enhancements for local and statewide tourist industries.
4. Many of the identified benefits are intangible and/or uncostable.
5. The current state of the art and available, or obtainable, data do not permit an accurate, quantitative evaluation of all benefits that can be attained. Comparative and parametric evaluation is possible.
6. Using a "willingness to pay" approach, the value of comfort and convenience can be estimated to be approximately $0.70 per entering vehicle.
7. No significant major adverse environmental effects of rest areas in general could be identified. Isolated instances of such adverse effects can usually be attributed to the lack of capacity or to inadequate maintenance (emergency response time and time to repair) of sanitary waste disposal facilities. Capacity inadequacy of these facilities is correlated with a general underestimating of rest area use. In some cases, specific attributes of a rest area location, or adjacent land use changes subsequent to the establishment of a rest area, may lead to adverse effects in terms of air or noise pollution or aesthetic impact.
8. Even though the entrances and exits to a rest area can cause perturbations in the passing traffic stream, no instances of an adverse safety effect due to rest areas, has been reported.
9. Classical, cost-benefit methods are generally not applicable to rest area related decisions because many benefits and disbenefits cannot be quantified in monetary terms. Utility or decision theory based analysis methodologies can be applied. Such a methodology has been developed as part of the research effort and can be used by responsible state highway agencies to choose between alternatives concerning the location, design, and operations of highway safety rest areas.

Rest Area Location, Design, and Operations

1. Rest areas should generally be spaced at intervals of between 40 and 50 miles and should offer the following minimum facilities and services: (a) all weather parking segregated by vehicle class; (b) flush-type toilets in sufficient number to allow access without extended waiting times, even during period of capacity use (this may require a reexamination of the distribution of these facilities between the sexes); (c) safe drinking water; (d) telephones (some of these telephones should incorporate an emergency, i.e., no coin, calling capability; (e) picnic tables, preferably sheltered from direct sun; (f) the provision of static displays of travel-related information including, at a minimum, highway maps, locally applicable laws and regulations governing the use of the rest area and of the highway system, emergency telephone numbers, and identification of nearby travel-related services and attractions; (g) exterior lighting; and (h) trash disposal.
2. Additional facilities at rest areas are desirable but not essential. The need for these additional facilities should be evaluated on a site-specific basis taking into account anticipated use levels and user population characteristics. These additional facilities include vending machines, pet exercise areas, children's playgrounds, staffed information centers, sanitary waste disposal for recreational vehicles, and real-time weather and roadway condition information.

3. All facilities should be fully accessible to handicapped travelers. This is especially essential for bathrooms, which should be so designed and partitioned to be usable by a handicapped person receiving assistance from a person of the opposite sex.

4. The average time that a vehicle spends in a rest area generally ranges from 10 to 15 minutes. Trucks and recreational vehicles generally have longer stays, especially during nighttime hours, and frequently violate current restrictions on maximum time in rest areas.

5. Operations and maintenance of highway rest areas is generally at an adequate to high level. There are, however, major perceived personal security problems, especially at night, which indicate the strong advisability of increasing the level of police and other security patrols. Such additional security measures are also recommended in view of an apparently increasing frequency of vandalism and of moral offenses at rest areas.

RECOMMENDED RESEARCH

A number of issues related to rest areas have been identified for which additional research would be beneficial. These issues address the identification, measurement, and evaluation of rest area benefits. Other possible research needs which address specific aspects of rest area design and operations are not included.

Rest Area Use

Currently used computational methods to estimate the level of anticipated rest area use are either jurisdiction specific or, if general, are based on relatively old data bases and do not include an adequate set of independent variables. A major study designed to develop a comprehensive, universally applicable prediction methodology is recommended. Such a study should assemble and analyze a nationwide data base. Dependent variables should include rest area use and time in rest area (i.e., parking lot turnover rate). Both of these variables should be stratified by vehicle class, by season, by day of week (weekday/weekend) and by hour of the day.

Independent variables for which data should be collected and whose effect and significance should be investigated will include the following at a minimum: (1) distances, both upstream and downstream, to the nearest adjoining rest areas, urban aggregations, freeway to freeway interchanges and major tourist attractions and other traffic generators; (2) route and area characteristics including possible regional variability; (3) the availability of competing stopping opportunities; (4) traffic volumes and traffic stream composition; (5) rest area attributes and facilities and services offered especially if these are apparent to, or can be ascertained by, the motorist before a decision to enter is made; and (6) advance signing.

Rest Area Benefits

The present study has identified, defined, and scaled rest area benefits to the extent possible, given the availability of data. It is recommended that studies be undertaken to address the following issues: (1) Assess whether the safety effects of highway rest areas can be quantified by a detailed analysis of individual accidents, including involved driver interviews and reconstruction of the accident causal chain. (2) Develop nationwide, stratified estimates of the "vehicle on shoulder" problem; the accident involvement potential of such vehicles; and the effect of rest areas on the frequency and distribution of vehicle shoulder stops. (3) Explore whether methodologies can be developed to (a) provide accurate estimates of the distribution of fatigue, and other temporary impairments, in the driving population; (b) estimate the effects of rest area location and spacing on these fatigue levels; and (c) relate these fatigue levels to accident frequency and severity. (4) Determine whether accurate estimates of the influence of rest areas and welcome centers on local and statewide tourist related economic activity can be developed using modern market research techniques and other economic analysis tools. This should include the development, testing, and validation of in-depth interview protocols, to be administered by trained personnel to a statistically representative, random sample of the traveling public.

Rest Area Operations

Restrictions on the maximum length of stay in rest areas vary widely throughout the United States. Violations of these restrictions are at a significant level. Strong arguments have been advanced, especially by groups representing commercial drivers, for a relaxation of these restrictions.

It is therefore recommended that a study be undertaken to investigate the benefits and costs of relaxing these restrictions on maximum length of stay. Specifically, it should be determined whether these restrictions should be eased so that rest area stops could contribute to meeting the requirements of the hours of service provisions of the Federal Motor Carrier Safety Regulations.

Private Business Involvement

The question of increased private business involvement in the establishment and operation of rest areas is receiving increasing attention from a number of states and from pertinent AASHTO committees. Toll facilities, built to interstate design standards, which may carry interstate designations, generally offer a much higher level of services at rest areas because of private business involvement in supplying automobile, food, and other services. Major extensions to the U.S. toll highway system have been proposed. On the other hand, some current toll interstate routes may revert to free operations as the bonded indebtness is paid off.

It is therefore recommended that a nationwide study be undertaken to investigate the advantages and disadvantages of an increase in private business involvement and the advisability of changes in applicable current laws and regulations, both state and federal, which govern rest area operations. The effect of such changes on the availability of adequate funds for rest area operations and maintenance should be explicitly addressed. The study should also stress the question of equity of services; specifically how such services would be made available on relatively sparsely traveled routes where commercial operations would not be profitable.

Rest Area Analysis Methodology

A fully developed analysis methodology, based on utility and decision theory approaches, has been developed as part of the current research effort. The methodology is designed to be used by cognizant local officials and to employ their knowledge, experience, and subjective judgment.

This methodology was applied to an existing rest area decision problem to illustrate its use. While this limited case study could not explore the full potential of the methodology, it did serve its intended purpose.

The methodology, delineated in Appendix A, is currently designed for paper and pencil implementation with the possible assistance of a standard PC spread sheet program. Although such application is entirely feasible, as demonstrated by the case study in Appendix B, it is quite complex and time consuming and may not appeal to many users. Widespread application of the methodology probably awaits the development of a computer assisted version.

A prototype of an interactive, PC-based, expert systems program for this purpose was developed and demonstrated during the current research effort. It is therefore recommended that both of the following studies be undertaken:

1. Validation of the methodology by local personnel, in a number of different jurisdictions, addressing actual local decision situations. These applications, which could use either manual or computer-aided techniques should be fully documented so that analysis of the users' comments can be used to revise, refine, and/or amplify the methodology if necessary.
2. Complete, test, debug, and validate a computerized version of this methodology including any revisions indicated by step 1, above.

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APPENDIX A

REST AREA ANALYSIS METHODOLOGY

Appendix A contains the detailed User Manual for the Rest Area Analysis Methodology. This Manual presents a step-by-step approach to this decision-aiding process. As such, the manual was developed as a stand-alone document for use by highway planners and managers.

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APPENDIX A

REST AREA ANALYSIS METHODOLOGY

1. INTRODUCTION

Rest areas have been an integral part of the highway system since the first such facility was established in Michigan in 1919. There is general agreement that rest areas enhance highway safety; increase the comfort and convenience of highway travel; and facilitate the transmission of information to the highway user. The need for these facilities, especially on rural limited access routes, is recognized by both highway agencies and highway users.

Given this general agreement on the need for rest areas there still remains considerable differences on such aspects of rest areas as:

- Optimum spacing and location
- Types of services and facilities to be included
- Specific design and construction aspects

• Continuous or non-continuous operations.

A methodology is required to assist in formulating and evaluating such decisions. Such a methodology has been developed under National Cooperative Highway Research Program (NCHRP) Project 2-15, "Identifying, Measuring & Evaluating the Benefits of Safety Roadside Rest Areas" (1).

This manual presents the overall approach of this methodology with detailed instructions for its application.

In many instances, the allocation of resources to the rest area program must compete with the demands of other portions of a State's highway construction, maintenance and operation responsibility. Although the resolution of such competition is difficult due to differences in both the cost and the benefit elements of the alternatives to be considered, and although decisions on such choices are often made on a non-technical and non-economic basis, the manual presents some guidance on application of this methodology to decisions of that type.

1.1 BACKGROUND AND APPROACH

The types of decisions mentioned above are traditionally formulated by comparing the total costs for each alternative with the total benefits that can be anticipated over its expected life. When both costs and benefits can be expressed in monetary terms, these decisions are assisted by the application of standard methods collectively referred to as cost-benefit or cost-effectiveness analysis.

Detailed methodologies have been developed and codified to assist decision-makers in the field of highway transportation. These methods are presented in "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements - 1977" published by the American Association of State Highway and Transportation Officials (AASHTO) (2). An updating of the support data for these procedures, and their conversion to an interactive microcomputer assisted methodology, is currently (1989) in progress under the auspices of AASHTO and the National Cooperative Highway Research Program.

Quite often major categories of costs and/or benefits cannot be expressed in quantitative terms. Many aspects of highway safety; user comfort and convenience; and community, environmental and institutional consequences cannot readily be quantified.

The possibility that such intangible benefits or costs (disbenefits) may have a major influence on decisions is explicitly recognized in the AASHTO Manual:

> "The Evaluation ... could utilize several different analytical approaches to take noncostable effects into account. In order of increasing complexity, sophistication, and cost, the leading candidates are probably expert judgment, cost-effectiveness analysis, scoring or weighting methods, and decision analysis. The choice of an evaluation approach should take into account both the nature of the problem and the needs, aims, and capabilities of the decision maker that is serves. It

is felt that the cost-effectiveness approach is generally desirable and is adequate for evaluating highway and transit improvements. In cases entailing important and complex impacts on diverse interest groups, however, either (1) scoring methods that involve interest groups in assigning weights or (2) decision analysis (which accomplishes the same result in a more rigorous manner) may be worth the added time and cost required." [page 3]

Most decisions concerning the location, design and operation of highway rest areas are based on costs and benefits which cannot be expressed in monetary terms. Research under NCHRP Project 2-15, as well as previous work, has shown that the majority of the benefits, and some potential disbenefits, of highway rest areas are concentrated in such items as highway safety, highway user comfort and convenience, impact on the local economy, enhancement of a State's image and environmental effects. These categories, to some extent, are "noncostable".

For these reasons, the analysis methodology presented in this manual is based on the general principles of decision theory. The methodology follows a utility based approach with the following conceptual framework and basic principles:

(1) The decision maker can identify and must choose between a number of alternatives, usually including the "do nothing" alternative.

(2) Associated with each alternative decision is a set of "consequences" which reflect user-specified criteria and affect different groups.

(3) The relative magnitude and importance of most of these consequences depend on one or more external future factors such as rest area usage.

(4) The relative importance of each consequence must be defined by the decision maker in terms of weighting factors.

(5) The individual consequences may be expressed in one of three different forms.

- On a continuous scale which can be expressed directly in dollar values or can be transformed into dollar values.
- On a continuous scale in terms of a measurement system which cannot accurately and reliably be transformed into dollar values.
- In terms of a series of qualitative descriptors.

(6) Each consequence can be assigned a definite level with an associated probability of occurrence. Furthermore, each consequence level can be assigned a specific utility value.

(7) The total utility of each alternative can be obtained by summing the utilities of the individual consequences. In mathematical terms the total utility, U_i of alternate i, can be expressed as

$$U_i = \sum_j W_j \sum_k p_{jk} U(S_{ijk})$$

where S_{ijk} is the level of consequence j for alternative i under future conditions k; $U(S_{ijk})$ is the utility associated with that consequence level; p_{jk} is the probability of realizing condition k for consequence j; and W_j is the relative weight of consequence j.

Of course, if all the consequences, both benefits and costs, that will enter into the analysis can, accurately, be estimated in dollar terms, the standard methods of cost benefit analysis can be applied. Details on the use of these methods ca- be found in many References (e.g. 3, 4) in addition to the AASHTO manual.

1.2 OVERVIEW

The Rest Area Analysis Methodology (RAAM) is a sequential procedure comprised of several steps. These steps are organized into four sequential phases as shown in Figure 1.

(1) Inputs - Inputs to the analysis include the following:

- The decision alternatives to be considered. Decisions may be sequential. For instance, a proposed new rest area may require three separate analyses covering, respectively, location, size and detailed design.
- The set of consequences to be included in the analysis. The general rule is to include all consequences which can be expected to vary significantly between selected alternatives. Conversely, consequences which are essentially

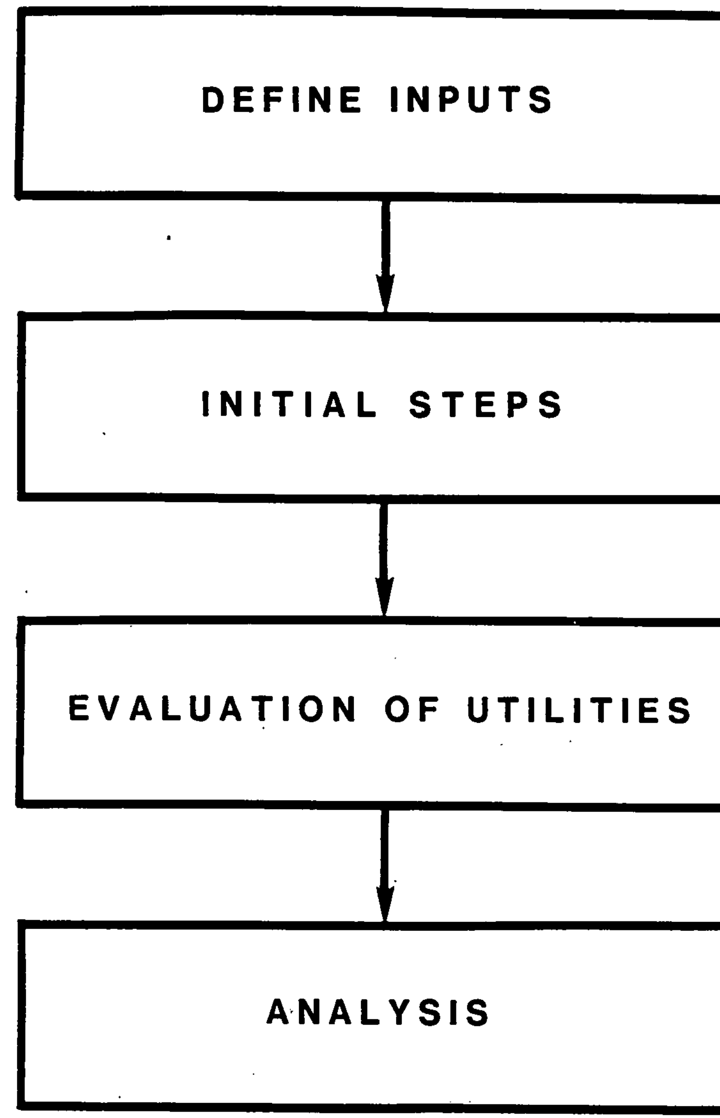


Figure 1. Major Phases of RAAM

invariant between alternatives can be omitted from the analysis.

- A postulated set of future conditions, expressed in terms of traffic volumes, traffic stream composition, rest area usage patterns and other factors which can be expected to affect the expected level of these consequences.

(2) Initial Steps - A number of initial steps must be completed in order to structure the ensuing analysis. These include:

- Assign Preliminary Weights reflecting the relative "importance" of the different consequences, considered. These weights may be revised later in the analysis.
- Select Measurement Scales: The appropriate scale, either quantitative or qualitative, for each consequence considered in the analysis must be selected.
- Estimate the level of each consequence, associated with each postulated future condition for each alternative.

(3) Evaluation of Utilities - Once the inputs are defined, and the initial steps completed, the utility for each consequence is evaluated by defining utility scales and then transforming the benefits and costs into utilities. These individual utilities are then summed for each alternative to obtain its total utility.

In standard applications of utility theory, the assumption that utilities are linear functions of consequence levels is not made. However, this additional computational sophistication is not considered necessary for the present application due to the limits on achievable precision and due to the subjective component of much of the input data. Section 6 of this Manual includes a brief summary of non-linear utility transformations for those users who desire to incorporate this feature into their analysis procedure.

(4) Analysis - The values of the total utility computed in the previous step for each alternative yield an initial ranking of alternatives. It is possible that arithmetical differences between the top ranking candidates may be relatively small. Also, subjective (i.e. non-quantitative) inputs may contribute a substantial part of the total utilities. Finally, the utility of the leading alternative may include considerable (exclusive of costs) negative contributions. Any of these conditions may indicate a need for additional analyses. These additional analyses may include sensitivity studies (especially in terms of assigned weights) and/or detailed examination of the relative contributions of the individual consequences to the total utility of the leading alternatives.

Sections 2 through 5 contain detailed descriptions and discussions of the four phases of the RAM methodology depicted in Figure 1.

1.3 DEFINITIONS

A number of terms and concepts are used throughout this manual. These are defined below:

Alternative - One of a set of possible decisions which, when implemented, will result in a unique, defined state of affairs.

Consequence - Any effect whose magnitude (i.e. level) may change as a function of the alternative selected, and/or as a function of future conditions.

Occurrence Probability - The relative probability that a defined set of future conditions which can affect the level of a consequence, will come to pass. Relative probabilities are numbers lying between 0.00 (impossible) and 1.00 (certain). The sum of all occurrence probabilities for a given consequence must be 1.00.

Utility - A measure of the relative desirability of a future consequence of a decision alternative, expressed as a real number between -1.0 and 1.0. The higner the number, the greater the desirability or utility.

Weight - A positive number representing the importance attached to a specific consequence, relative to all other onsequences. These weights are specified so that they sum to 100 over all consequences.

1.4 SYSTEM CONSIDERATIONS

The RAAM is designed to assist users in formulating specific decisions. In many cases these decisions will apply to a single

existing or proposed highway rest area. The effect of such a decision will, however, extend beyond the specific rest area considered.

Motorists do not stop at every rest area they encounter. User surveys, and other research, indicates that discretionary stops are made at intervals of approximately 130 miles, equivalent to slightly more than two hours of travel. Establishing a new rest area, closing an existing rest area, or increasing the capacity or attractiveness of an existing rest area will thus affect the usage of other existing rest areas. Furthermore, rest areas compete with alternate, off-highway stopping opportunities.

In determining the types of consequences to be included in the analysis and in evaluating their anticipated levels, the analyst must consider system effects. At a minimum, any rest area analysis alternatives which may change the usage of other rest areas should consider the effect of a decision on the rest areas immediately upstream and downstream of the subject site.

Conversely, any planned or proposed changes at one or more adjoining rest areas at any time during the analysis period (i.e. the economic service life of the proposed improvement), must be represented when determining consequence levels and probabilities for an analysis of one of these sites. The analyst must also consider the possibility that an adjoining or nearby rest area may be located in another state.

Procedurally these system effects can be taken into account in a number of different ways:

- Evaluate each consequence level over the entire affected portions of the rest area system rather than for a single rest area.
- Define a separate set of consequences which specifically concern adjoining or otherwise affected rest areas or system considerations in general.

A combination of these two approaches is possible. Some consequences may include the effects of more than one rest area; others may be specific to one rest area.

2. INPUTS

This section of the Manual discusses the inputs necessary for the implementation of the RAAM. These inputs fall into three separate categories as follows:

- Definition and description of all alternatives.
- Definition and description of the consequences of implementing any of the alternatives that will be considered.
- Definition of future scenarios that are likely to affect the level of these consequences together with their relative probability of occurrence.

These three items are discussed below.

2.1 ALTERNATIVES

The selection of alternatives includes two separate steps.

2.1.1 Initial Listing

The initial listing of possible candidate alternatives should be as comprehensive and detailed as possible. For instance, a decision concerning an existing rest area which is physically or functionally inadequate would consider the following broad classes of possible alternatives:

- Rehabilitate
- Reconstruct
- Relocate
- Close
- Do Nothing

The analysis, however, requires a more detailed definition of those alternatives. Each of the first three classes of alternatives listed above includes a range of possibilities. Several levels of rehabilitation and reconstruction are possible. Relocation may involve different alternate sites as well as a range of sizes and facilities that could be constructed at each of these.

Closing of a rest area may be complete or partial. A portion of the rest area may remain open while some services, e.g. toilets, are closed or removed. Partial closing may also affect the time (hours of the day or months of the year) that the rest area is closed.

All viable alternatives should be defined at this stage. Subsequent screening, discussed below, will serve to eliminate infeasible alternatives.

2.1.2 Screening

Preliminary screening of alternatives is accomplished by a qualitative estimate of the probable consequences of each alternative in each of eight major categories:

- Costs - the overall level of costs (both initial and recurring) in relation to possible funding sources (e.g. Federal Aid, local participation).
- Highway Safety - the anticipated effect on accident frequency and severity.
- Highway User Consequences - Anticipated effects on driver comfort and convenience.

- Institutional Consequences - Consequences to highway and other governmental agencies and institutions.
- Environmental Consequences - Air, noise, ground and surface water pollution effects and aesthetic impact.
- Economic and Social Consequences - Specific and general economic impact, land use consideration and general quality of life.
- Implementation Effects - Technical feasibility, lead time and the probability of successful public opposition (i.e. court action or legislative initiative).
- System Effects - Consequences to other rest areas on the system.

This evaluation should be made in terms of the most probable expectation of future conditions and will involve consideration of such items as historical or projected traffic characteristics and growth rates and possible changes in legislation or in funding levels or sources. This screening is designed to evaluate, for each alternative, whether:

- There will be major effects in any of the listed categories.
- These effects will be positive (i.e. beneficial) or negative (i.e. adverse).
- Any anticipated adverse effects are so severe as to warrant immediate rejection of any alternative being considered.

The screening of alternatives is best illustrated by an example. The hypothetical situation considered is as follows:

- An existing rest area shows severe physical deterioration to such a degree as to present potential hazard to users as well as considerable capacity insufficiency.
- Two possible nearby alternate sites have been identified.
- The state would like to place a staffed information center in the general location of the existing rest area.
- Existing rest areas downstream of the site being analyzed are predicted to encounter capacity problems in the near future.

Each entry in Table 1 represents the evaluation of an alternative in terms of one of the eight major categories of consequences. The following codes are used:

+ Major Positive Attribute

- Major Negative Attribute

x Basis for rejection

(Blank) No major positive or negative attributes

Eleven different alternatives have been identified. These include closing the rest area; rehabilitating it; reconstruction to meet 1990 capacity demand and reconstruction to meet anticipated demand for the year 2010. In addition, relocation to either of two possible alternate sites is possible. At each of these sites the proposed new rest area could be designed for one of three possible levels of service. The "do nothing" alternative is, as customary, also included.

Preliminary examination of Table 1 identifies three alternatives that should be rejected immediately:

- Rehabilitation - not feasible due to the type and degree of existing deterioration.
- Relocate to site B and design high level type of rest area - available land at site B is inadequate for this type of design and obtaining additional land would either affect existing high level land use or ecologically sensitive wetlands.
- Do nothing - cannot be considered due to imminent hazard to the public.

Each of the other eight alternatives show both positive and negative attributes and should, therefore, remain as candidates for further analysis. The evaluation of these eight alternatives, in terms of the eight listed factors, showed the following:

<u>Cost</u> - Closing the rest area or reconstructing it to meet current demand would result in considerably lower total cost; constructing a high level rest area at alternate site A would result in considerably higher costs.

<u>Safety</u> - Site A, in view of its approach alignment and proximity to an existing interchange, is considered likely to result in less safe operations than either site B or the existing location. Site B has perfect approach alignment and will also improve overall rest area spacing. It is thus likely to enhance highway safety.

<u>User Consequences</u> - Closing the existing rest area, without replacement, would obviously have adverse user consequences.

Table 1. Screening of Alternatives

Alternative	Cost	Safety	User Consequences	Institutional	Environmental	Economic & Social	Implementation	System
	Evaluation Factors							
1. Rehabilitate - to original level							X	
2. Close	+	-	-	-		-		-
3. Reconstruct - Year 1990	+			-			+	
4. Reconstruct - Year 2010				+	-			+
5. Relocate - Site A-Minimum		-		-	+			
6. Relocate - Site A-Adequate		-			+			
7. Relocate - Site A-High	-	-		+	+			+
8. Relocate - Site B-Minimum		+		-			-	
9. Relocate - Site B-Adequate		+		-			-	
10. Relocate - Site B-High						X		
11. Do Nothing			X					

Institutional - Only reconstructing the existing rest area to meet year 2010 demand or building a high level rest area at site A will permit establishing a staffed information center.

Environmental - A rest area at Site A will permit connections to a municipal sewage disposal system with adequate capacity. Reconstruction at the existing site to meet year 2010 demand will require major expansion of the existing septic system with possible adverse ground water effect.

Economic & Social - Closing the existing rest area, without replacement, would divert appreciable truck traffic into a nearby smaller town whose street system would be strained.

Implementation - Reconstruction of the existing site to meet 1990 demand could be implemented almost immediately. Any construction at site B is likely to meet considerable local opposition, including possible legal action, and consequent delay in implementation.

System - Closing the existing rest area, without replacement, would bring on an almost immediate capacity problem at downstream rest areas. Construction or reconstruction, at any of the three sites, to meet year 2010 capacity demands would defer the onset of capacity problems at adjoining rest area locations.

2.2 CONSEQUENCES

The set of potential consequences must be selected in accordance with the following criteria:

- Sufficient detail to permit the accurate determination of the direction and relative magnitude or importance.
- Include all pertinent consequences while limiting their number so as to permit a meaningful analysis.
- Include consequences in which major attributes have been identified during the preliminary screening of alternatives.
- Take system considerations into account.
- Exclude consequences which are substantially invariant among alternatives.
- Defined so that either quantitative or qualitative evaluation for each alternative is possible without acquiring an unreasonably large new data base.

If any alternative being considered would require the preparation of an environment impact statement (EIS), the set of consequences selected should parallel the structure of the EIS to minimize the work effort.

No single rule can be given for selecting the set of consequences to be used in the analysis. In line with the criteria listed above, this selection should be made on the basis of:

- The background and ultimate purpose of the decision process.
- The characteristics, including type, area, land use and affected traffic, of the alternatives being considered.
- The types, extent and precision of the data available or obtainable.

- Jurisdiction specific policies, requirements and procedures including all requirements of potential funding agencies.

Table 2 contains a check list of consequence categories arranged within the eight major classes previously defined. This table is not an exhaustive listing but is intended to serve as a guide to the analyst.

Consequence categories may be selected at any level of aggregation. The highest level of aggregation should be used in order to minimize the number of consequences, thus simplifying the analysis. However, care needs to be taken that the aggregation level is not so high as to encompass and confound two or more separate effects which may work in opposite direction. For instance the category "Highway Department Operations" may include the positive attributes (benefits) "vehicle staging area" and "communicate with motorists" as well as the negative attribute (disbenefit), "increased work load". In such a case it would be preferable to use separate categories.

After the consequences are selected, an analysis matrix can be formed as illustrated in Table 3.

2.3 OCCURRENCE PROBABILITIES

The majority of all rest area decisions involve a prediction of future conditions. The nominal useful life of a rest area is usually taken as 20 years although some elements, e.g. ROW, grading, buildings, some utility connections, may have a much longer physical life. Rest area decisions must be based on

Table 2. Checklist of Possible Consequence Categories for Rest Area Analysis

1. Cost

   1.1 Total Cost

   1.2 Annual Cost
   1.2.1 Initial
   1.2.2 Operating
   1.2.3 Maintenance

   1.3 Service Life

   1.4 Funding Sources & Limitations
   1.4.1 Initial (ROW, Construction)
   1.4.2 Recurring

   1.5 Participation
   1.5.1 Other governmental agencies (Federal, state)
   1.5.2 Local governmental agencies
   1.5.3 Quasi governmental agencies (e.g Chamber of Commerce)
   1.5.4 Private business

2. Safety

   2.1 Change in highway accident occurrence (absolute or percentage)
   2.1.1 Shoulder stop accidents
   2.1.2 Sleepy driver accidents
   2.1.3 Other accident causalities
   2.1.4 All accident types and causalities

   2.2 Changes in Economic cost of highway accidents (same as 2.1)

   2.3 Entrance/Exit Accidents

   2.4 Accidents within the Rest Area

3. User Consequences

   3.1 Driver Comfort and Convenience

   3.2 Excess Driving

4. Institutional Consequences

   4.1 Highway Agency Operations

   4.2 Other Governmental Agencies

Table 2. Checklist of Possible Consequence Categories for Rest Area Analysis (conc.)

5. Environmental Consequences

    5.1 Air Pollution

    5.2 Noise Pollution

    5.3 Ground Water Effects

    5.4 Surface Run Off Effects

    5.5 Aesthetics

6. Economic/Social Consequences

    6.1 General Economic Impact
        6.1.1 Statewide
        6.1.2 Local

    6.2 Tourism Impact
        6.2.1 Statewide
        6.2.2 Local

    6.3 Land Use Effects

    6.4 Community Effects
        6.4.1 Economic
        6.4.2 Traffic
        6.4.3 Quality of Life

7. Implementation Effects

    7.1 Lead Time
        7.1.1 Land Acquisition
        7.1.2 P.S. & E.
        7.1.3 Approval Process
        7.1.4 Construction

    7.2 Opposition Probability & Effectiveness

    7.3 Availability During Construction

8. System Effects

    8.1 Specific Rest Areas

    8.2 Overall

relating anticipated costs and benefits over the life of the facility being considered.

The benefits resulting from the operation of a rest area are, in most cases, a function of the use of that rest area. This use, in turn, depends on the volume and composition of passing highway traffic and on the proportion of that traffic that enters the rest area. Traffic volume predictions are usually made for a 20 year period. These predictions are based on historically based, long term trends. Between 1975 and 1987 the average annual rate of increase in vehicle miles of travel on rural arterial highways has been as follows:

Average Annual Rate of Growth in VMT (Percent)

	Interstate	Non-Interstate
Cars	2.52	0.70
Trucks	6.16	4.56
All Vehicles	3.63	1.82

Year to year variations are affected by the cost of motor fuel and by general economic conditions. System wide average rates should, however, not be used for the analysis of specific projects. Traffic volumes on individual sections are affected by local conditions such as changes in the highway network or in activity patterns at major traffic generators. Traffic forecasts by the planning division, or similar organization, of the state highway agency should be used whenever possible.

Table 3. Analysis Matrix - Step 1

Consequences		Alternatives 1	2	3	→	n
A.						
B.						
C.						
D.						
↓						
X.						

Traffic stream composition, as well as traffic volumes, changes over time. Between 1975 and 1987 the proportion of passenger cars on Interstate highways decreased from 73 to 64 percent. For non-Interstate rural arterials the decrease was from 75 to 65 percent. Here local data should be used if available.

Nationwide, the proportion of mainline traffic for each vehicle class that enters a rest area varies widely, from less than one percent to 50 percent. For any given rest area location, this proportion depends on the location and characteristics of the rest area; overall rest area spacing; the existence of alternate non-rest area stopping opportunities; traffic stream composition and of the distribution of trip lengths and trip purposes within the traffic stream. Studies have shown that the best predictors of future rest area usage proportions are historical records for the location being analyzed or records collected for locations with similar land use and traffic stream characteristics.

No reliable algorithm has been developed that can be used to predict rest area usage in the absence of such comparative or historical data. A set of prediction formulae were developed by FHWA almost 20 years ago. Analyses of more recent data indicate that these formulae appear to lead to serious underestimation of actual rest area usage. Based on these data, the following default values can be used to estimate "P", the proportion of mainlining passenger car traffic entering a rest area, in terms of "D", the distance to the nearest upstream rest area:

D $\leq$ 20 miles — P = 0.06

20 miles < D $\leq$ 50 miles — P = 0.003D

D > 50 miles — P = 0.15

For trucks, other than 2 axle-4 tires, these values should be increased by 50 percent; for recreational vehicles these values should be increased by 100 percent. For staffed welcome centers, the computed value of P should be increased by 0.05.

For non-Interstate rural primary routes, the following values can be used:

P (primary) = 0.67 P (Interstate) for recreational routes

P (primary) = 0.50 P (Interstate) for non-recreational routes

In the absence of any historical data or other basis for estimation, the following values for the percent of main line traffic that will enter the rest area can be used:

All Traffic	12 percent
Passenger Cars	10 percent
Trucks	15 percent
Recreational Vehicles	20 percent

In any case, predicted future rest area usage is an uncertain estimate. This uncertainty is represented in the analysis procedure by the assignment of probabilities to various possible future scenarios. In the absence of other indications, three such scenarios should be postulated:

- Actual usage equals predicted usage
- Actual usage higher than predicted usage
- Actual usage lower than predicted usage

and an occurrence probability assigned to each of these. These probabilities will reflect the quality and amount of available information and the confidence of the analyst in the estimation process. The probability that actual usage will equal predicted usage should be estimated first. For average conditions a probability of 0.5 should be assigned to this scenario. For estimates based on a good historical data base with relatively small year to year variability and good reasons to anticipate future steady state conditions this proportion may be as high as 0.8.

On the other hand if the estimate is based on sparse historical data; if the location being analyzed is located in a changing area or one highly sensitive to economic fluctuations; or if major changes in the highway system or in major traffic generators are possible, then the probability assigned may be as low as one-third. If default values are used, the probability assigned should not exceed 0.4. In the absence of indications to the contrary, the remaining probabilities should be split equally between the high and low scenarios. The sum of all assigned probabilities must be unity.

Although expected rest area usage is usually the major determinant of the anticipated level of both benefits and costs, other factors may also contribute to the estimated level of expected consequences:

- Future price levels for labor, material, energy, and equipment used in rest area maintenance and operations.

This aspect assumes special importance if the alternatives considered are characterized by different tradeoffs between initial and recurring costs.

- Changes in abutting land use. Intense development near the rest area location may exacerbate otherwise minor adverse consequences concerning water supply, sanitary waste disposal or other environmental effects.
- Changes in laws or regulations. These may concern drinking water or sanitary effluent quality standards; permissible rest area activities (e.g. overnight stay by recreational vehicles, car pool staging, vending or other possible business activities, etc.); or require special facilities (e.g. handicapped access).

The different scenario probabilities should be estimated for each consequence and entered into the analysis matrix as shown in Table 4. The analyst should limit the number of scenarios to those for which a significant occurrence probability can be assigned. There may be only one scenario for a given category (e.g. initial cost levels, for a rest area of a given size and design, if paid from already appropriated funds are independent of future developments).

Table 4. Analysis Matrix - Step 2

Consequences	Occurrence Probability	Alternatives 1	2	3	→	n
A.	p_{A1}					
	p_{A2}					
	p_{A3}					
B.	p_{B1}					
	p_{B2}					
C.	p_{C1}					
	p_{C2}					
	p_{C3}					
	p_{C4}					
D.	p_D					
↓	↓					
X.	p_{X1}					
	p_{X2}					
	p_{X3}					

3. INITIAL STEPS

After the consequences and their respective occurrence probabilities are defined in the analysis matrix (Table 4), three steps must be taken in preparation for the evaluation of utilities:

- Assign preliminary weights,
- Select a measurement scale for each consequence, and
- Estimate consequence levels.

3.1 PRELIMINARY WEIGHTS

The consequences included in the analysis are generally not of equal importance. These assessments of relative importance are represented by assigning a weight to each consequence.

Although any internally consistent method of assigning weights can be used, the Point Allocation Method is recommended. In this method the analyst allocates points to represent the weight of each consequence such that the sum of all weights is a fixed number, usually 100.

These assigned weights reflect local priorities and conditions. For instance, a policy directive to reduce accidents irrespective of costs would result in safety being assigned a higher weight than costs; conversely, a policy directive to provide minimum rest area service at least costs would change the ratio of the weights assigned to costs and to comfort and convenience.

One method of assigning these weights is to assign a value of 1.0 to the most important consequence as determined by the responsible agency. The relative importance of every other consequence category is estimated relative to the most important

consequence as a ratio, R_i, where $0 \leq R_i \leq 1.0$. For example, if consequence, i, is ranked as being half as important as the most important category, then $R_i = 0.5$. After all selected consequence categories, i, are assigned ratios, R_i, the weight, W_i, of each is calculated as:

$$W_i = 100 \times \frac{R_i}{\sum_i R_i}$$

The preliminary weights thus determined are entered into the analysis matrix as shown in Table 5. These weights may be revised later in the analysis (see Section 4.1.8).

3.2 MEASUREMENT SCALES

The consequences, defined in Section 2.2, may be expressed in one of four different ways:

(1) As a numerical (interval) scale expressed in monetary terms

(2) As a numerical (interval) scale expressed in non-monetary terms

(3) As a qualitative (ordinal) scale representing a ranking

(4) As a dichotomy if the consequence can only assume one of two levels, usually the presence or absence of a specific feature (e.g. availability of Federal Aid funding).

A dichotomy, represents a limiting case of (3) in which the ordinal scale consists of only two values, as long as one of these values is always to be preferred to the other. If such a preference cannot be determined, then the consequence can only be

Table 5. Analysis Matrix - Step 3

Consequences	Weight	Occurrence Probability	Alternatives 1	2	3	→	n
A.	W_A	P_{A1} P_{A2} P_{A3}					
B.	W_B	P_{B1} P_{B2}					
C.	W_C	P_{C1} P_{C2} P_{C3} P_{C4}					
D.	W_D	P_D					
↓	↓	↓					
X.	W_X	P_{X1} P_{X2} P_{X3}					
	$\Sigma W = 100$						

expressed on a nominal scale. Nominal scale consequence categories should not be retained in the analysis. They may find application, at the conclusion of the analysis, in the subjective process of making a final choice among any closely rated alternatives.

The analyst must select a unique measurement system, quantitative or qualitative, to evaluate the level of each consequence for each alternative. The availability of information is the prime determinant of which scale to use. Quantitative scales, whether monetary or other, cannot be used unless reliable data are available to estimate a definite value for the consequence, for each alternative considered under each scenario.

Any quantitative scale must be monotonic in terms of utility. That is, a higher numerical value must either consistently represent a more desirable outcome than a lower numerical value or, alternatively, the higher numerical value must, consistently, represent a less desirable outcome (e.g. costs). For instance, a decision concerning choice of ground cover for rest area landscaping should not use a quantitative scale for "rate of growth" since very high and very low growth rates may both be less desirable than some intermediate value.

Scales consisting of verbal (qualitative) terms may be formulated from expression of size (e.g. very small to very large); intensity (e.g. negligible to extreme); quality (e.g. very poor to excellent); or other appropriate descriptors. While quantitative scales are usually continuous, the use of qualitative scales require that the number of distinct points on the scale must be

established beforehand. This number should not be excessively large since the resulting scale would be difficult to apply; nor should it be so small so as to make it impossible to distinguish between different consequence levels. An odd number of points should be selected so as to have a defined midpoint and to facilitate possible subsequent analyses (see Section 5). Five to nine descriptors are usually adequate as illustrated in Table 6. These scales may be combined. For instance, if a given consequence could be either positive or negative, depending on the alternative and the occurrence probability, then scales C and D of Table 6 could be combined to form one 9 point scale. Qualitative scales may also be expressed in numerical terms as exemplified by "Rate on a scale from zero to ten".

A dichotomous, two-valued, scale should be used for a given consequence when only one of two outcomes is possible and one is always preferred.

3.3 <u>ESTIMATE CONSEQUENCE LEVELS</u>

The level of each consequence, for each alternative, applied to each postulated condition, must be defined in terms of the specified measurement scales. The success of this estimation activity depends on the judgment and experience of the analyst.

There are few universal principles or general rules that can be applied in estimating the levels of consequences associated with each rest area alternative. Available information, and factors to be considered in this determination, are summarized below in terms

Table 6. Representative Qualitative Scales

A	B
Not significant	Highly Adverse Effect
Somewhat significant	Adverse Effect
Significant	Somewhat Adverse Effect
Very Significant	No Effect
Extremely Significant	Somewhat Beneficial Effect
	Beneficial Effect
	Highly Beneficial Effect

C	D
No Change	No Change
Slight Improvement	Slight Deterioration
Moderate Improvement	Moderate Deterioration
Significant Improvement	Significant Deterioration
Major Improvement	Major Deterioration

E
Strong Public Support
Moderate Public Support
Little or No Public Opinion
Moderate Public Opposition
Strong Public Opposition

of the major classes previously defined. System effects may be included in each consequence category or considered separately.

3.3.1 Direct Costs

If the alternatives being considered are well defined, including, if necessary, preliminary designs, then fairly accurate quantitative estimates of initial costs are possible. There may be some greater uncertainty concerning ROW costs, if additional land is required, especially if these costs will be determined by future condemnation proceedings. Some uncertainty may also be introduced for alternatives with appreciable implementation lead time especially during a period of rapidly changing prices and interest rates.

Historical data can be used to estimate annual operating and maintenance costs for each future scenario. Service life and equivalent interest rates are normally defined by State policies. In the absence of such policies, recommendations concerning a choice of values appear in the AASHTO Manual.

The potential sources of required funds may need to be considered. This will be the case if different alternatives will be wholly or partly financed from different sources. For instance, a new or relocated rest area may be eligible for Federal Aid while rehabilitation of an existing rest area may be financed totally with State funds.

Different State agencies may participate to varying degrees in different alternatives. Local contributions, both public and private, may be available for different alternatives. Finally,

some alternatives may involve revenue to the State which will partly offset the estimated costs. These may involve such items as pay telephones, vending machines, privately operated information centers and other private business enterprises. Current trends indicate that private business involvement may play an increased role in the future establishment and operation of rest areas.

3.3.2 Highway Safety

Although there is general agreement that highway rest areas have a beneficial effect on highway safety, as reflected in official FHWA and AASHTO policies, there is relatively little statistical or theoretical data available that could serve as a basis for quantifying these benefits. Based on available studies and on conceptual analyses, it can be shown that the effect of rest areas on highway safety operates through a number of distinct mechanisms.

Shoulder Stops

It has been shown that the availability of a rest area reduces the number of discretionary shoulder stops and, to a lesser degree, the number of forced shoulder stops. Vehicles stopped on shoulders, or entering or leaving the shoulder in connection with such a stop, are a significant cause of freeway and rural arterial accidents.

The following formulae have been developed, on the basis of past research results, to estimate the number of shoulder stop accidents per year, by severity class, that are prevented by an Interstate rest area:

Fatal Accidents = 2.22 x Y

Injury Accidents = 35.3 x Y

PDO Accidents = 50.0 x Y

where

$$Y = \frac{0.133 \times E(PC) \times P + 0.244 \times E(O) \times (1-P)}{1000 \times (1192 - 563 \times P)} \times 365 \times AADT$$

and

- P - Proportion of passenger cars in the traffic stream
- E(PC) - Proportion of passenger cars in traffic stream entering rest area
- E(O) - Proportion of other vehicle types in traffic stream entering rest area
- AADT - Annual Average Daily Traffic

Data on projected traffic stream volumes and composition should be available from State records or from estimates made by the planning division. Rest area usage should be estimated on the basis of experience. This expected usage should be the same as used as the basis for the preliminary designs used for cost estimates (Section 3.3.1). In the absence of any of these data, or for preliminary estimating purposes, the following default values can be used.

P = 0.63

E(PC) = 0.10

E(O) = 0.15

Using these default values, the above equation reduces to:

$Y = 9.6 \times 10^{-6} \times AADT$

or, in other words, a reduction of

(AADT/47,000) fatal accidents per year

(AADT/2,900) injury accidents per year

(AADT/2,100) PDO accidents per year

<u>Excess Travel</u> - Interviews in rest areas, and other data, have shown that approximately one third of all drivers would leave the Interstate route to seek a stopping opportunity if a rest area were not available. The excess travel so generated will lead to additional accident exposure. This additional exposure will result in an increase of accidents which can be estimated by:

Increase in Accidents of Type i = (0.324 x E(PC) x P + 0.194 x E(O) x (1 - P)) x 2 x D x R_i x AADT x 365 x 10^{-8}

where

- D - Excess travel distance taken as the distance from the next interchange to the nearest facility or location where toilets and telephones are available
- R_i - Accident rate (per 100 million vehicle miles) for accidents of severity type i, on the portions of the conventional highway network that will be used for this excess travel
- AADT - Annual Average Daily Traffic

AADT and R_i should be available from historical data or, in the case of AADT, estimated for the analysis period by the planning division. D should be measured in the field taking into account interchange configuration (i.e. the opportunity of an immediate return to the Interstate highway in the same direction of travel).

Of course this type of accident consequence should only be included in the analysis if there is at least one interchange between the location being analyzed and the next downstream rest area <u>and</u> if D is smaller than the distance from the intervening interchange to the next rest area. If a rest area services both directions of traffic, then this calculation must be done for each direction.

If there is no such interchange it can be assumed that part of the traffic will be diverted at the nearest upstream intersection. However, this diversion implies both anticipation of the need for a stop and knowledge that there is no rest area. For these reasons the computation of prevented excess driving accidents, utilizing the formulae given above, should be made using parameters applicable to the upstream location and dividing the computed result by two.

In the absence of data, or for preliminary estimating purposes, the following default values can be used:

D = 3 miles

R(Fatal) = 3.09 fatal accidents per 100 MVM

R(Injury) = 71.23 injury accidents per 100 MVM

R(PDO) = 600 PDO accidents per 100 MVM

Using default values this accident reduction will be given by:

Reduction in Accidents of Type i = 0.68 x 10^{-6} x AADT x R_i,

a reduction of approximately

(AADT/480,000) fatal accidents per year

(AADT/21,000) injury accidents per year

(AADT/2,500) PDO accidents per year

Driver Fatigue

Driver fatigue has been cited as a contributing factor in at least 10 percent of all rural highway accidents. Data show that the proportion of fatigued drivers in the traffic stream is significantly reduced by the use of highway rest areas. However, a quantitative estimate of the effect of a rest area on fatigue related accidents is not possible since no data are available concerning the proportion of all drivers in the traffic stream who are fatigued. The effect of a rest area decision on fatigue related accidents can, therefore, only be estimated parametrically. Such an estimate should consider the following factors.

- The proportion of fatigue related accidents, as determined from historical data, on the roadway being considered as compared to that proportion for similar roadways in the State
- Existing and proposed rest area spacing
- The characteristics of anticipated traffic especially average trip length, trip purpose, day-night split and the relationship of the location being analyzed to major trip origins and destinations
- Expected rest area usage.

Figure 2 can serve as a guide to the reduction in accidents that can be achieved by a reduction in driver fatigue levels at rest areas.

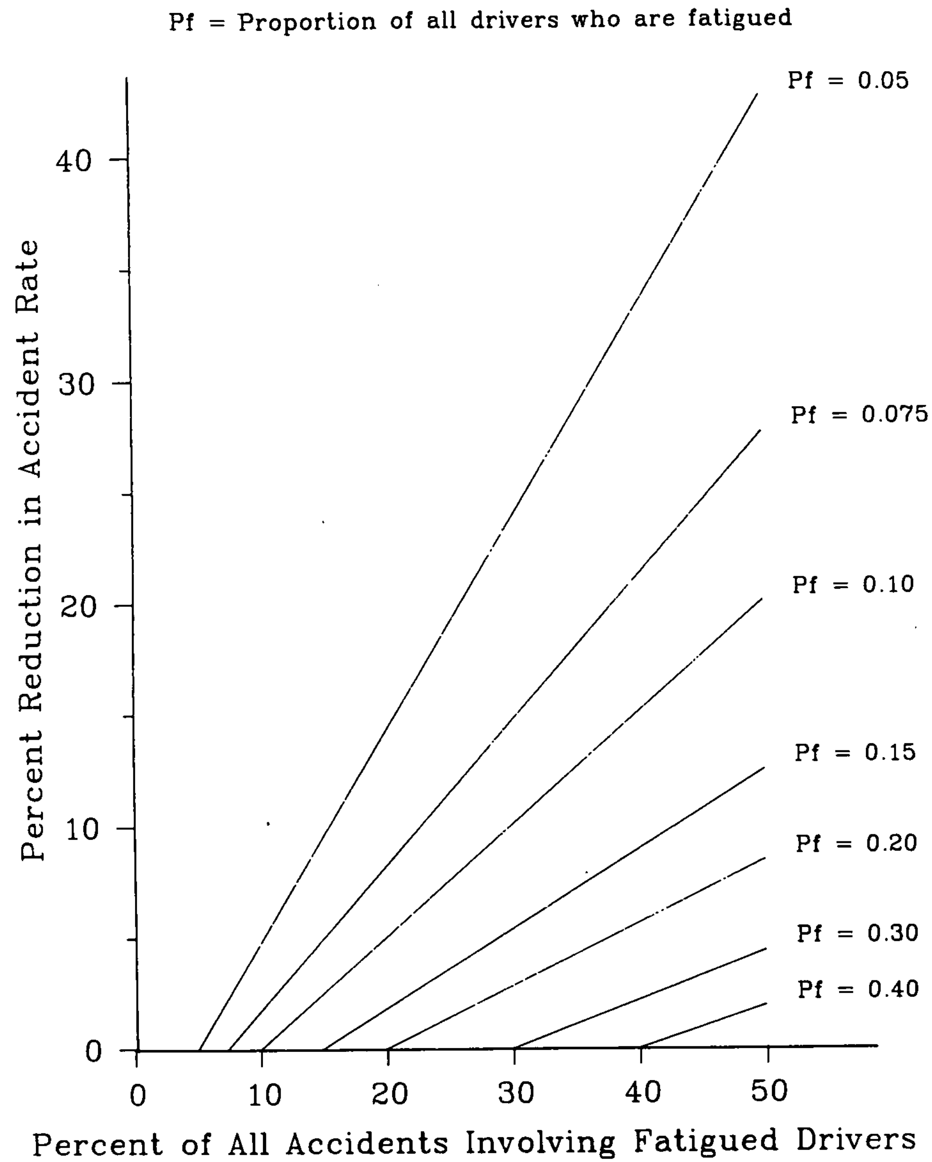


Figure 2. Possible Reduction in Accident Rates

Other

Rest areas also exert beneficial effects which tend to reduce highway accidents through:

- Preventive maintenance and load checking
- Reduction in driving under adverse road and weather conditions
- Opportunity for trip planning to minimize excess driving and additional accident exposure
- Recovery possibility for temporarily impaired drivers.

None of these, however, can be quantified with available data. Only qualitative estimates are possible. The effect of preventive maintenance and load checking in rest areas on the reduction of forced shoulder stops has been included in the discussion of that topic.

3.3.3 User Consequences

The third major consequence of changes in rest area spacing, location, facilities or operations, is the effect on travelers' comfort and convenience.

Comfort and convenience are broad, intangible and subjective concepts generally incapable of being directly quantified or expressed in monetary terms. The "amount" of comfort and convenience that can be allocated to a given rest area is a function of location, size, facilities offered and usage patterns. Other factors include volume/capacity ratios (i.e. the probability of facility or parking lot overcrowding); the relationship of the

rest area location to alternate stopping opportunities; and general ambiance (e.g. aesthetic appeal, shade, etc.).

In view of the highly subjective nature of these criteria, this evaluation should be made on a relative basis. One alternative under consideration is selected as the base line condition; all other alternatives are evaluated in terms of the degree that they exceed, or fall short of, this baseline condition.

Interviews with rest area users indicate that perceived comfort and convenience are valued, on a willingness to pay basis, at an approximate average of $0.70 per entering vehicle. However, available data does not allow relating this amount to the factors mentioned above.

A related user consequence is that the presence of a rest area may prevent excess driving. Excess driving generates additional accident exposure (already discussed) and increased operating and time costs. This consequence may be evaluated in terms of the amount of extra driving involved, or by converting these estimates to monetary terms. Most states have determined standard unit cost figures for both vehicle driving expenses and for the value of time. If such figures are not available, the following default values (in 1987 dollars) can be used:

Vehicle Operating Costs:	Passenger Cars	$0.09 per mile
	Commercial Vehicles	$0.22 per mile
Value of Time:	Work Related Trips	$8.50 per hour
	Other Trips	$6.50 per hour

3.3.4 Institutional Consequences

Institutional consequences include all those that affect the operations of the highway agency involved and of other governmental agencies other than direct operation and maintenance costs. A major item is that a rest area can serve as focus of communications with motorists:

- Provide information concerning the highway system and local geography so as to facilitate trip planning and route optimization.
- Provide information concerning potential destinations, services and attractions, so as to enhance local industry and tourism while satisfying motorist information needs.
- Provide information on current roadway and weather conditions and on routing and other actions to be taken under abnormal or emergency conditions.
- Receive information from motorists about highway conditions and incidents.

These items cannot be quantified nor expressed, even in qualitative terms, on an absolute scale. A relative scale must be used. This is done by selecting one of the alternatives as the base line condition and evaluating the other alternatives as relatively better or worse than that base line.

Other institutional consequences, including such items as the potential for official vehicle staging or other items which affect the execution of governmental activities or functions, should be evaluated in a similar manner.

3.3.5 Environmental Consequences

In selecting an appropriate measurement scale for environmental consequences, which mostly consist of changes in air, noise and ground water pollution levels, a number of factors must be considered including

- Although quantitative measures are available for a number of these effects, e.g. dB as a measure of noise pollution and mgd and BOD as, respectively, measures of the quantity and quality of sanitary effluent, these cannot normally, be transferred into monetary terms.
- Identical quantitative values of these measures may lead to different consequence levels depending on adjacent land use or other factors.
- Both average and peak values of a given environmental effect must be considered.
- Translating a numerical difference in a quantified environmental effect into a significant difference in consequences may be difficult or impossible, especially if the quantitative scale used, e.g. dB, is not linear.

For these reasons, qualitative evaluation scales should be considered and the evaluation should again be made in relative terms. For items such as aesthetic impact no other possibility exists.

Air pollution represents a somewhat special case in that a quantitative measure, tons of pollutants (CO, HC and NOX) per unit time is not only available but also widely used. Quantification

of these consequences requires the following:

- A fine grained classification distribution of the rest area vehicle population.
- The distribution of vehicle age and vehicle maintenance status within that population.
- A knowledge of environmental conditions, especially ambient temperature and humidity, that affect the performance and emission of automotive engines.
- The distribution of time in rest area by vehicle class.

The last item on this list is of major importance. Not only does the restart of a cold engine increase pollutant emission but also the custom of the drivers of large trucks to idle engine while in a rest area must be taken into account. This last aspect will assume increased importance if, as requested by the trucking industry, maximum restrictions on time in rest area are relaxed so that a rest area stop can meet the requirements for "rest stops" of the Federal Motor Carrier Safety Regulations.

3.3.6 <u>Economic/Social Consequences</u>

Examination of Table 2 shows that the category of economic and social consequences includes many effects. Normally the most important of these are the general and specific impacts of a highway rest area on a State's image and economy and, particularly, on statewide and local tourism.

Although one or two States have attempted to make rather broad quantitative estimates of the tourism impact of a rest area or welcome/information center program, no such estimates have been

developed for individual rest areas. The willingness of providers to pay for advertisements in rest areas where sanctioned (e.g. California, Oregon, Vermont), indicates that such an impact exists. The evaluation of the magnitude of such an impact must, however, be made in qualitative terms taking the following factors into account:

- The number, type and prominence of tourist attractions in the immediate area of the rest area location as well as statewide.
- The extent of promotion of competing tourist attractions in other areas of the State as well as in adjoining States.
- The composition, especially in terms of trip purpose and vehicle type, of the affected traffic stream.
- The general characteristics (passage or destination) of the State.

Apart from possibly generating additional tourism activity, a rest area may have indirect effects on a State's economy in the form of an enhancement or deterioration of a State's image in the perception of out-of-state travelers. A qualitative, subjective evaluation of travelers' perceptions should consider the relative attributes of the alternatives and those of rest areas nearby and in adjoining states. Poor design, lack of certain facilities available in other rest areas, deferred or inadequate maintenance, and insufficient capacity or inadequate number of rest areas, may contribute to a negative impact. Well designed and managed rest areas will enhance a State's image.

3.3.7 Implementation Effects

The final category of consequences to be evaluated includes all aspects of implementation that may differ between the alternatives being considered. The two major topics under this heading are lead time and public reaction.

In many cases, lead time can be quantified on the basis of past experience with similar projects. However, if approval of an outside agency, e.g. FHWA, is required, if an EIS must be prepared and approved, if ROW has to be acquired, or if project implementation depends on the availability of not yet appropriated funds, the prediction of implementation lead time may involve a high degree of uncertainty. In such cases a qualitative measure of implementation lead time may be preferred.

In evaluating differences in lead time between alternatives the relative magnitudes of lead time and construction time should be taken into account. It may be advisable to define lead time to encompass the period from decision to completion of construction. The availability of the facility during construction should be considered. Alternatively, availability could, by itself, be evaluated as a consequence.

In evaluating lead time on a quantitative scale, e.g. months, the possible non-linear nature of this scale in accurately reflecting the relative level of consequences should be taken into account. For instance, a difference between one and two months may have a higher impact than a difference between eleven and 12 months. In areas of the country where outdoor construction is

possible for only part of the year, a numerical lead time measurement scale may be expressed as a step function.

A major consequence (which may also affect lead time) is the probability of public controversy and opposition. In scaling the magnitude of this effect, factors to be considered include

- The nature of each alternative decision and the probability that it will generate public and/or legislative opposition.
- The structure of the legally mandated approval process for each of the alternatives being considered.
- The possibility of legal action at various stages of this approval process, its anticipated duration and the probability of success.
- The probable attitude, potential action and legislative influence of local political representatives.
- The possible effect of a protracted approval process on the amount and availability of needed funds.

These items must be evaluated in qualitative terms based on the information available and on the experience and judgment of the analyst.

3.3.8 System Effects

As previously mentioned, system effects may be considered within the context of individual consequence category. System effects may also generate one or more consequences categories.

A rest area will influence the usage of adjacent rest areas. The magnitude of this influence depends on rest area spacing and

on other attributes of the affected rest areas.

The major system effect to be considered is the change in rest area usage at adjacent existing rest areas due to changes at a specific rest area location. The effect will be most pronounced at the next downstream rest area but will also be felt at the upstream rest area, especially in jurisdiction which use "Next Rest Area N Miles" signing. The effect may also be felt beyond the immediately adjacent locations.

In estimating anticipated usage of a rest area, any proposed work at other nearby rest areas, during the analysis time frame, must be considered if the proposed work will significantly affect rest area capacity or services offered.

Nearly every highway organization has a geographically based organization. Rest area maintenance and operations are normally the responsibility of a local, district, regional or other office. The maintenance and operations costs of these rest areas are charged against the local budget. Many states have, especially in recent years, imposed strict controls over year to year changes in highway district budgets and/or manpower levels. Such budgetary constraints, as well as constraints on other resources, may need to be considered in formulating rest area decisions especially if these decisions entail significant changes in maintenance and operation expenses or manpower requirements (e.g. the establishment of a new rest area).

3.3.9 Summary

The preceding discussion is not intended as an exhaustive

treatment of the subject of evaluating consequence levels. Other consequences may be considered and other measurement scales used depending on the purpose of the analysis, the type of alternatives considered, the information available to the analyst and the policies and procedures of the affected organization. Any measurement scale can be defined and used if it:

- Increases monotonically in the direction of increased desirability taking into account the fact that costs or disbenefits are considered to be negative quantities.
- Is applied uniformly and consistently to all alternatives and all occurrence probabilities.

After completion of the evaluation process, the level of each consequence for each alternative and for each occurrence (postulated condition) is entered into the analysis matrix as illustrated in Table 7. Before computing the utilities associated with each of these levels it is recommended that an additional screening of alternatives, with the potential of reducing the computational work load, be done.

This additional screening consists of a check for "dominance". This is best illustrated by an example. Assume that the consequence levels for two alternatives, P and Q, have been evaluated. If, upon examination, it is seen that for every consequence considered, and for each occurrence probability, the level assigned to alternative P represents a more desirable outcome than the level assigned to alternative Q, then alternative Q does not need to be considered further.

Table 7. Analysis Matrix - Step 4

Consequences	Weight	Occurrence Probability	Alternatives 1	2	3	→	n
A.	W_A	p_{A1} p_{A2} p_{A3}	L_{1A1} L_{1A2} L_{1A3}	L_{2A1} L_{2A2} L_{2A3}	L_{3A1} L_{3A2} L_{3A3}		L_{nA1} L_{nA2} L_{nA3}
B.	W_B	p_{B1} p_{B2}	L_{1B1} L_{1B2}	L_{2B1} L_{2B2}	L_{3B1} L_{3B2}		L_{nB1} L_{nB2}
C.	W_C	p_{C1} p_{C2} p_{C3} p_{C4}	L_{1C1} L_{1C2} L_{1C3} L_{1C4}	L_{2C1} L_{2C2} L_{2C3} L_{2C4}	L_{3C1} L_{3C2} L_{3C3} L_{3C4}		L_{nC1} L_{nC2} L_{nC3} L_{nC4}
D.	W_D	p_D	L_{1D1}	L_{2D1}	L_{3D1}		L_{nD1}
↓	↓	↓	↓	↓	↓		↓
X.	W_X	p_{X1} p_{X2} p_{X3}	L_{1X1} L_{1X2} L_{1X3}	L_{2X1} L_{2X2} L_{2X3}	L_{3X1} L_{3X2} L_{3X3}		L_{nX1} L_{nX2} L_{nX3}

p_{jk} - Probability of occurrence, "k", which influences consequence, j.
L_{ijk} - Level for alternative, "i", of consequence, "j", for occurrence, "k".
W_j - Importance weighting of consequence, j.

Referring to Table 7, this process can be stated as:

Eliminate alternative q if there is any alternative p such that

$$L_{pjk} \geq L_{qjk}$$

for all j and all k provided that

$$L_{pjk} > L_{qjk}$$

for at least one combination of j and k.

Care must be taken when checking for dominance that this process does not eliminate a high ranking alternative which may, ultimately, be part of a set of recommended multiple alternatives as discussed in Section 5.3.

Before computing utilities the weights assigned in Section 3.2 should be reviewed carefully. It will be recalled that these weights were determined on the basis of agency policy and purposes and the background of the ongoing decision process. The completion of the preceding step will have indicated the maximum improvement that is possible for each consequence given the set of candidate alternatives. The consequences which show little difference in levels between alternatives, or for which little improvement can be expected no matter which alternative is selected, will also have been identified. This information should be factored into the process of assigning weights keeping in mind that consequences which are substantially invariant between alternatives need not be retained in the analysis.

4. EVALUATION OF UTILITIES

The evaluation of utilities for each consequence and for each alternative encompasses three activities:

- Defining utility transformation for all consequences
- Computing the utility of each consequence, for each alternative and for each postulated condition
- Determining the total utility associated with each alternative.

4.1 DEFINE UTILITY TRANSFORMATIONS

The basic premise of utility analysis is that utilities are additive. This addition can, however, not be made until all consequence levels are expressed on a common scale. This common utility scale is a continuous numerical scale which ranges from -1.0 to 1.0.

A two step procedure defines the transformation functions used to convert the assigned consequence measurement scales to the common utility scale.

(1) Determine for each consequence, the point on the measurement scale which will be equated with one of the bounding utility values of ±1.0 (Reference Outcome).

(2) Define the set of algorithms that will be used to transform consequence scale values to utilities.

4.1.1 Reference Outcomes

There are two methods for defining reference outcomes (i.e. bounds on the consequence scale) which are mapped onto the utility bounds of +1 or -1. Note that benefits are bounded from above and

cost, or disbenefits, are bounded from below.

(1) Select the most favorable (or most unfavorable) outcome on the measurement scale for a given consequence.

(2) Select an artificial outcome on the measurement scale of a consequence, which is more desirable, or more undesirable, than any of the estimated outcomes.

The use of reference outcomes with greater absolute magnitudes than any of the estimated consequences in the set of alternatives to be evaluated may permit the subsequent inclusion of additional alternatives without the need to recompute utilities. It may also facilitate the sensitivity analysis described in Section 5.1. However, this approach will also compress the possible range of computed utilities and minimize the arithmetic differences in total utilities.

Furthermore, defining a reference outcome which, in absolute numerical values, is higher than any of the consequence levels also implies that no alternative - scenario combination for that consequence will attain an absolute utility value of 1.0. This approach effectively reduces the weight assigned to that consequence. To compensate, the weight assigned to the consequence should be multiplied by the ratio: (reference outcome/maximum estimated consequence level). Following this step, all weights should be normalized to sum to 100.

The selected reference outcome for each consequence, expressed on the measurement scale, is then entered into the analysis matrix as illustrated in Table 8. This step, repeated for all

consequences, completes the analysis matrix. The bounds on the utility scales are then selected in accordance with the rules given below. The first three rules apply to consequences expressed in numerical terms on an interval scale; Rule 4 is to be used for all consequences expressed qualitatively on an ordinal scale.

Rule 1 - If all levels of a consequence (e.g. accident rates) are benefits (i.e. no alternative to be considered will lead to an increase in accident rates) then assign the reference outcome to have a utility of 1.0. Since all consequence levels are benefits, the measurement scale is bounded from below by zero.

Rule 2 - If all consequence levels are costs, or disbenefits, then assign the reference outcome to have a utility of -1.0. The measurement scale will then be bounded by zero and -1.0.

Rule 3 - If the consequence levels include both benefits and disbenefits, or both costs and revenues, then determine whether the largest benefit or the largest cost has the greater absolute magnitude. If this is a benefit then select the upper bound in accordance with Rule 1. The lower bound will then be the ratio of the largest disbenefit, considered as a negative quantity, to the reference outcome. If the absolute value of the largest cost, or disbenefit, exceeds the absolute value of the largest benefit then select the lower bound by Rule 2. The upper bound will then be the ratio of the largest benefit to the reference outcome in absolute terms.

Rule 4 - If the consequences are purely qualitative on an ordinal scale then the measurement scale will always be bounded by

Table 8. Analysis Matrix - Step 5

Consequences	Weight	Occurrence Probability	Alternatives 1	2	3	→	n	Reference Outcome
A.	W_A	p_{A1}	L_{1A1}	L_{2A1}	L_{3A1}		L_{nA1}	R_A
		p_{A2}	L_{1A2}	L_{2A2}	L_{3A2}		L_{nA2}	
		p_{A3}	L_{1A3}	L_{2A3}	L_{3A3}		L_{nA3}	
B.	W_B	p_{B1}	L_{1B1}	L_{2B1}	L_{3B1}		L_{nB1}	R_B
		p_{B2}	L_{1B2}	L_{2B2}	L_{3B2}		L_{nB2}	
C.	W_C	p_{C1}	L_{1C1}	L_{2C1}	L_{3C1}		L_{nC1}	R_C
		p_{C2}	L_{1C2}	L_{2C2}	L_{3C2}		L_{nC2}	
		p_{C3}	L_{1C3}	L_{2C3}	L_{3C3}		L_{nC3}	
		p_{C4}	L_{1C4}	L_{2C4}	L_{3C4}		L_{nC4}	
D.	W_D	p_D	L_{1D1}	L_{2D1}	L_{3D1}		L_{nD1}	R_D
↓	↓	↓	↓	↓	↓		↓	↓
X.	W_X	p_{X1}	L_{1X1}	L_{2X1}	L_{3X1}		L_{nX1}	R_X
		p_{X2}	L_{1X2}	L_{2X2}	L_{3X2}		L_{nX2}	
		p_{X3}	L_{1X3}	L_{2X3}	L_{3X3}		L_{nX3}	

L_{ijk} - Level of consequence "j" for alternative "i" for occurrence, "k"
R_j - Reference Outcome for consequence "j"

zero and 1.0 representing, respectively, the least and most favorable outcome.

4.1.2 Transformation Functions

The transformation functions between the utility bounds determined in 4.1.1 are judgmentally defined subject to the following constraints:

(1) The utility assigned to a more desirable outcome must be higher than those of all less desirable outcomes.

(2) The rate of change of marginal utility must be monotonic.

The definition of a transformation function will depend on whether the consequence measurement scale is expressed on an interval scale (i.e. continuous) or whether it is expressed on an ordinal scale (i.e. discrete).

Continuous Measurement Scales - The theory of utility analysis as reported in the literature accommodates both linear and non-linear transformations.

An assumption of linearity facilitates the computational aspects of the analysis. Since departures from linearity do not generally affect the results of the analysis to a significant degree it is recommended that such linear transformations be used when there is no strong evidence to the contrary. Section 6.2 of this Manual contains a brief discussion of non-linear transformations.

The fact that a linear transformation is used does not automatically imply that this function will be continuous or that it will pass through the origin. This is illustrated in Figure 3.

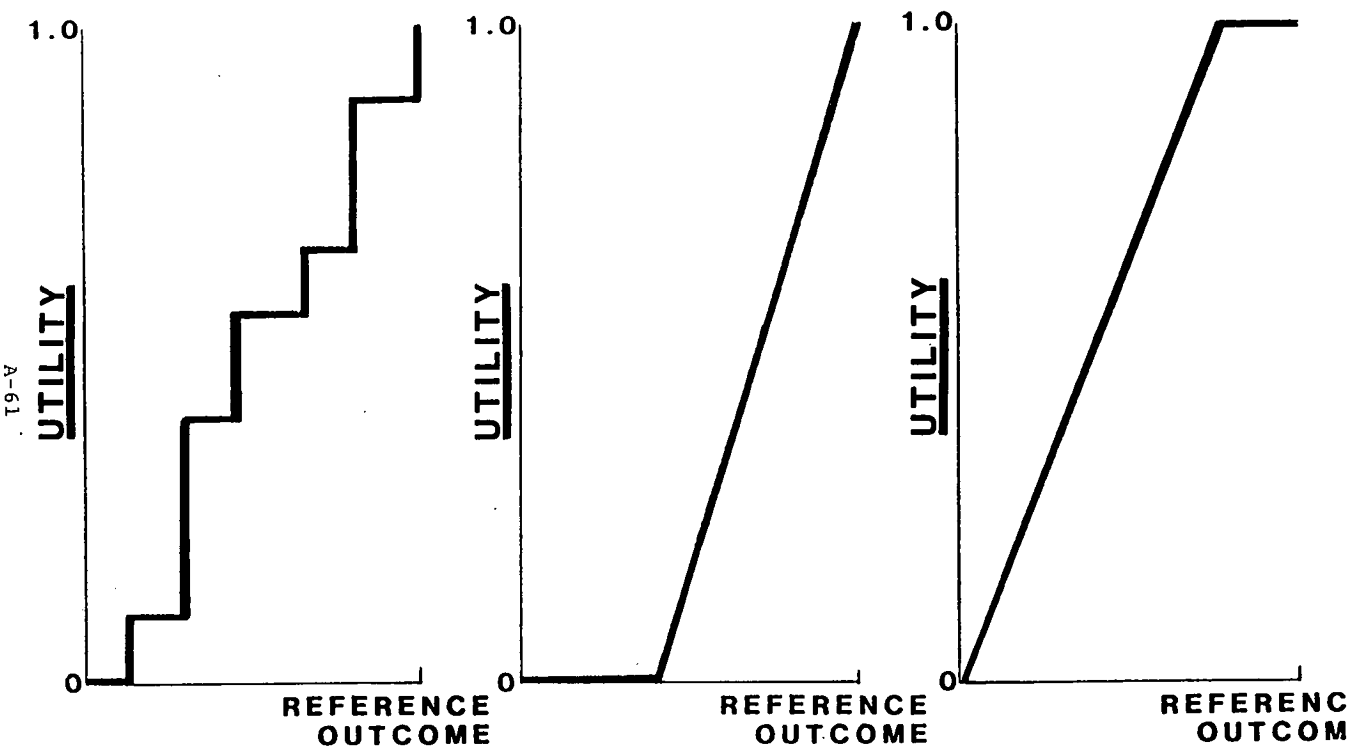


Figure 3

UTILITY TRANSFORMATION FUNCTIONS

Figure 3(A) is a step function which represents the case where utility increases by defined intervals as different thresholds in a consequence level are reached. If a minimum level of a consequence must be reached before utility starts to increase, a transformation of the type shown in Figure 3(B) can be used. Similarly if, after reaching a certain point, an increase in consequence level will not result in additional utility (e.g., the effect of excess capacity on user comfort and convenience) the relationship shown in Figure 3(C) may be applicable.

<u>Discrete Measurement Scales</u> - The step function depicted in Figure 3(A) is the appropriate transformation to use for all consequences expressed in qualitative terms or other discrete measurement scales. Transformation of such scales consists of assigning a utility value to each defined point on the measurement scale. These scales need not consist of equal intervals.

4.2 <u>COMPUTE UTILITIES</u>

Utility values are computed for each consequence, for each alternative, and for each postulated occurrence by applying the appropriate utility transformation functions to each of the previously estimated consequence levels. The calculations should be done using an appropriate level of precision with careful attention to the correct arithmetical sign. All quantitative benefits produce positive values of utility and all such costs and disbenefits, negative values of utility.

Costs and disbenefits expressed on an ordinal, qualitative scale will always produce positive values of utility in accord with

the requirement of Rule 3 in Section 4.1.1; the utility transformation function of such scales is always bounded by 0.0 (least favorable) and 1.0 (most favorable). This requirement preserves the relative utility of the different alternatives.

The computed utilities are then entered into a computation matrix as illustrated in Table 9. This matrix forms the basis for determining the expected total utility of each alternative. This computation consists of evaluating the function

$$U_i = \sum_j W_j \sum_k p_{jk} u_{ijk}$$

to obtain the expected total utility, U_i, for each alternative "i". Computationally this is accomplished by multiplying each computed utility (U_{ijk}) by its associated occurence probability (p_{jk}) and by the weight (W_j) assigned to consequence "j". The total utility for each alternative is then obtained by addition. Any standard spread sheet program can be used for these calculations. The results are entered into the computation matrix as shown in Table 10.

Table 9. Computation Matrix - Step 1

Consequences	Weight	Occurrence Probability	Alternatives 1	2	3	→	n
A.	W_A	p_{A1} p_{A2} p_{A3}	u_{1A1} u_{1A2} u_{1A3}	u_{2A1} u_{2A2} u_{2A3}	u_{3A1} u_{3A2} u_{3A3}		u_{nA1} u_{nA2} u_{nA3}
B.	W_B	p_{B1} p_{B2}	u_{1B1} u_{1B2}	u_{2B1} u_{2B2}	u_{3B1} u_{3B2}		u_{nB1} u_{nB2}
C.	W_C	p_{C1} p_{C2} p_{C3}	u_{1C1} u_{1C2} u_{1C3}	u_{2C1} u_{2C2} u_{2C3}	u_{3C1} u_{3C2} u_{3C3}		u_{nC1} u_{nC2} u_{nC3}
D.	W_D	$p_D=1.0$	u_{1D}	u_{2D}	u_{3D}		u_{nD}
↓	↓	↓	↓	↓	↓		↓
X.	W_X	p_{X1} p_{X2} p_{X3}	u_{1X1} u_{1X2} u_{1X3}	u_{2X1} u_{2X2} u_{2X3}	u_{3X1} u_{3X2} u_{3X3}		u_{nX1} u_{nX2} u_{nX3}

u_{ijk} - Utility of consequence "j" for alternative "i" under occurrence "k"

Table 10. Computation Matrix - Step 2

Consequences	Weight	Occurrence Probability	Alternatives 1	2	3	→	n
A.	W_A	p_{A1} p_{A2} p_{A3}	u_{1A1} u_{1A2} u_{1A3}	u_{2A1} u_{2A2} u_{2A3}	u_{3A1} u_{3A2} u_{3A3}		u_{nA1} u_{nA2} u_{nA3}
B.	W_B	p_{B1} p_{B2}	u_{1B1} u_{1B2}	u_{2B1} u_{2B2}	u_{3B1} u_{3B2}		u_{nB1} u_{nB2}
C.	W_C	p_{C1} p_{C2} p_{C3}	u_{1C1} u_{1C2} u_{1C3}	u_{2C1} u_{2C2} u_{2C3}	u_{3C1} u_{3C2} u_{3C3}		u_{nC1} u_{nC2} u_{nC3}
D.	W_D	$p_D=1.0$	u_{1D}	u_{2D}	u_{3D}		u_{nD}
↓	↓	↓	↓	↓	↓		↓
X.	W_X	p_{X1} p_{X2} p_{X3}	u_{1X1} u_{1X2} u_{1X3}	u_{2X1} u_{2X2} u_{2X3}	u_{3X1} u_{3X2} u_{3X3}		u_{nX1} u_{nX2} u_{nX3}
Total Utility	-	-	U_1	U_2	U_3		U_n

u_{ijk} - Utility of alternative "i" for consequence "j" under occurrence probability "k"

U_i - Total Utility fo Alternative, "i"

5. ANALYSIS

The basic thesis of utility analysis, as stated in Section 1, is that the alternative that shows the greatest expected total utility should, in the absence of any other considerations, be selected. The RAAM results illustrated in Table 10 will identify that alternative. Careful examination of these computed results is recommended for a number of reasons:

- The analysis process is based on the application of considerable judgment involving subjective inputs. A review of these judgments is always warranted prior to final decision-making.
- In many cases, especially those involving major projects, the analyst recommends a course of action but does not make the actual decisions. Many jurisdictions require, or prefer, that the decision maker be presented with two or more alternatives together with detailed arguments for and against each of these. Detailed analyses will help in structuring these arguments.
- Throughout the analysis process intermediate decisions and are based on available information and data. The adequacy of this information and of these data must be assessed. This assessment may indicate a need to obtain additional, or more reliable, information and should be done for quantitative data; for subjective or judgmental inputs concerning the valuation of intangibles; for the prediction of future trends; and for the assignment of relative

weights. Individual estimates may need to be replaced using a more formal, structured group decision making mechanism.

The analyses need consider only the highest ranking alternatives. A possible exception to this rule is when the low ranking of an alternative is due to cost related consequences which depend on the realization of one of several possible funding alternatives. If the decision will not be implemented until that uncertainty is resolved, then that alternative should be retained.

It may be advisable to implement the RAAM for each of the possible funding alternatives. These analyses will then yield the preferred alternative for each possible funding source. The most common example of this is the case where some, but not all, of the alternatives _may_ be eligible for substantial federal funding contributions but the eligibility criteria and/or the availability of these funds depend on yet uncompleted federal budget actions.

5.1 SENSITIVITY ANALYSIS

Sensitivity analyses are designed to measure the rate of change of a computed result as one or more input parameters are varied systematically. The computed result is the total utility of an alternative; the parameters that can be investigated include occurrence probabilities; consequence levels and weights. In implementing sensitivity analyses by repeating the RAAM calculations with different input data, a number of points must be kept in mind.

- The sum of all occurrence probabilities for a given consequence must be 1.0. A change in any probability necessitates a change in at least one other.
- Similarly, the weights assigned to the consequences must sum to 100. One or more consequence weights can be set equal to zero to investigate the effect of a restricted consequence set.
- Varying consequence levels, especially for consequences expressed in quantitative terms, may require recomputation of the utility transformation function. This will be the case if the extreme value of the range over which the consequence level is varied exceeds the reference outcome in absolute terms.

Sensitivity analyses should normally concentrate on assigned weights. Occurrence probabilities and consequence levels should only be included if there is significant uncertainty in the original determination of these attributes. The analyst may wish to record such uncertainty at the time the determination is first made (e.g. Step 2, Table 4 and Step 4, Table 8). There are two possible procedures:

- Record consequence levels as a range instead of as a single value
- Increase the number of scenarios, and their associated occurrence probabilities.

5.2 COMPONENT ANALYSIS

Component analysis can be used when two, or at most three,

alternatives appear to be clearly superior in total utility, to all others. This method consists of determining the arithmetic difference between the total utility of two alternatives and then disaggregating this difference so as to determine the contribution, both magnitude and direction, of each consequence category to this difference. Further disaggregation can show the effects of assumptions (i.e. occurrence probabilities) concerning future scenarios on their relative contribution.

These disaggregated results will permit the analyst to eliminate consequences whose levels are not significantly different between the alternatives considered and concentrate on those which have the most bearing on the relative utilities. The analyst will then be in a position to define the exact set of assumptions under which one alternative is to be preferred to another. The equilibrium level of the variables used, e.g. relative weights or occurrence probabilities, can easily be computed.

The computational procedure for comparing two alternatives, ($i = 1, 2$) consists of the following steps:

(1) Evaluate $D_j = W_j[\sum_k p_{jk}u_{1jk} - \sum_k p_{jk}u_{2jk}]$ for all consequences, j

(2) Eliminate from further consideration all consequences, j, for which $|D_j| <$ "a", where "a" is some threshold. The analyst's judgment and the distribution of the D_j will determine the value of "a" to be used. A possible first approximation for this threshold value is

$$a = \frac{U_1 - U_2}{n_c}$$

where n_c is the number of consequences included in the analysis.

(3) Rank order the remaining D_j in terms of their absolute values.

(4) Starting at the top of this rank ordering determine the reasons (consequence level, weight or occurrence probability distribution) for its magnitude.

Following this determination the analyst can decide whether to accept the results, whether to change some of the input parameters or whether additional information or analysis is necessary before decision can be reached.

5.3 FORMULATE RECOMMENDATION

At the conclusion of the analysis process, the analyst will have a basis for formulating a recommendation. When one alternative is clearly preferable in terms of total utility, and the analyst has confidence in his data and judgments, then his recommendation can be unequivocal.

Alternatively, the analyst may make a conditional recommendation if the preferred alternative strongly depends on assumptions which cannot be validated. A conditional recommendation may also be presented to the decision maker if the choice between two alternatives depends on relatively minor changes in assigned weights.

The complete analysis may show that two or three alternatives exhibit differences in total expected utilities that are small relative to the precision used to determine these utilities. In such cases, the final decision will have to be made at the administrative/political level. It is possible that these detailed analyses will indicate the major advantages and disadvantages of the leading alternatives. A review of these results may lead to the formulation of one or more additional alternatives not previously considered. If such is the case, the RAAM should be repeated, with these alternatives included.

5.4 COST-UTILITY ANALYSIS

Both the generalized analysis methodology presented in this manual and traditional methods of cost-benefit analysis consider costs as elements of the analysis. In many situations costs will be the controlling factor or, at least, will place a constraint on the range of alternatives that can be considered. This condition was illustrated in the discussion of preliminary screening of alternatives of Section 2.1.2.

Cost-utility analysis reflects this potentially dominant position of cost related elements by relating the total utility for a given alternative with the cost of that alternative. The cost-utility procedure is implemented as follows:

(1) Using the procedures of Sections 3 and 4 compute the total utility for each alternative including all consequences except those associated with initial, operating and maintenance costs or service life.

(2) Using available data on initial and recurring costs, service life and estimated equivalent interest rates compute Uniform Annual Costs or Net Present Worth by applying standard engineering economics computational procedures.

(3) Order the alternatives in terms of increasing costs, using the figure of merit computed in (2). Arrange the results in three columns showing, respectively, alternative, costs and total utility.

(4) Eliminate any alternative which shows negative total utility or which has
   - <u>both</u> higher costs and lower total utility, or
   - equal costs and lower total utility, or
   - higher costs and equal total utility

   than any other alternative.

After the completion of Step 4 the decision maker can consult this listing to determine the optimum alternative given a fixed level of available funds. This procedure is especially applicable to situations where the analysis must be completed before the level of available funds has been determined.

In some cases the critical element may be initial (i.e. ROW, design, construction) costs rather than total costs. In those cases the computations of Step (2) should be restricted to these cost elements and recurring (i.e. operations and maintenance) costs should be included as disbenefits in Step (1).

The procedures for sensitivity analyses described in Section 5.1 are applicable to this procedure.

6. ADDITIONAL TOPICS

The preceding five sections have presented and discussed the basic aspects of the Rest Area Analysis Methodology (RAAM). This section discusses two additional related topics: weighted ranking and non-linear tranformations.

6.1 WEIGHTED RANKING

Utility analysis, in dealing with non-quantitative benefits and disbenefits, accounts for the fact that the difference between alternatives for any consequence generally cannot be expressed as an even interval scale especially when major aspects of the analysis involve the evaluation of consequences expressed on non-quantifiable ordinal scales. This is illustrated in Figure 3.

In those cases where an assumption of equal intervals can be supported, then the procedure presented can be simplified. This simplification is not recommended. It may find application under the following conditions:

- The analysis includes many alternatives and is being performed for preliminary planning purposes to determine which alternatives are sufficiently viable to warrant further consideration or
- The number of alternatives surviving the preliminary screening described in Section 2.1.2 is so large that a complete analysis would involve an undue computational load.

This simplified procedure using equal interval scales for all consequences is referred to as weighted ranking. It is one of the

"scoring methods" mentioned in the quotation from the AASHTO manual included in Section 1.1. The procedure starts with the matrix of Table 5 and encompasses the following steps.

(1) Rank all alternatives for each consequence and for each occurrence probability (i.e. each row in the matrix of Table 5). The most desirable alternative, in terms of a specific consequence and under the specified conditions of the occurrence probability is assigned a rank of 1, the next a rank of 2 and so on. The assigned ranks are entered into the matrix as shown in Table 11. In case of ties, use the average rank of the tied alternatives.

(2) Eliminate any alternatives if all of its consequence specific ranks are dominated by another or if these ranks all fall below the median rank.

(3) If any alternatives are eliminated in (2), then adjust the ranks of the surviving alternatives accordingly.

(4) Determine the rank sum, RS_i, of each alternative, i, by evaluating

$$RS_i = \frac{1}{100} \sum_j W_j \sum_k p_{jk} R_{ijk}$$

where

W_j = Weight assigned to consequence, j

p_{jk} = Probability of occurrence, k, for consequence, j

Table 11. Decision Matrix - Weighted Ranking Method

Consequences	Occurrence Probability	Alternatives 1	2	3	→	n		Weight
A.	P_{A1}	R_{1A1}	R_{2A1}	R_{3A1}		R_{nA1}		W_A
	P_{A2}	R_{1A2}	R_{2A2}	R_{3A2}		R_{nA2}		
	P_{A3}	R_{1A3}	R_{2A3}	R_{3A3}		R_{nA3}		
B.	P_{B1}	R_{1B1}	R_{2B1}	R_{3B1}		R_{nB1}		W_B
	P_{B2}	R_{1B2}	R_{2B2}	R_{3B2}		R_{nB2}		
C.	P_{C1}	R_{1C1}	R_{2C1}	R_{3C1}		R_{nC1}		W_C
	P_{C2}	R_{1C2}	R_{2C2}	R_{3C2}		R_{nC2}		
	P_{C3}	R_{1C3}	R_{2C3}	R_{3C3}		R_{nC3}		
	P_{C4}	R_{1C4}	R_{2C4}	R_{3C4}		R_{nC4}		
D.	P_D	R_{1D}	R_{2D}	R_{3D}		R_{nD}		W_D
↓	↓	↓	↓	↓		↓		↓
X.	P_{X1}	R_{1X1}	R_{2X1}	R_{3X1}		R_{nX1}		W_X
	P_{X2}	R_{1X2}	R_{2X2}	R_{3X2}		R_{nX2}		
	P_{X3}	R_{1X3}	R_{2X3}	R_{3X3}		R_{nX3}		
Rank Sum		RS_1	RS_2	RS_3		RS_n		

R_{ijk} - Rank of alternative "i" for consequence "j" under occurrence probability "k"

R_{ijk} = Rank of alternative, i, for consequence, j, and occurrence, k.

This rank sum, RS_i, is entered at the bottom of each column of Table 11.

(5) Rank all alternatives in terms of increasing values of RS_i where the smallest value is "best" or "most preferred".

In interpreting this ranking the validity of the basic assumption, equal intervals, must be reviewed. Sensitivity studies, as discussed in Section 5.1, can be applied to weighted rankings. Note that no inferences should be based on the arithmetical (i.e., numerical) difference between the rank sums of adjoining alternatives.

6.2 NON-LINEAR UTILITY TRANSFORMATIONS

The discussion, in Section 4.1.2, of Transformation Functions recommended that, in most cases, these functions should be defined to be linear to ease the computational effort. However there may be sufficient grounds to use a non-linear formulation.

For instance, if an increase in annual costs from $50,000 to $100,000 is considered less important than one from $250,000 to $300,000 then the transformation function for this disbenefit (cost) may have the following form:

$$\text{Utility} = \left(\frac{\text{Reference Outcome} - \text{Estimated Consequence Level}}{\text{Reference Outcome}}\right)^{c} - 1.0$$

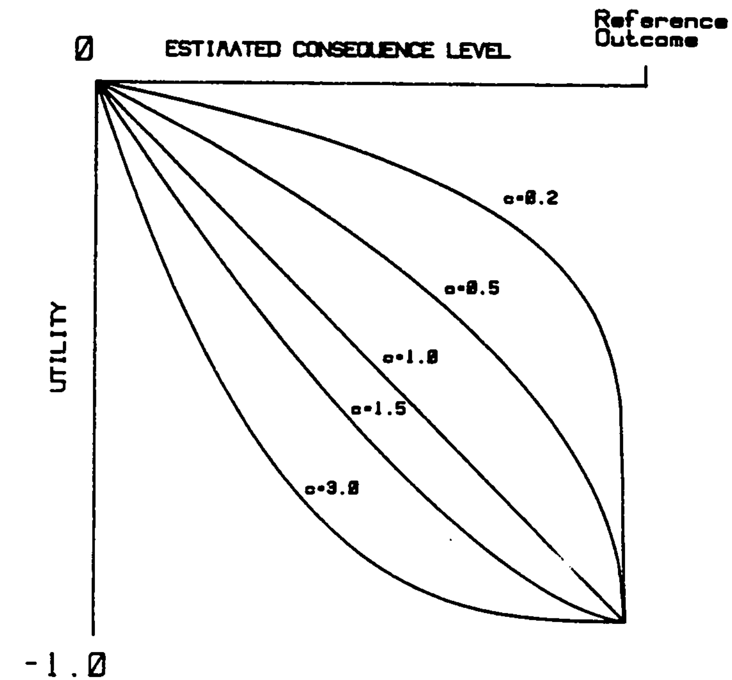
where "c" is a number smaller than one. Conversely, if increments

where "c" is a number smaller than one. Conversely, if increments
at the low end of the measurement scale are considered more important than increments at the high end then a value of "c" greater than one, would be selected. Figure 4 illustrates the effect of the selection of "c" in the above equation. It is seen that c = 1 is the special case of a linear transformation.

Similarly, Figure 5 shows non-linear exponential transformations for benefits. In this figure the function plotted is

$$\text{Utility} = \left(\frac{\text{Estimated Consequence Level}}{\text{Reference Outcome}}\right)^{c}$$

Combinations of transformations can be used. For instance, the ascending part of Figure 3(B) could use one of the non-linear curves of Figure 5.

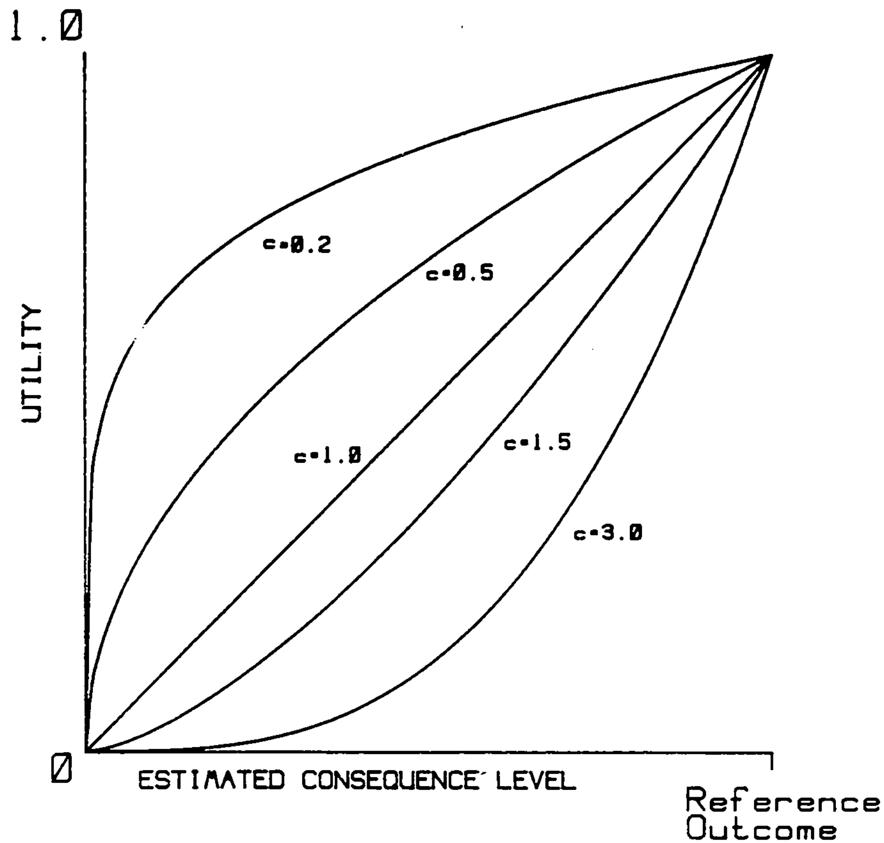


$$\text{Utility} = \left(\frac{\text{Reference Outcome} - \text{Estimated Consequence Level}}{\text{Reference Outcome}}\right)^{c} - 1.0$$

Figure 4

EXPONENTIAL UTILITY TRANSFORMATION

(DISBENEFITS)



$$\text{UTILITY} = \left(\frac{\text{Estimated Consequence Level}}{\text{Reference Outcome}}\right)^{c}$$

Figure 5

EXPONENTIAL UTILITY TRANSFORMATION

(BENEFITS)

REFERENCES

1. King, G.F., "Evaluation of Safety Roadside Rest Areas", NCHRP Report 324, December 1989.
2. American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements - 1977, AASHTO, Washington, D.C., 1978.
3. Winfrey, R., Economic Analysis for Highways, International Textbook Co., Scranton, PA, 1969.
4. Sassone, P.G. & Schaffer, W.A., Cost-Benefit Analysis - A Handbook, Academic Press, NY, 1978.

APPENDIX B

ILLUSTRATIVE EXAMPLE

Appendix B presents an example illustrating the application of the Rest Area Analysis Methodology. This outline of a case study addresses an actual problem.

This illustrative case study examines the need for additional rest area facilities for northbound traffic on FAI Route 81 between Roanoke and Staunton in Roanoke, Botetourt, Rockbridge, and Augusta Counties, Virginia.

The case study uses existing data and additional inputs from personnel of the Virginia Department of Transportation and the Virginia Transportation Research Council. No special data collection effort, for the purposes of the case study, was undertaken beyond a field inspection of the locations.

The implementation of the Rest Area Analysis Methodology (RAAM) requires the acquisition of considerable data as well as judgmental inputs based on experience and on the policies of the involved agency. Therefore, RAAM implementation should involve agency personnel; in fact, most of the required data are only available from that agency or from other parts of the state government. These data needs include detailed traffic and highway design data and ROW, design, construction, maintenance and operation costs for the different alternatives.

Potential environmental effects, especially involving ground and surface water, are evaluated using information on existing base conditions. Social, economic, institutional, and political effects and constraints can best be evaluated by local and state personnel familiar with the area and the applicable policies and procedures.

A quantitative assessment of consequence levels requires detailed information on the proposed rest area location, preliminary plans which specify its size (i.e., capacity), range of services and facilities offered, and certain other important features (e.g., sanitary waste disposal).

This illustrative case study utilized assumptions by the research staff and qualitative descriptors. In an actual RAAM application more quantitative data would probably be available, thereby reducing the extent of assumptions and qualitative descriptors. Furthermore, individual consequences were defined at a higher level of aggregation than would be the case in an actual application.

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APPENDIX B

ILLUSTRATIVE EXAMPLE

1. BACKGROUND

FAI 81 is part of one of the major highway corridors connecting the Northeast with the Southeast and South Central states, Figure 1. The route traverses Virginia, in a general NE/SW direction from the West Virginia to the Tennessee lines, traversing the more sparsely settled western portions of the State. Only one major city, Roanoke, with an estimated 1986 population of 101,900, is located along the route.

The Route 81 corridor involves 13 counties and 11 independent cities whose area, or a substantial portion thereof, lie within 20 miles of the highway. Demographic data for these counties and cities are presented in Table 1. Aggregate data for the corridor and for the State of Virginia are shown below.

	I81 Corridor	Virginia
Population (1986)	980,000	5,787,100
Area (sq. mi.)	10,438	39,704
Pop. Density (persons/sq.mi.)	93.9	145.8
Percent Urban (1980)	25.2	66.0
Population Increase, 1970-1980, Percent	16.1	15.0

Thus, while the corridor involves more than one quarter of the State's area, it contains less than 17 percent of the State's

Table 1. I81 Corridor Population

County	Population (1986)	Population Density sq. mi. (1986)	Percent Change 1970-1980	Percent Change 1980-1986	Percent Urban (1980)
Augusta	91,500	91.0	6.4	0.6	44.0
Bland	6,400	17.8	17.1	0.5	--
Botetourt	24,700	45.3	27.9	6.2	0.5
Carroll	34,200	70.3	15.1	1.2	19.3
Clarke	10,300	57.8	23.0	3.2	--
Craig	4,200	12.8	12.0	5.7	--
Floyd	11,800	30.9	18.3	1.6	--
Frederick	58,100	137.0	24.9	6.9	37.2
Giles	17,600	48.6	6.4	-1.3	14.1
Grayson	16,600	37.2	7.4	--	--
Montgomery	66,100	169.6	34.7	4.5	64.5
Page	20,000	63.9	17.0	2.9	18.5
Pulaski	47,900	147.4	17.7	-1.1	48.2
Roanoke	200,100	649.7	8.6	1.5	90.0
Rockbridge	31,100	51.2	4.1	-2.6	43.9
Rockingham	81,400	93.5	22.7	6.1	30.0
Russell	32,200	67.2	29.5	1.3	11.1
Shenandoah	28,200	55.1	20.6	2.5	9.5
Smyth	33,000	73.0	6.4	-1.0	21.1
Tazewell	50,400	96.9	26.9	-0.2	39.4
Warren	23,300	107.3	38.6	10.1	52.5
Washington	65,300	113.8	17.6	-0.3	37.4
Wythe	25,600	55.1	15.3	0.3	28.0
Entire Corridor	980,000	93.9	16.1	2.0	25.2

Note: Data for counties in this table has been merged with data for the independent cities as follows:

Augusta County	- Staunton, Waynesboro
Carroll County	- Galax
Frederick County	- Winchester
Pulaski County	- Radford
Roanoke County	- Roanoke, Salem
Rockbridge County	- Buena Vista, Lexington
Rockingham County	- Harrisonburg
Washington County	- Bristol

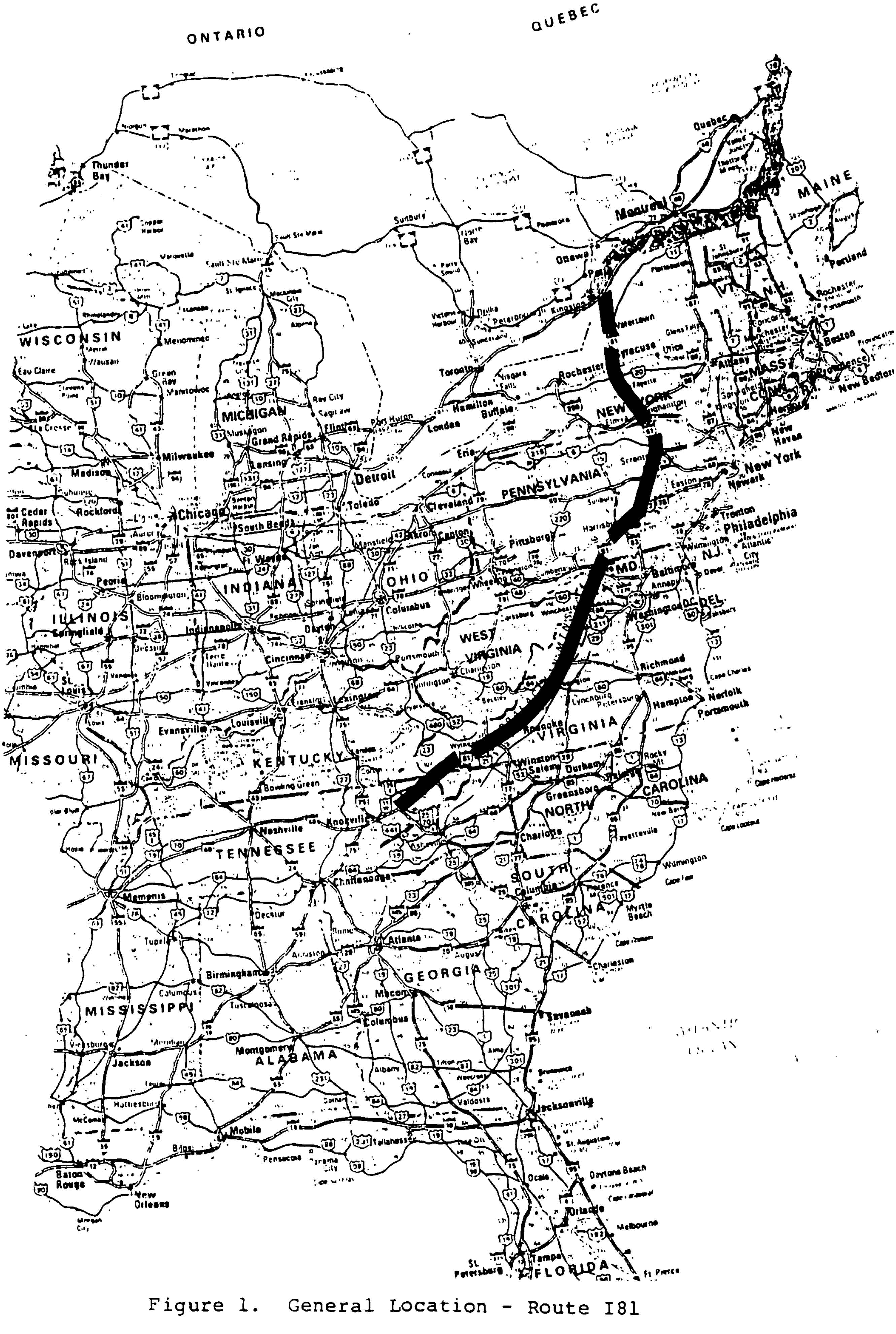

Figure 1. General Location - Route I81

population. Consequently, corridor population density is less than two thirds of the statewide average. Population growth in this corridor has lagged behind that of the remainder of the State in recent years, reversing an earlier faster growth rate, as shown below.

<u>Region</u>	<u>Average Annual Increase, Pct.</u>	
	<u>1970-1980</u>	<u>1980-1986</u>
Entire State	1.40	1.32
I81 Corridor	1.50	0.32
State Outside I81 Corridor	1.38	1.54

The length of the route in Virginia is 325 miles. Initial plans called for a total of 25 rest areas, thirteen for northbound traffic and twelve for southbound traffic for an average rest area spacing of 25 miles. However only fourteen of these rest areas have been completed, seven for each direction. The status of the rest area system in November 1987 is shown in Figure 2.

As a result of this partial implementation of the rest area master plan, there is now a section of northbound I81, 103 miles in length, between rest area 22N at Ironto, Montgomery County (Milepost 129), and rest area 26N at Verona, Augusta County (Milepost 232) in which there are no open rest areas. Three additional rest areas were planned within this section at, approximately, the following locations:

Rest Area 23N	Botetourt County	Milepost 157
Rest Area 24N	Rockbridge County	Milepost 179
Rest Area 25N	Rockbridge County	Milepost 201

This area, shown in Figure 3, is located in the foothills of the Appalachian Mountains with generally rolling topography. South of the Botetourt-Rockbridge County Line (Milepost 174) there are very few opportunities to locate a rest area without extensive cut and fill operations. The northern half lies in the Shenandoah Valley and, especially north of Milepost 200, the topography gradually becomes more level with numerous parcels of abutting land which appear suitable for locating rest areas. Abutting land is, almost universally, devoted to farming and there are very few structures, and no cities or villages, immediately adjacent to the highway right of way.

There are 24 interchanges in the 103 miles between rest areas 22N and 26N as shown in Table 2. One of these (Exit 47) is a partial interchange with no exit possible for northbound traffic and three (Exits 42, 52 and 56) are freeway to freeway interchanges. There are thus 20 opportunities for travelers to leave the Interstate route to seek services. The spacing of these exits ranges from 1.3 to 8.1 miles with an average spacing of 4.8 miles. Logo service signing has been erected at nearly all exits; in many cases a service station is located near the foot of the ramp and is visible from the highway.

Bi-directional Average Daily Traffic (ADT), in 1987, ranged from 18,630 to 41,150 with the higher values occurring at the south end of the analysis section near the City of Roanoke (Table 3). The percent of commercial traffic ranges from 19.7 to 32.6 with the higher values found in the middle of the section where ADT figures

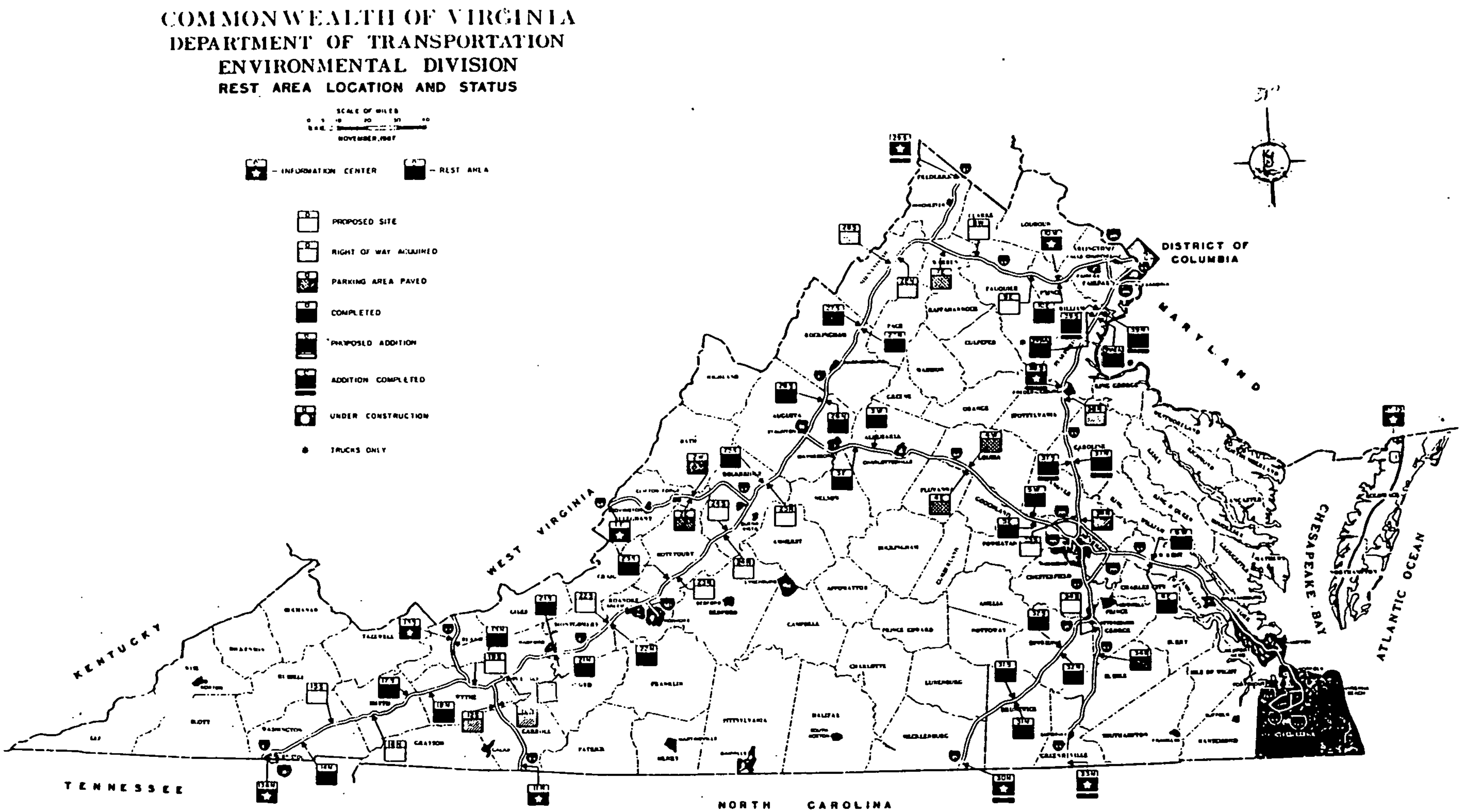

Figure 2. Current Status Virginia Rest Area System

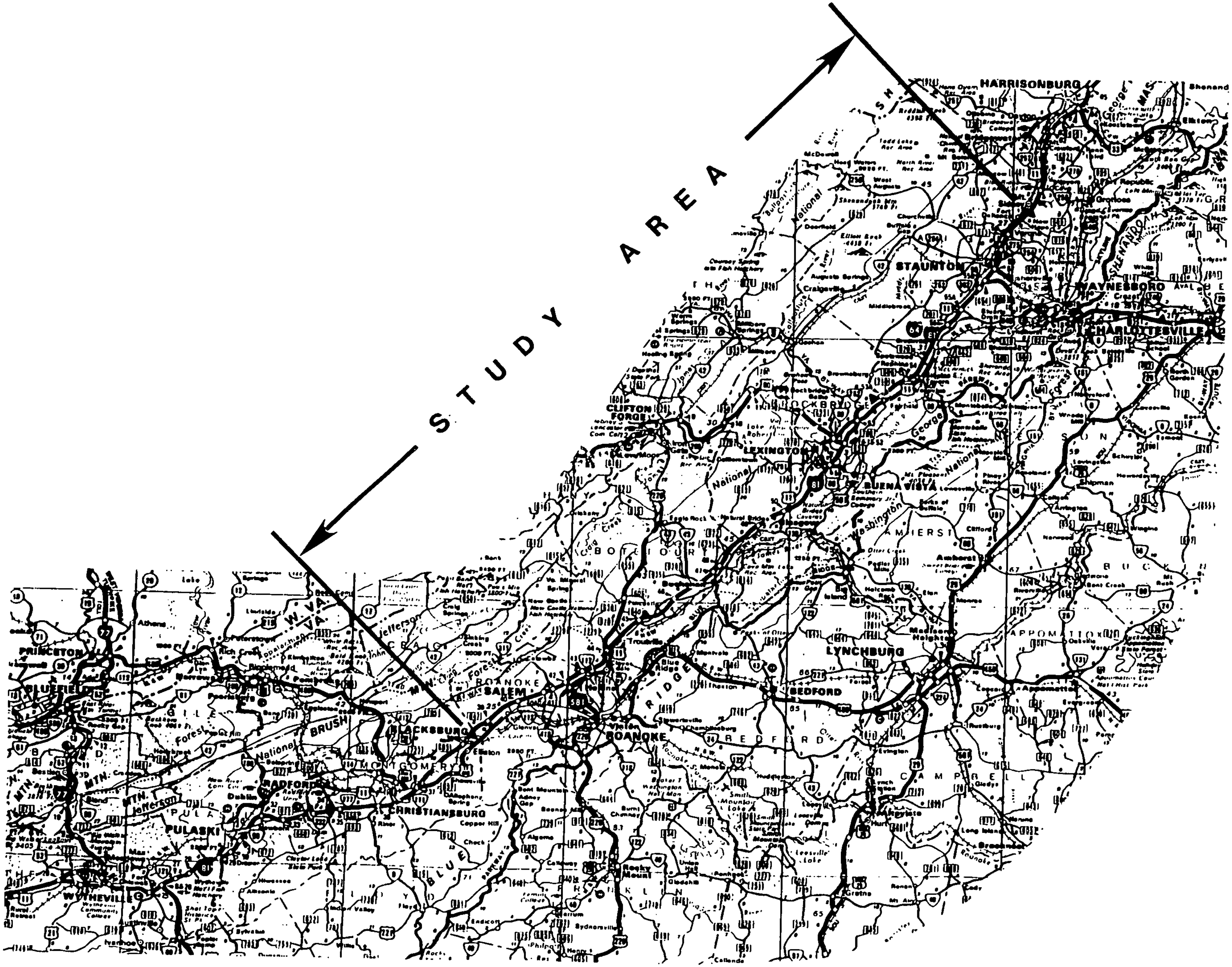

Figure 3. Case Study Site

Table 2. Interchanges, I81, Northbound

No.	Route	Milepost	Type	Comments
Rest Area	22N	129	--	
39	VA 647	132	Diamond	
40	VA 112	137	Modified Diamond	
40A	VA 311	140	(Parclo)	See Note
41	VA 419	141	Modified Diamond	
42	I581, US 220	144	Split Diamond Tee	Freeway-Freeway
43	VA 115	146	Diamond	
44	US 220	150	Diamond	
45	VA 640	156	Diamond	
46	US 11	162	Modified Diamond	
47	US 11	168	Partial Diamond	No Northbound Exit
48	VA 614	169	Diamond	
49	US 11	176	Diamond	
50	US 11	181	Parclo	
51	US 60	189	Parclo	
52	I64	191	Left Split Diamond Tee	Freeway-Freeway
53	US 11	195	Diamond	
53A	VA 710	201	Diamond	
54	VA 606	205	Diamond	
55	US 11	213	Diamond	
55A	VA 654	218	Diamond	
55B	VA 262	221	Modified Diamond	
56	I64	222	Modified Three Leg Directional	Freeway-Freeway
57	US 250	223	Modified Diamond	
58	VA 275	226	Diamond	
59	VA 612	228	Diamond	
Rest Area	26N	232	--	

Note: Exit 40A is shown on the 1988 Official Virginia Highway Map and on the 1983 Geological Survey Radford Quadrangle Map but is not shown on the Virginia DOT Straight Line Diagrams (last revised May 7, 1985).

Table 3. Average Daily Traffic - 1987
I81 Between Exits 38 and 60

Exit Number		Passenger Cars (1)		Trucks (2)		ADT (3)
From	To	No.	Pct.	No.	Pct.	
38	39	20750	73.8	7360	26.2	28110
39	40	21600	74.2	7510	25.8	29110
40	41	25850	75.4	8455	24.6	34305
41	42	32500	79.0	8650	21.0	41150
42	43	27500	80.3	6755	19.7	34255
43	44	23000	77.8	6575	22.2	29575
44	45	14000	69.3	6205	30.7	20205
45	46	14200	70.0	6100	30.0	20300
46	47	13400	69.7	5815	30.3	19215
47	48	12900	69.2	5730	30.8	18630
48	49	13300	68.6	6075	31.4	19375
49	50	13650	67.3	6635	32.7	20285
50	51	13650	67.4	6600	32.6	20250
51	52	14550	69.0	6530	31.0	21080
52	53	14650	69.0	6575	31.0	21225
53	54	15050	69.3	6675	30.7	21725
54	55	15000	68.9	6780	31.1	21780
55	56	17300	70.8	7120	29.2	24420
56	57	20050	73.9	7080	26.1	27130
57	58	18450	72.4	7040	27.6	25490
58	59	17450	71.4	6980	28.6	24430
59	60	16550	71.0	6745	29.0	23295

(1) Includes 2 axle, 4 tire pickups and vans

(2) Includes buses

(3) Bi-directional

are the lowest. The number of trucks is fairly uniform throughout the entire section as shown in Figure 4.

Vehicle origin data were not reported in 1987. Data collected in 1986 indicate that the average daily number of out-of-state passenger cars is fairly constant throughout the analysis section, ranging from 3000 south of Staunton to 5500 in Roanoke. In-state passenger car traffic shows much greater variability, with a better than 3.2:1.0 ratio between the heaviest and lightest link, reflecting the predominance of local traffic in and near Roanoke.

The nearest operating permanent count station, 15N, is located at Milepost 241, nine miles north of rest area 26N, the north end of the analysis section. Figure 5 shows monthly variability in northbound traffic at this location for average weekdays as well as for weekends. The fact that Sunday traffic consistently exceeds weekday traffic and the high summer peak strongly indicate a large recreational component in the traffic stream. This inference is further supported by an analysis of directional split shown in Figure 6. These data indicate a dominant southbound movement on Saturday followed by a northbound return movement on Sunday.

The applicability of these data to the entire analysis section is supported by an examination of traffic volumes at count station 20N located at Milepost 16, 113 miles south of rest area 22N. These data indicate the same Saturday to Sunday reversal, and summer peaking, though not quite as pronounced. Count station data are shown below.

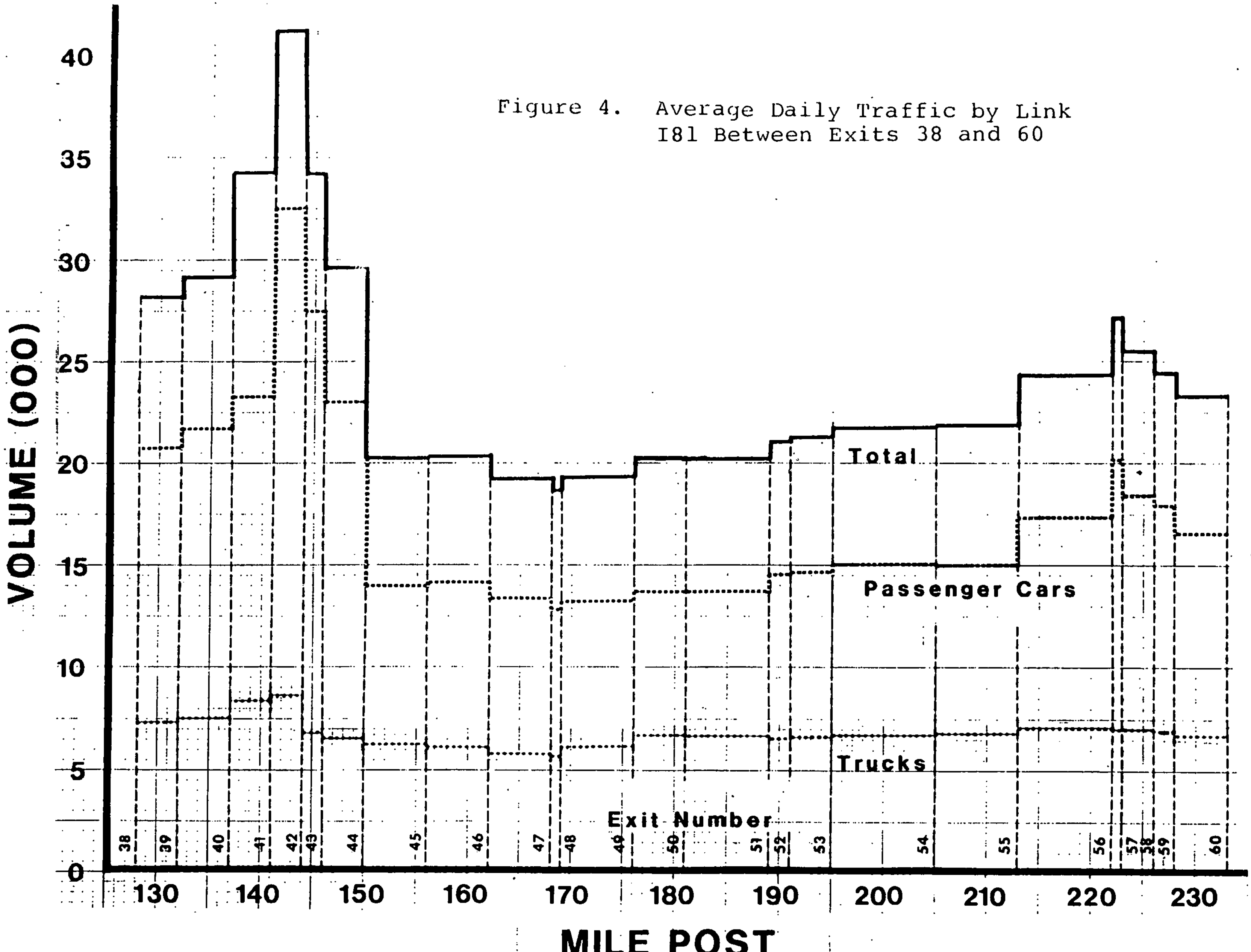

Figure 4. Average Daily Traffic by Link
I81 Between Exits 38 and 60

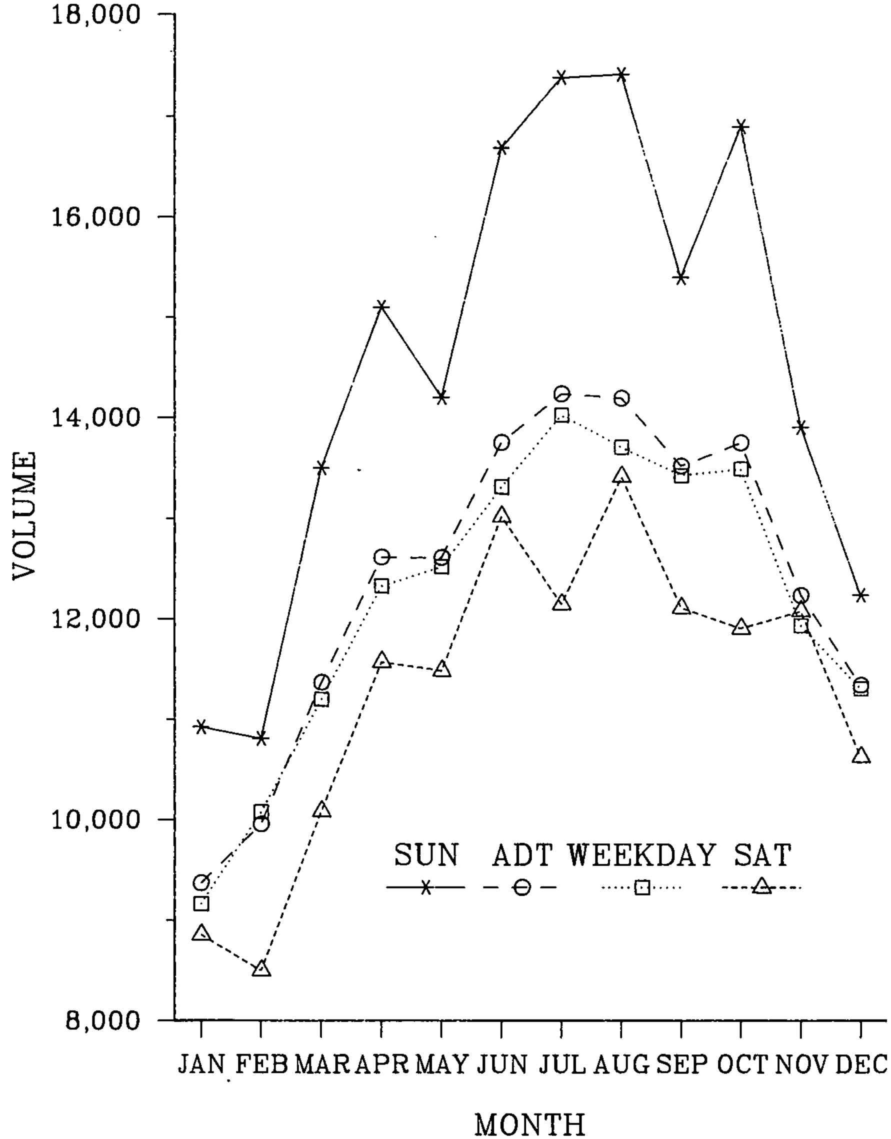

Figure 5. Daily and Seasonal Variation in Traffic Volumes at Count Station 15N

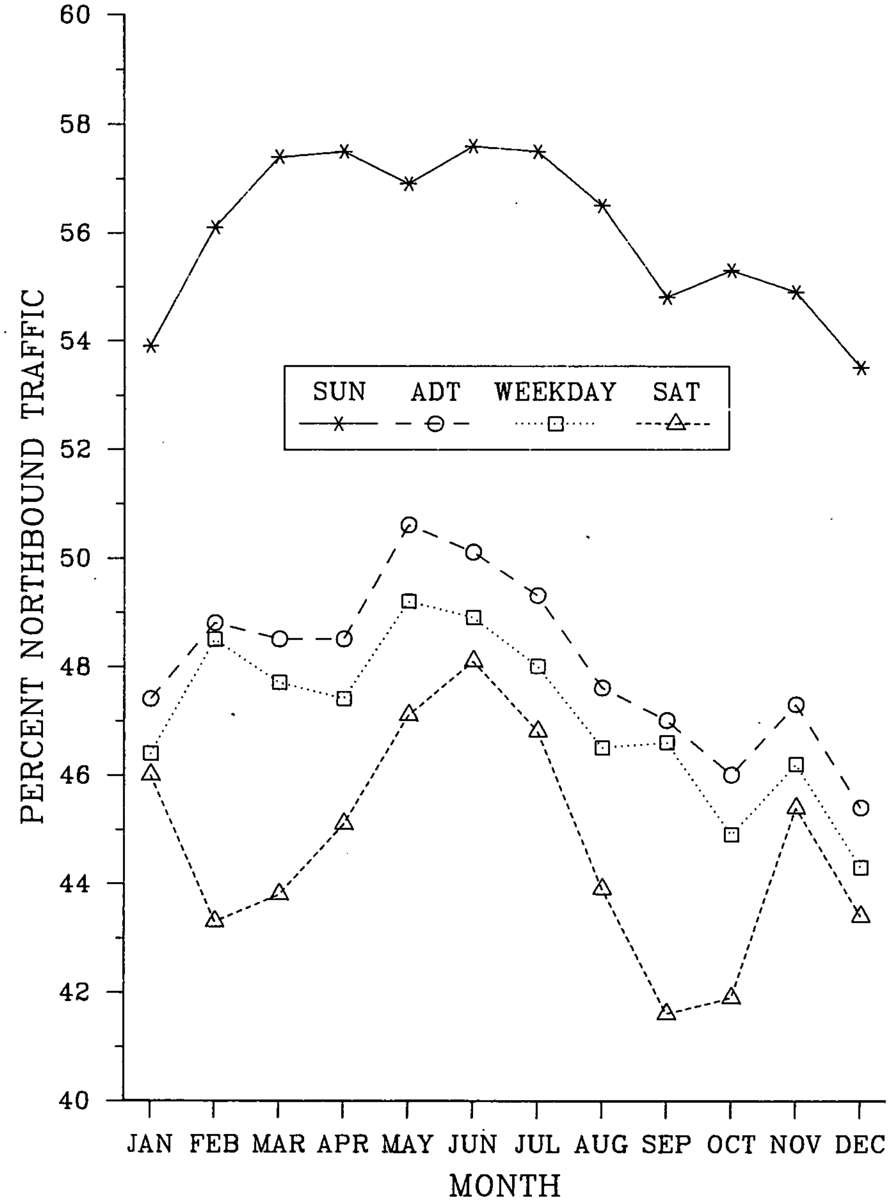

Figure 6. Directional Split of Traffic at Count Station 15N

	Count Station	
	15N	20N
Northbound Traffic as Proportion of ADT		
Saturday	.446	.471
Sunday	.561	.554
June-Aug. ADT as Proportion of AADT	1.133	1.124
Jan.-Feb. ADT as Proportion of AADT	0.778	0.785
Ratio of Average Northbound Sunday Traffic to Average Northbound Weekday Traffic	1.191	1.044

2. ALTERNATIVES

Any decision can be resolved into a choice between alternatives. The first step in the analysis generates a listing and definition of these alternatives.

2.1 INITIAL LISTING

Possible alternatives can be defined within the framework of the rest area master plan, as developed by the Virginia Department of Transportation, which was shown in Figure 2. The approximate location of the three proposed additional rest areas are shown in more detail in Figure 7 to 9. In addition to the customary "do nothing" alternative there are seven possibilities:

- Construct Rest Area 23N
- Construct Rest Area 24N
- Construct Rest Area 25N
- Construct Rest Areas 23N and 24N
- Construct Rest Areas 23N and 25N

- Construct Rest Areas 24N and 25N
- Construct Rest Areas 23N, 24N and 25N

The original master plan was developed based on the criterion of 25 miles as a desirable rest area spacing. In more recent years, however, the consensus of opinion has been that an average rest area spacing of 40 to 50 miles is adequate. A recent survey of states indicated that the current median spacing for interstate rest areas is approximately 45 miles. A parallel survey of rest area users indicates a preferred median spacing of 50 miles.

Excluding the 103 mile gap which is the subject of the current investigation, the average spacing of existing rest areas is 37 miles for northbound traffic and 46 miles for southbound traffic.

Both West Virginia and Tennessee maintain rest area-welcome centers located just beyond their State lines. As shown in Figure 2, Virginia DOT has completed ROW acquisition for rest areas 28S and 28N. Opening of these rest areas would reduce the average spacing to about 32 miles Northbound and about 40 miles Southbound. The maximum rest area spacing outside the study section would be reduced to about 48 miles Northbound and 55 miles Southbound.

If additional rest areas are opened in the 103 mile section under consideration, the effect on average spacing would be as follows assuming that rest area 28N is also opened:

No. of New Rest Areas Constructed	Average Spacing (miles)
1	36.1

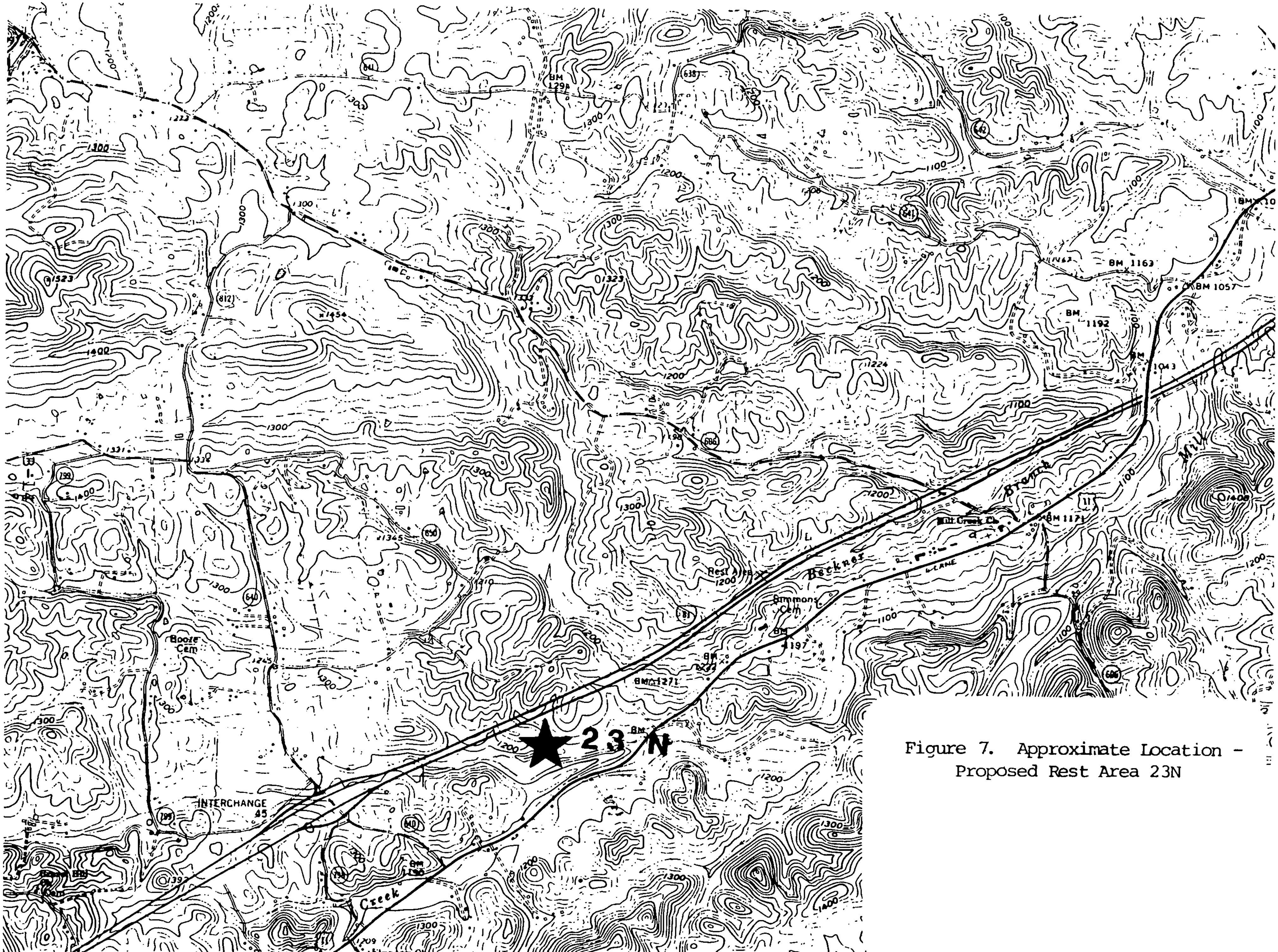

Figure 7. Approximate Location -
Proposed Rest Area 23N

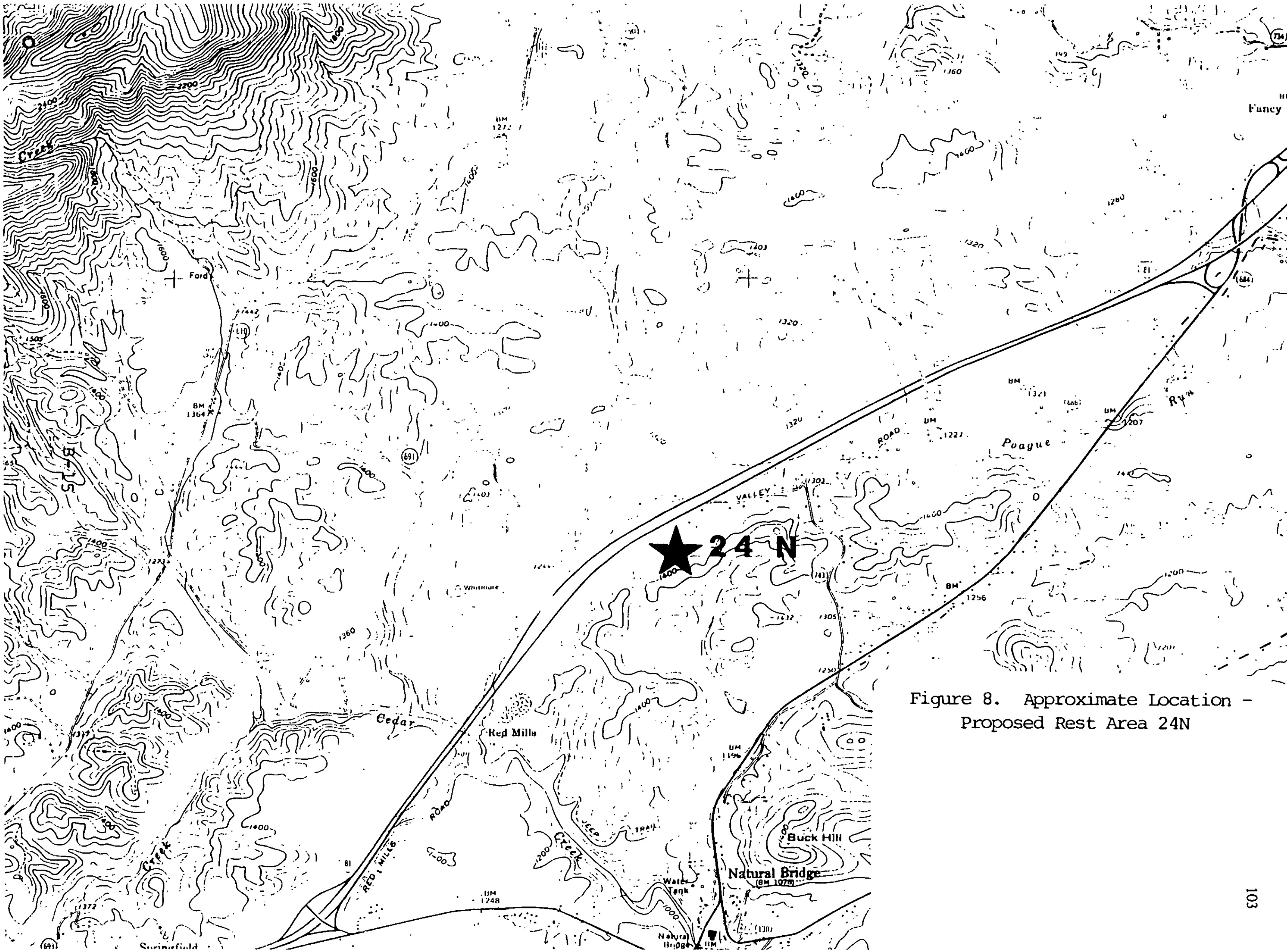

Figure 8. Approximate Location - Proposed Rest Area 24N

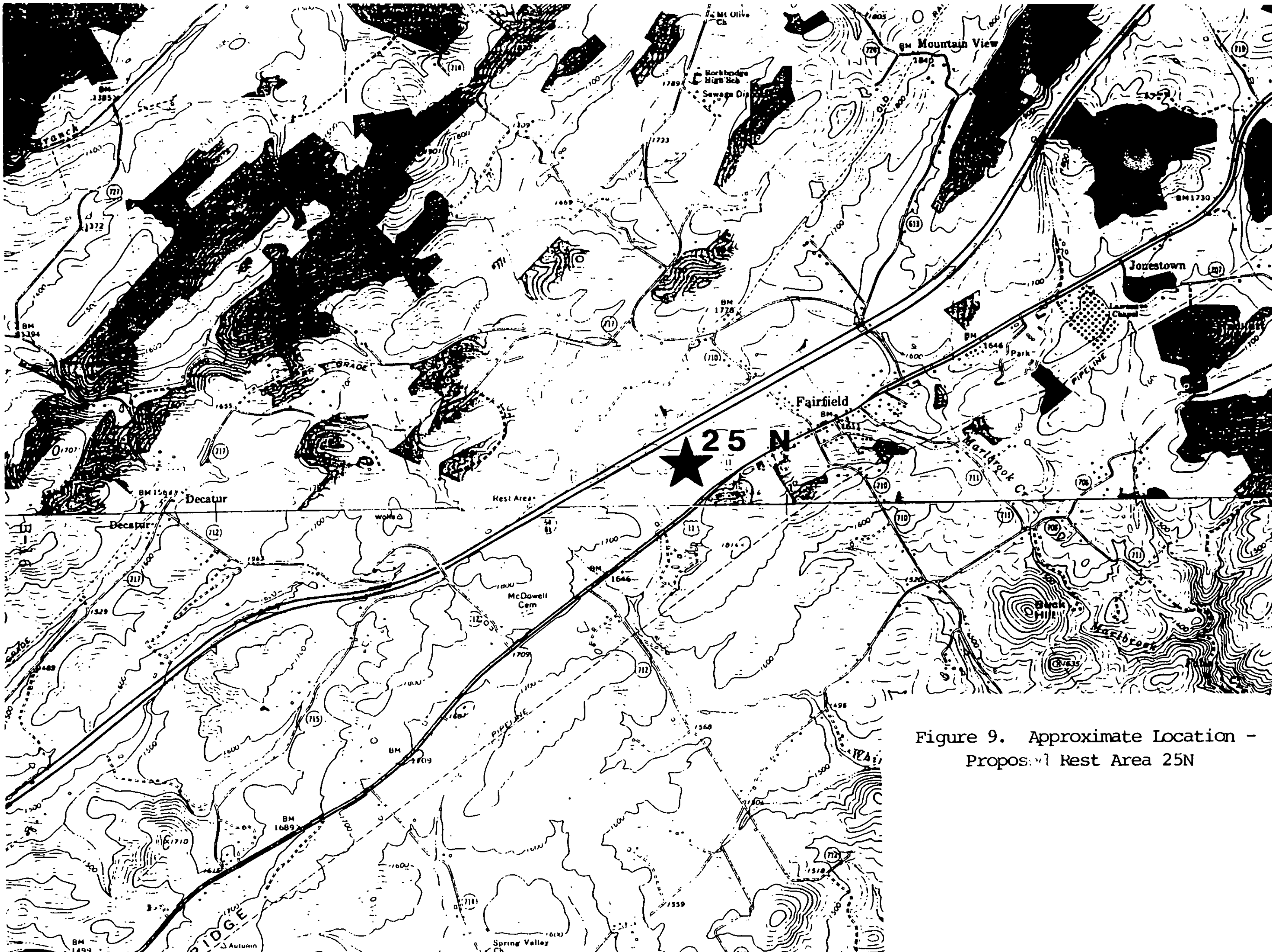

Figure 9. Approximate Location - Propos·d Rest Area 25N

No. of New Rest Areas Constructed	Average Spacing (miles)
2	32.5
3	29.5

The resulting maximum rest area spacing for each alternative is listed below (excluding the 62.2 mile gap at the north end of the route).

Rest Area(s) to be Constructed	Maximum Spacing (miles)
23N Only	75.6
24N Only, or 23N & 24N	53.7
25N Only	71.6
23N & 25N, or 23N, 24N & 25N	47.6
24N & 25N	50.0

Routes I64 and I81 run concurrently for approximately 30 miles between I81 exits 52 and 56. Rest area site 25N is located in that 30-mile stretch and, if implemented, would reduce an existing gap of about 74 miles between rest areas 2E and 3E for eastbound I64 traffic to 38 miles (25N to 3E). At the south junction point (Exit 52 on I81), I64 carries about one-third of the traffic of I81.

This listing, of course, does not exhaust the set of all possible alternatives. This case study will only consider the eight alternatives listed above, since:

- Proposed rest area site 24N is located midway in the 103 mile section.

- The master plan rest area locations are approximate; any location within several miles of the nominal mile post given could be considered in the final design.
- Selecting other locations on the basis of topographic or environmental (water supply and/or sanitary waste disposal) considerations would require a new data base and a level of analysis considerably beyond the scope of this case study.

These alternatives do not consider staged implementation. For example:

- An alternative which consists of construction of a <u>single</u> rest area, to meet current or immediate future demands for parking or other facilities with provisions (e.g. ROW, grading, etc.) for future expansion; and/or
- An alternative consisting of two rest areas; one to be constructed immediately and the other at some future date.

could be added to the analysis (see Section 10).

2.2 SCREENING OF ALTERNATIVES

Initial screening of alternatives should eliminate obviously unfeasible alternatives. This subject is covered in Section 2.1.2 of the Users Manual.

The results of a preliminary screening of the eight identified alternatives are shown in Table 4 and discussed below.

2.2.1 Costs

The total costs, construction as well as maintenance and operations, reflect the number of rest areas to be constructed and

Table 4. Screening of Alternatives

Alternative	Cost	Safety	User Consequences	Institutional	Environmental	Economic & Social	Implementation	System
1. Do Nothing	+							
2. 23N	-							
3. 24N		+	+	-		+		
4. 25N				-				
5. 23N & 24N	-	+	+	-		+		
6. 23N & 25N	-			-				+
7. 24N & 25N	-	+	+	X		+		
8. 23N & 24N & 25N	X	+	+	X		+		+

Legend:

+ Major Positive Attribute

- Major Negative Attribute

x Basis for rejection

(Blank) No major positive or negative attributes

the costs associated with each. Prior to the preparation of preliminary designs for each of the three potential sites, it is difficult to assess costs for individual rest area locations. The topography at and near site 23N, however, is considerably more difficult than that at the other two locations. This difference is likely to increase construction costs at that site relative to the others.

Furthermore, the construction of <u>three</u> new rest areas does not appear to be feasible given current and anticipated continuing budgetary constraints.

2.2.2 <u>Safety</u>

It has been shown that the safety effect of rest areas are related to rest area spacing. For that reason, those alternatives which lead to significant reductions in maximum rest area spacing have been assigned a significant positive effect.

2.2.3 <u>User Consequences</u>

It is assumed that the services and facilities offered will be independent of either rest area location or number of rest areas constructed. If it is further assumed that the construction of additional rest areas will not affect service at existing locations, then the effect on user consequences will be largely a function of rest area spacing. The listing for this category thus parallels that for safety effects.

2.2.4 <u>Institutional</u>

The major institutional effect of new rest area construction is an increase in maintenance and operational responsibility for

the cognizant highway districts and residencies. The maintenance responsibilities for the three candidate locations and for existing rest areas is shown in Table 5.

The information in Table 5 indicates that rest area operational and maintenance responsibilities, by districts and residencies, would be as follows for each of the eight alternatives (rest areas under construction not included):

		Number of Rest Areas for which each Organization is responsible — Alternative							
		1	2	3	4	5	6	7	8
Districts:	Salem	4	5	4	4	5	5	4	5
	Staunton	7	7	8	8	8	8	9	9
Residencies:	Salem	1	2	1	1	2	2	1	2
	Lexington	2	2	3	3	3	3	4	4

Alternative 1, do nothing, also represents existing conditions. Current Virginia budget procedures allocate funds to districts and to residencies within districts. These allocations are mainly based on past expenditure levels and, due to general budgetary constraints, are not always fully responsive to changes in responsibility. The addition of more than one new rest area to a given district or residency may thus generate major problems in providing adequate operations and maintenance. Furthermore, any additional rest areas assigned to the Staunton District (Lexington Residency) would further unbalance the distribution of

Table 5. Rest Area Operational and Maintenance Responsibility

Location	County	District	Residency
21N	Montgomery	Salem	Christiansburg
21S	Montgomery	Salem	Christiansburg
22N	Montgomery	Salem	Christiansburg
23N*	Botetourt	Salem	Salem
23S	Botetourt	Salem	Salem
24N*	Rockbridge	Staunton	Lexington
25N*	Rockbridge	Staunton	Lexington
25S	Rockbridge	Staunton	Lexington
26N	Augusta	Staunton	Staunton
26S	Augusta	Staunton	Staunton
27N	Rockingham	Staunton	Harrisonburg
27S	Rockingham	Staunton	Harrisonburg
29S	Frederick	Staunton	Edinburg
1E (FAI 64)	Alleghany	Staunton	Lexington

*Candidate sites

Note: Rest area locations 28S, 7E (FAI 66) and 2E and 2W (FAI 65) which are in various stages of ROW acquisition are all located in Staunton District. 2E and 2W are in Lexington Residency.

responsibility between maintenance organizations especially in view of the rest areas, currently in various stages of construction, in that district/residency.

2.2.5 Environmental

Environmental effects are site specific and are thus difficult to evaluate pending the selection of precise locations for the candidate rest areas. Examination of detailed US Geological Survey Maps indicate no obvious adverse environmental factors except for the presence of a stream and a church in the area of the proposed location of Rest Area 23N. There is, however, an existing rest area, for southbound traffic, in this general area which apparently has no adverse environmental effects. For these reasons, no preliminary assignment of major environmental effects has been made.

2.2.6 Economic and Social

Economic and social effects deal with the specific and general economic impact of the potential rest area locations, with land use considerations and with the general quality of life. All three candidate sites are in sparsely settled areas in which the predominant land use is agriculture.

A rest area may have a positive local economic effect if information at the rest area leads to the diversion of through traffic to local tourist attractions or points of interest. The principal attractions to be considered include Natural Bridge (Exits 49 and 50); the Stonewall Jackson House and VMI in Lexington (Exit 51); the Woodrow Wilson Birthplace in Staunton (Exits 55B,

57, 58); and many attractions in and near Charlottesville, off I64 (Exit 56 on I81). Proposed rest area location 24N, between Exits 49 and 50, appear to be the best of the three sites for informing motorists of these attractions. Alternatives which include implementation of 24N have, therefore, been given a positive rating in this category.

2.2.7 Implementation

Based on the information currently available, there are no major implementation effects for any of the alternatives considered.

2.2.8 Systems

All alternatives (except "do nothing") will have system effects in that they may decrease maximum and/or average spacing. Furthermore, "filling the gap" is likely to improve the usage/capacity ratio of existing rest areas 26N, on northbound I81, and 3E on eastbound I64. This effect will be more pronounced the farther north a new rest area is constructed. The two alternatives which involve implementing both sites 23N and 25N will have the best effect on the overall system and are assigned a positive rating.

Construction of rest area 23N or 24N may also reduce the demand at existing rest area 21N (see Figure 2) if proper advance signing (i.e. NEXT REST AREA - M MILES) is used. The effect will, however, probably be slight since the City of Roanoke lies between locations 23N and 24N. Examination of Figure 2 also indicates a potential effect on usage at rest area 2W, on I64, if any

additional rest area is constructed south of the south junction of I81 and I64. However, the northbound to westbound movement is not significant since alternate, shorter routes using I77 or US220 are available (see Figure 3).

2.2.9 Summary

Examination of Table 4 indicates that alternatives 7 and 8 should be eliminated from further considerations for the reasons stated in Sections 2.2.1 and 2.2.4 respectively. The analysis of the remaining six alternatives is presented in the following sections.

3. CONSEQUENCES

Section 2.2 of Appendix A discusses the general subject of the selection of consequences in each of eight major categories. Table 2 of Appendix A lists some consequences that can be included in the analysis.

The discussion in the preceding section showed that differences in consequence levels between alternates were likely for six of the eight categories. The next step in the Rest Area Analysis Methodology normally consists of selecting one or more specific consequences within each applicable category. Since this preliminary analysis is undertaken without the availability of preliminary plans and without the close involvement of the cognizant local officials a high level of aggregation will be used in the form of general consequence categories. Seven categories will be included; environmental and implementation effects cannot be assessed in the absence of site specific data and are omitted.

4. OCCURRENCE PROBABILITIES

Between 1983 and 1987 bi-directional traffic on I81 passing the three candidate locations increased at the following compound annual rate:

Location	Pct. Annual Increase
23N	8.2
24N	9.4
25N	6.7

In comparison, over the same time period, vehicle miles of travel for the entire U.S. rural interstate system increased at a compound annual rate of 4.4 percent. The statewide rate of increase for Virginia was 6.5 percent.

These high historical growth rates for I81 will probably not be sustained over the projected 20 year life of any new rest area given the decreasing population growth rates of the I81 corridor population. The increase in the percentage of trucks in the traffic stream, from 29.8 percent in 1983 to 36.0 percent in 1987 for the U.S. Interstate system, is, however, likely to continue as is the increase in recreational travel. Although comparable data for the locations under study are not readily available, I81 commercial traffic can be expected to match the U.S. pattern especially in view of the increasing industrialization of areas to the south in North Carolina and Tennessee.

Although historical data on rest area usage are scarce the increased proportion of trucks and recreational vehicles in the traffic stream, the general aging of the population and other

factors appear to have led to an increase in rest area usage as a function of passing traffic. This belief is supported by data collected in several states in the 1980's that indicate that rest area usage as a proportion of passing traffic averaged between 30 and 50 percent higher than that predicted by an FHWA equation which was based on 1971 data. This increased usage over a period of approximately ten years translates into an annual rate of increase of approximately 3.4 percent.

Future scenarios will be based on probabilities associated with different levels of demand for rest area use. Rest area use is a function of traffic volume levels and composition, and the proportion of that traffic which enters the rest area, variables that may change over time. The historical data cited in the preceding paragraphs shows that the general trends will continue in the future but possibly at a reduced rate. A decrease in the <u>demand</u> for rest area usage, as a proportion of main line traffic volumes, is unlikely. A decrease in traffic volume levels, over the twenty year analysis period, could only occur in the case of a severe, prolonged economic downturn ; substantial changes in the price and/or availability of motor fuel; or major technological changes in personal and/or freight transportation.

Based on these considerations and on recent historical trends which indicate an average annual rate of increase of 7.9 percent in rest area usage, four scenarios will be considered in the analysis. These scenarios, and their associated probabilities, are defined below.

(A) A net decrease or no change in the demand for rest area usage. This scenario has been assigned an occurrence probability of 0.05.

(B) An average annual increase in rest areas usage demand of 6.0 percent or less which would lead to an approximate doubling of that demand over a period of 20 years. This scenario has been assigned a probability of 0.35.

(C) An average annual increase in rest area usage demand between 6.0 and 9.5 percent which would lead to rest area usage between three and six times higher than the current figure. This scenario has been assigned a probability of 0.50.

(D) An average annual increase in rest area usage demand in excess of 9.5 percent. This scenario has been assigned a probability of 0.10.

These four scenarios are shown graphically in Figure 10, the computations leading to their development are outlined in Table 6. In t:ese computations, possible future increase in traffic volume have been constrained to that level which can be accommodated on I81 without major widening of the roadway or other improvements. Furthermore, the possible effect of future changes in abutting land use or in applicable laws and regulations has not been considered in postulating possible future scenarios.

The computations shown in Table 6 involved the following steps:

FOUR FUTURE SCENARIOS

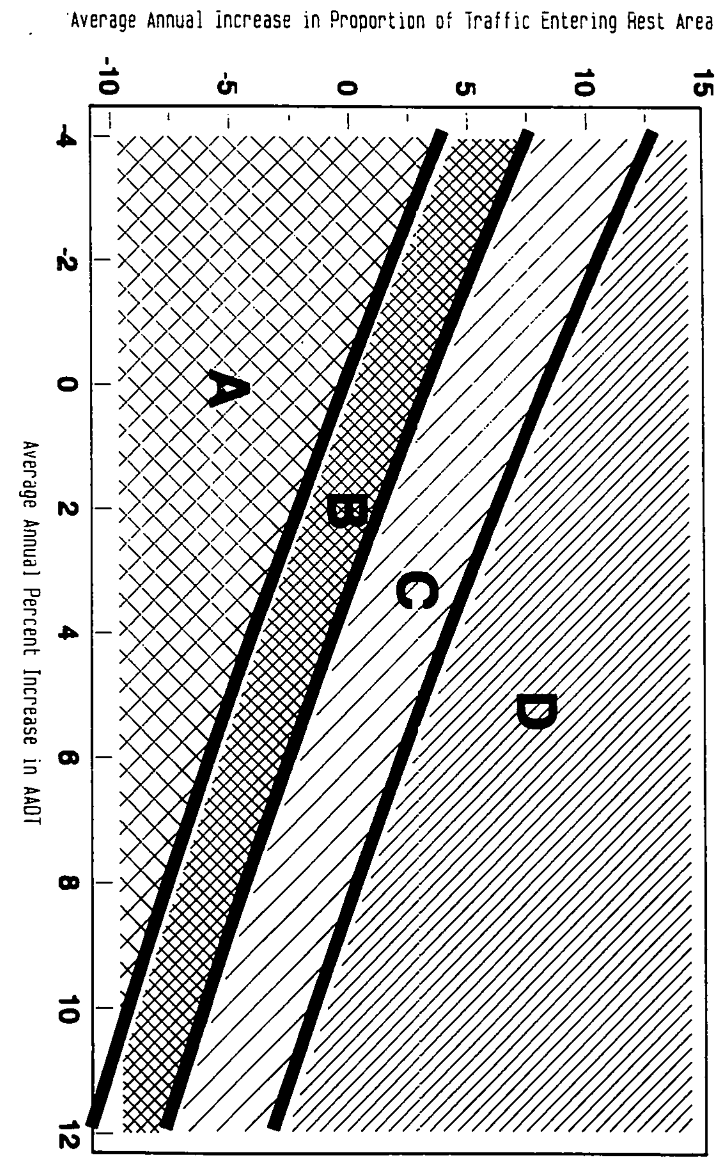

Figure 10.

Table 6. Computation of Occurrence Probabilities

			Average Annual Percent Increase in AADT			
			8.0	4.0	0.0	-0.2
			Compound Percent Increase After 20 Years			
			366(175)*	119	0	-33
			Probability of Occurrence			
Average Annual Percent Increase in Proportion Entering	Compound Percent Increase After 20 Years	Probability of Occurrence	0.1	0.6	0.2	0.1
0	0	0.1	175 / 0.01	119 / 0.06	0 / 0.02	-33 / 0.01
2	49	0.3	310 / 0.03	226 / 0.18	49 / 0.06	-1 / 0.03
4	119	0.5	502 / 0.05	380 / 0.30	119 / 0.10	46 / 0.05
6	221	0.1	783 / 0.01	603 / 0.06	221 / 0.02	114 / 0.01

Legend: Pct. Increase in Rest Area Usage / Probability

Pct. Increase 20 years	Avg. Annual Pct. Incr.	Prob.	Cumul. Prob.
-33	-2.0	0.01	0.01
-1	-	0.03	0.04
0	-	0.02	0.06
46	1.9	0.05	0.11
49	2.0	0.06	0.17
114	3.9	0.01	0.18
119	4.0	0.16	0.34
175	5.2	0.01	0.35
221	6.0	0.02	0.37
226	6.1	0.18	0.55
310	7.3	0.03	0.58
380	8.2	0.30	0.88
502	9.4	0.05	0.93
603	10.2	0.06	0.99
783	11.5	0.01	1.00

*Although the computed 20 year compounded increase is 366%, the maximum increase is limited to 175%. Any increase beyond that (i.e. to an AADT over 60,000) would require major reconstruction of I81 including additional lanes.

(1) Select four levels of possible annual rates of increase in AADT together with their probability of occurrence. These values are shown as the column headings in Table 6.

(2) Compute the compound AADT growth rate over a period of 20 years.

(3) Select four levels of possible annual rates of increase in "Proportion Entering" together with their probability of occurrence. These values are shown as the row headings in Table 6.

(4) Compute the compound growth rate for "Proportion Entering" over a period of 20 years.

(5) For each cell of the matrix, i.e. each unique combination of AADT and "Proportion Entering" growth rate, compute the increase in rest area usage after 20 years and the associated probability.

(6) Rank order the sixteen cells of the matrix in terms of "percent increase in rest area usage".

(7) Compute the average annual increase that would yield the 20 year increase computed in (5) and form a cumulative distribution.

(8) Select four points from that cumulative distribution as the future scenarios.

The computation of the occurrence probabilities for individual cells in the matrix of Table 6 assumes statistical independence of the two variables - change in AADT and change in proportion

entering. This assumption does not hold absolutely. For instance, both rates of change will be affected by changes in traffic stream composition and in the distribution of trip purposes. However, it is believed that any departure from the assumption of independence is not severe enough to have significant effect on the computed results.

These scenarios are defined in terms of changes in the demand for rest area usage. Whether this usage will be realized is a function of rest area availability and of actual or perceived capacity constraints.

5. WEIGHTS

The relative weight to be given each type of consequence is based on locally determined policies and conditions. The following indices of relative importance have been furnished by personnel from the Virginia Department of Transportation.

Cost	10
Safety	4
User Consequence	8
Institutional	5
Environmental	8
Economic & Social	4
System	3

Based on these data, omitting environmental consequences and using the Point Allocation Method, the following weights have been computed:

Cost	29
Safety	12
User Consequences	23
Institutional	15
Economic & Social	12
System	9

6. MEASUREMENT SCALES

Generally, the analysis measurement scale, for each consequence, is either quantitative (interval) or qualitative (ordinal). When a quantitative scale is used, the rating of the consequence for an alternative is computed or selected by considering both the location[s] of the proposed rest area[s] and the preliminary design[s] (size, services and facilities). Absent this detailed information (and for the purposes of a preliminary analysis such as this) qualitative scales appear to be more appropriate for five of the six consequence categories.

For the category "costs" a modified interval scale, more properly a ratio scale, was constructed using the following assumptions.

- There are no differences in operation and maintenance costs or in ROW and construction costs between the three sites except that construction costs for site 23N are 10 percent higher due to more difficult topography.
- Operations and maintenance costs represent one third of total annual costs.
- Half of the operations and maintenance costs are fixed; half is a function of usage.

- If two new rest areas are constructed, the size and usage for each will be 75 percent of that for a single new rest area.
- No provision is made for inflation or for changes in equivalent interest rates.
- For computational purposes, it will be assumed that usage grows linearly over the 20-year analysis period and operations and maintenance costs at the midpoint of that period represent the average costs over the entire period.

Factors affecting the choice of an appropriate measurement scale are discussed in Section 3.2 of Appendix A. The construction of such a scale, for a specific consequence, involves the consideration of:

- Verbal descriptors which reflect the attributes of that consequence.
- The minimum number of distinct points that will yield the desired resolution.
- Whether the anticipated levels of the consequence will represent positive, negative or mixed effects.

Qualitative measurement scales selected for five consequence categories are shown in Table 7. The scales were adopted from the examples of Table 6 of Appendix A. One of these three scales applicable for three of the consequence categories allows for both positive and negative effects. The other two scales allow only for either all positive or all negative effects.

Table 7. Measurement Scales

Safety/User/Systems	Institutional	Economic & Social
Extremely Adverse Effect	No Change	No Change
Highly Adverse Effect	Slight Deterioration	Slight Improvement
Adverse Effect	Moderate Deterioration	Moderate Improvement
Somewhat Adverse Effect	Significant Deterioration	Significant Improvement
Slightly Adverse Effect	Major Deterioration	Major Improvement
No Effect		
Slightly Beneficial Effect		
Somewhat Beneficial Effect		
Beneficial Effect		
Highly Beneficial Effect		
Extremely Beneficial Effect		

7. CONSEQUENCE LEVELS

The assignment of levels for each consequence category and for each occurrence probability is shown in Table 8 and discussed below:

These consequence levels have been assigned under the following assumptions:

- Any rest area constructed will be able to meet the demand of all postulated scenarios except D.
- There will be no capacity improvements at any other rest areas except that rest area 2E, which now consists only of a paved parking lot, may be completed.

7.1 COSTS

The first step in determining the relative costs of each alternative consists of determining relative usage that corresponds to each of the four postulated growth rates. These ratios are as follows:

Scenario	Relative Usage
A	1
B	2
C	4.5
D	6

The relative costs can then be determined, for each alternative, by assuming that original construction is for the "most likely" future demand level, i.e. Scenario C. These relative costs (RC) can be determined using the following equation.

$$RC = MC + 0.5C \times (0.5 + 0.5 \times D/4.5) = C\,[M + 0.25\,(1 + D/4.5)]$$

Where C represents annualized ROW and construction costs, D is the relative usage and M is a multiplier (1.1 for site 23N, 1.0 for the other two sites). The cost computations are shown in Table 9.

Insofar as the do nothing alternative is concerned, increases in maintenance and operation costs for the existing rest areas have been estimated by assuming that half of the increase in demand would use the existing locations. Although there are no immediate construction or ROW costs associated with alternative 1 (do nothing) it must be recognized that the existing rest areas do not have a remaining useful life equal to that of newly constructed rest areas. In view of this fact, operating and maintenance costs of the existing facilities have, therefore, been increased by 50 percent.

7.2 SAFETY

The safety effects of rest areas are the result of a number of factors including decreases in shoulder stops; in the proportion of the driving population fighting fatigue; and in excess travel on the conventional system to search for services. The magnitude of this safety effect is a function of both average and maximum rest area spacing and the demand/capacity ratio. Excessive demand for rest area services may, by itself, adversely affect highway safety insofar as it induces approach roadway, deceleration lane and shoulder parking especially by trucks.

A qualitative assessment, using a nine point scale, of the safety effects of the various alternatives is shown in Table 8.

Table 8. Case Study Analysis Matrix

Consequence	Wt.	Occurrence Prob.	Alternative: Do Nothing	23N	24N	25N	23N & 24N	23N & 25N	Reference Outcome
Cost	29	0.05	0.42C	1.41C	1.31C	1.31C	1.91C	1.91C	
		0.35	0.46C	1.46C	1.36C	1.36C	1.99C	1.99C	2.33C
		0.50	0.56C	1.60C	1.50C	1.50C	2.20C	2.20C	
		0.10	0.63C	1.68C	1.58C	1.58C	2.33C	2.33C	
Safety	12	0.05	No Effect	Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Highly Beneficial	Highly Beneficial
		0.35	Somewhat Adverse	Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Highly Beneficial	
		0.50	Adverse	Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Highly Beneficial	
		0.10	Highly Adverse	Somewhat Beneficial	Beneficial	Somewhat Beneficial	Highly Beneficial	Highly Beneficial	
User	23	0.05	No Effect	Somewhat Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Extremely Benef.	Extremely Beneficial
		0.35	Somewhat Adverse	Somewhat Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Extremely Benef.	
		0.50	Adverse	Somewhat Beneficial	Highly Beneficial	Beneficial	Highly Beneficial	Extremely Benef.	
		0.10	Extremely Adverse	Slightly Beneficial	Beneficial	Somewhat Beneficial	Highly Beneficial	Extremely Benef.	
Institutional	15	All	No Change	Mod. Deterioration	Significant Det.	Significant Det.	Mjr Deterioration	Mjr Deterioration	Major Det.
Economic & Social	12	All	No Change	Moderate Improvement	Significant Impr.	Slight Improvement	Major Improvement	Major Improvement	Major Impr.
System	9	0.05	No Effect	Beneficial	Highly Beneficial	Extremely Beneficial	Highly Beneficial	Extremely Benef.	Extremely Beneficial
		0.35	Somewhat Adverse	Somewhat Beneficial	Beneficial	Highly Beneficial	Beneficial	Extremely Benef.	
		0.50	Highly Adverse	Slightly Beneficial	Somewhat Benef.	Beneficial	Beneficial	Highly Beneficial	
		0.10	Extremely Adv.	Slightly Beneficial	Slightly Benef.	Somewhat Beneficial	Somewhat Benef.	Beneficial	

Table 9. Computation of Relative Costs

The table below gives relative costs in terms of a parameter C defined as the ROW and construction costs for a basic rest area of relative size 1.

Alternative	Scenario	Relative Cost Function	
1. Do Nothing	A	1.5C(0 + 0.25(1 + 0.5/4.5)	= 0.42C
	B	1.5C(0 + 0.25(1 + 0.5 x 2/4.5)	= 0.46C
	C	1.5C(0 + 0.25(1 + 0.5 x 4.5/4.5)	= 0.56C
	D	1.5C(0 + 0.25(1 + 0.5 x 6/4.5)	= 0.63C
2. 23N	A	C[1.1 + 0.25(1 + 1/4.5)]	= 1.41C
	B	C[1.1 + 0.25(1 + 2/4.5)]	= 1.46C
	C	C[1.1 + 0.25(1 + 4.5/4.5)]	= 1.60C
	D	C[1.1 + 0.25(1 + 6/4.5)]	= 1.68C
3. 24N	A	C[1.0 + 0.25(1 + 1/4.5)]	= 1.31C
	B	C[1.0 + 0.25(1 + 2/4.5)]	= 1.36C
	C	C[1.0 + 0.25(1 + 4.5/4.5)]	= 1.50C
	D	C[1.0 + 0.25(1 + 6/4.5)]	= 1.58C
4. 25N		Same as 24N for all scenarios	
5. 23N + 24N	A	$C[\frac{1.5(1.1+1.0)}{2} + 0.25(1+1.5/4.5)]$	= 1.91C
	B	$C[\frac{1.5(1.1+1.0)}{2} + 0.25(1+1.5x2/4.5)]$	= 1.99C
	C	$C[\frac{1.5(1.1+1.0)}{2} + 0.25(1+1.5x4.5/4.5)]$	= 2.20C
	D	$C[\frac{1.5(1.1+1.0)}{2} + 0.25(1+1.5x6/4.5)]$	= 2.33C
6. 23N + 25N		Same as (23N+24N) for all scenarios	

7.3 USERS

To a considerable extent the level of the consequence dealing with "user comfort and convenience" depends on the same rest area spacing parameters as does the safety consequence category. The levels have therefore been assigned in accordance with both resulting average and maximum spacing for both I81 and I64.

7.4 INSTITUTIONAL

As previously discussed, the major institutional effect consist of additional maintenance and operations responsibility to residencies and districts. The assignment of consequence levels has therefore been made in consideration of the existing maintenance and operational responsibility of the residencies and districts that would be affected by the proposed construction as documented in Section 2.2.4.

Although the proportional increases in responsibility for Staunton district and Lexington residency are lower than those for Salem district and residency, the absolute number of rest areas to be operated by both Staunton district and Lexington residency would be so high, especially in view of other locations now in various stages of ROW acquisition or construction (see Table 5), that significant adverse effects can be expected. Construction of two new rest areas, with some deterioration affecting two different residencies, can be expected, jointly, to have a major adverse effect.

7.5 ECONOMIC & SOCIAL

Two types of economic and social effects need to be considered:

- Diversion of traffic seeking the services to be provided by rest areas (e.g. rest room, telephone, vending) from adjacent communities.
- Diversion of traffic from the highway to adjacent communities to visit attractions on the basis of information received in rest areas.

As previously noted, there is a gasoline service station near most exit ramps in the section of interest. Furthermore, with the possible exception of Lexington and Buena Vista, there appear to be no communities between Roanoke and Staunton which are close enough to I81 or large enough to attract through travelers looking for rest area type facilities. Both Lexington and Buena Vista are reached from Exit 51.

Attractions which might be of interest to the through travelers are generally located off I81 north of Exit 50 or off I64 east of I81 Exit 56. Based on these considerations, alternatives which include implementing site 24N have been rated highly. Development of site 25N, the only candidate site north of the Lexington-Buena Vista area has received a somewhat lower ranking even though it is the only site which serves eastbound I64 travellers. Site 23N has been rated lower than 24N due to its farther distance from the area of tourist interest.

7.6 SYSTEMS

The establishment of any new rest areas will affect the usage levels and operations of existing rest areas and may affect other rest areas, in various stages of planning, ROW acquisition, or construction, not included in this analysis. Most of this effect will be on downstream rest areas, some of whose potential users will be intercepted by a new facility. Some effect may also be felt by upstream rest areas depending on the proportion of repeat traffic, i.e. drivers who are aware of the actual rest area spacing, and on the effectiveness of any "NEXT REST AREA X MILES" signing.

Examination of Figure 2 shows the following rest area locations which should be considered:

Downstream:	26N on I81
	3E on I64
Upstream:	22N on I81
	2E on I64 (Paved Parking Area Only)
	1E on I64 (Information Center)

The spatial relationships of these rest areas to the three proposed locations are shown in Figure 11. Examination of this figure shows the following:

- Locations 25N and 24N, in that order, will have the greatest effect in reducing demand at 26N.
- Location 25N is the only one that can have an effect on 3E, 2E and 1E.

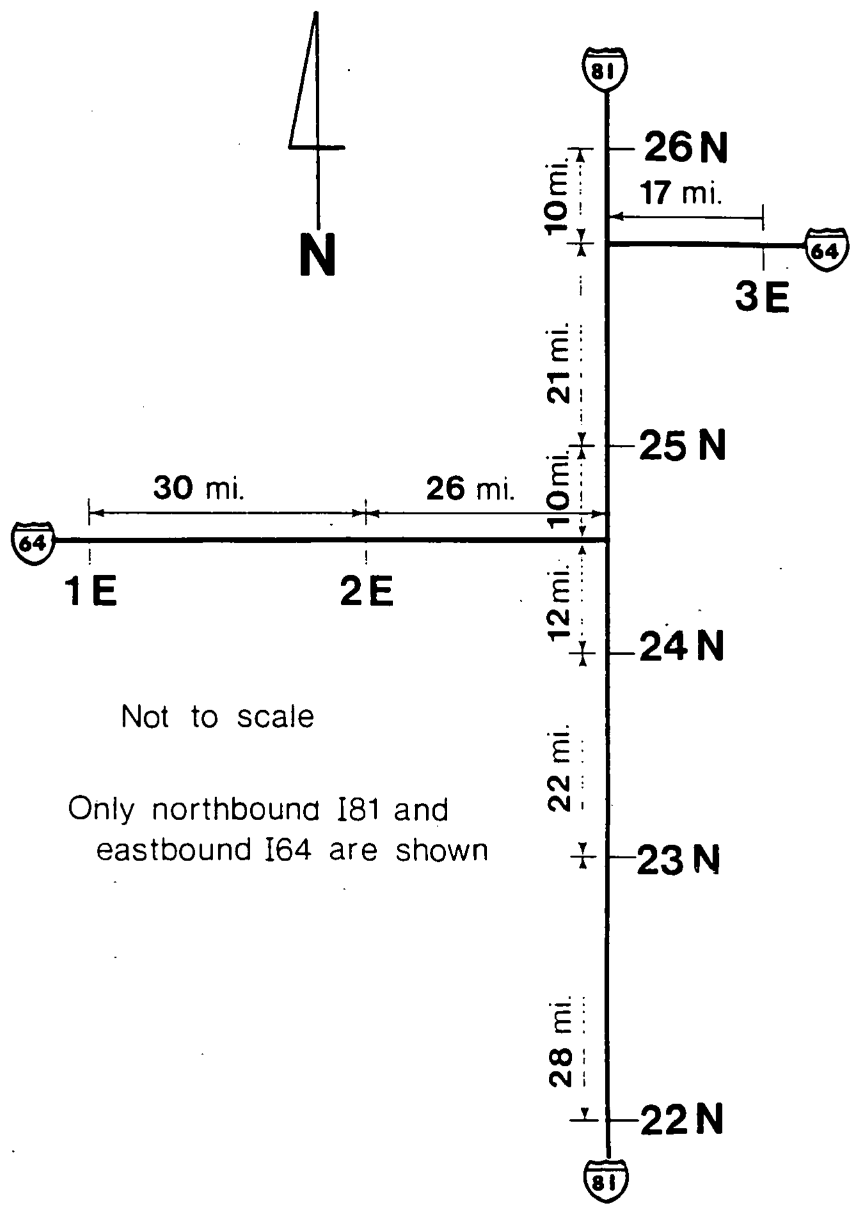

Figure 11. Existing and Proposed Rest Areas

- Locations 23N and 24N will have the greatest effect in reducing demand at 22N.

The assignments of systems consequence levels are based on these considerations.

7.7 SUMMARY

The preceding sections have discussed the rationale behind the assignment of individual consequence levels. The determination of the relative consequence level especially for those evaluated on a qualitative (ordinal) scale, requires experience, a detailed knowledge of the area, and an appreciation of the interaction of pertinent factors under different assumptions concerning conditions in the future.

In accordance with Section 3.3.4 of the Procedure Manual, two checks are to be made at the conclusion of this step in the analysis.

Weights: The steps in the analysis completed so far do not indicate any basis for changing the weights previously assigned.

Dominance: Detailed examination of Table 8 indicates that no alternative dominates any other.

8. EVALUATION OF UTILITIES

The conversion of the consequence levels to a common utility scale and the determination of the total utility of each alternative, is a four step procedure.

- Define reference outcomes
- Define transformation functions

- Compute utilities
- Sum utilities

Five of the six consequence types are evaluated in terms of qualitative scales. For each of these the best, or worst, outcome appearing in Table 8 has been selected as the "reference outcome" and assigned a numerical value of ±1.0. Furthermore, the semantic descriptors are assumed to form even interval step functions of five, seven or eleven steps respectively.

Costs are estimated in terms of a ratio scale which specifies the <u>relative</u> costs of each alternative. An even interval scale is appropriate with the largest numerical value selected as the reference outcome. These transformations functions are shown in Table 10. It should be noted that the scale for "safety" is a seven-step truncated version of the eleven step function shown in Table 7. It should also be noted that the rule that all ordinal (qualitative) scales must range from 0.00 to +1.00 results in the assignment of positive utility values to adverse outcomes.

The total utility for each alternative was computed by multiplying the transformed utility values by the associated weights and occurrence probabilities for each consequence-probability scenario and summing for all consequences. A sample calculation for alternative 3 (Rest Area Location 24N) is shown below

Table 10. Utility Transformation

Descriptor	Value	Descriptor	Value
SAFETY:		User/Systems	
Highly Adverse Effect	0.00	Extremely Adverse Effect	0.00
Adverse Effect	0.16	Highly Adverse Effect	0.10
Somewhat Adverse Effect	0.33	Adverse Effect	0.20
No Effect	0.50	Somewhat Adverse Effect	0.30
Somewhat Beneficial Effect	0.67	Slightly Adverse Effect	0.40
Beneficial Effect	0.83	No Effect	0.50
Highly Beneficial Effect	1.00	Slightly Beneficial Effect	0.60
		Somewhat Beneficial Effect	0.70
		Beneficial Effect	0.80
		Highly Beneficial Effect	0.90
		Extremely Beneficial Effect	1.00
Institutional		Economical & Social	
No Change	1.00	No Change	0.00
Slight Deterioration	0.75	Slight Improvement	0.25
Moderate Deterioration	0.50	Moderate Improvement	0.50
Significant Deterioration	0.25	Significant Improvement	0.75
Major Deterioration	0.00	Major Improvement	1.00

Total Utility = 29 x -1 x (0.56 x 0.05 + 0.58 x 0.35 + 0.64 x 0.50 + 0.68 x 0.10) +
12 x (1.00 x 0.05 + 1.00 x 0.35 + 1.00 x 0.50 + 0.83 x 0.10) +
23 x (0.90 x 0.05 + 0.90 x 0.35 + 0.90 x 0.50 + 0.80 x 0.10) +
15 x 0.25 + 12 x 0.75 + 9 x (0.90 x 0.05 + 0.80 x 0.35 + 0.70 x 0.50 + 0.60 x 0.10)
= 33.68

The results of all computations are shown in Table 11.

9. <u>ANALYSIS</u>

Table 10 shows that alternative 3, constructing a single rest area at location 24N, results in the highest total utility. Given the relatively large difference between this alternative and the next highest ranking one, alternative 6, construction of rest areas at locations 23N and 25N, additional analysis is not strictly required. However, such analyses were implemented for a number of reasons including:

- The desire to illustrate this aspect of the evaluation methodology.
- The fact that nearly the entire analysis depends on subjective inputs expressed as qualitative descriptors.
- The fact that implementation of 24N precludes the stage implementation of the second ranking, two rest area, alternative.

Table 11. Computation of Utilities

Consequence	Weight	Occurrence Probability	1 Do Nothing	2 23N	3 24N	4 25N	5 23N & 24N	6 23N & 25N
Cost	29	0.18	0.00	-0.61	-0.56	-0.56	-0.82	-0.82
		0.35	-0.20	-0.63	-0.58	-0.58	-0.85	-0.85
		0.50	-0.24	-0.69	-0.64	-0.64	-0.94	-0.94
		0.10	-0.27	-0.72	-0.68	-0.68	-1.00	-1.00
Safety	12	0.05	0.50	0.83	1.00	0.83	1.00	1.00
		0.35	0.33	0.83	1.00	0.83	1.00	1.00
		0.50	0.16	0.83	1.00	0.83	1.00	1.00
		0.10	0.00	0.67	0.83	0.67	1.00	1.00
User	23	0.05	0.50	0.70	0.90	0.80	0.90	1.00
		0.35	0.30	0.70	0.90	0.80	0.90	1.00
		0.50	0.20	0.70	0.90	0.80	0.90	1.00
		0.10	0.00	0.60	0.80	0.70	0.90	1.00
Institutional	15	1.00	1.00	0.50	0.25	0.25	0.00	0.00
Economic & Social	12	1.00	0.00	0.50	0.75	0.25	1.00	1.00
System	9	0.05	0.50	0.80	0.90	1.00	0.90	1.00
		0.35	0.30	0.70	0.80	0.90	0.80	1.00
		0.50	0.10	0.60	0.70	0.80	0.80	0.90
		0.10	0.00	0.60	0.60	0.70	0.70	0.80
Total Utility			18.03	25.58	33.68	24.25	25.49	29.01

* The fact that alternative 6 is the only other alternative whose computed total utility is higher than the average total utility for all six alternatives.

9.1 SENSITIVITY ANALYSIS

A sensitivity analysis in terms of weights was made to evaluate the effect of widening or narrowing the spread of the weight for the various consequences as follows:

The average weight for the six consequences is 16.7. The consequences were divided into two groups depending on whether their weight is above or below this average value. Group A consists of "cost" and "user" whose weights are higher than the average value. Group B contains the other four consequences whose weights are below the average weight. The weights were than systematically varied as follows:

(1) Raise Group A weights by 25 percent and lower Group B weights by 25 percent.

(2) Raise Group A weights by 10 percent and lower Group B weights by 10 percent.

(3) Lower Group A weights by 10 percent and raise Group B weights by 10 percent.

(4) Lower Group A weights by 25 percent and raise Group B weights by 25 percent.

(5) Set all weights equal to 100/6 = 16.7.

The recomputed weights were then normalized to sum to 100 and the computation of Table 11 repeated for each of the five scenarios.

The results of those analyses are shown in Table 12. Examination of this table shows that changing relative weights, within the limits selected, has only relatively minor effect on the rank ordering of the different alternatives but does affect the spread in total utilities. The ratio of total utility of alternative 3 (24N) to alternative 6 (23N + 25N) changes from 1.33 to 1.08. This point is emphasized by the last column of Table 12B which contains the values of total utility for each alternative computed under the assumption of equal weights. Under that assumption, the relative rank of these two alternatives is reversed.

9.2 COMPONENT ANALYSIS

A component analysis of the two top ranking alternatives, No. 3 (24N) and No. 6 (23N + 25N), was implemented in accordance with the procedures outlined in Section 5.2 of the RAAM Users Manual (Appendix A).

(1) Evaluate D_j, the weighted difference in utility for each consequence, j, across all occurrence probabilities where

$$D_j = W_j[\Sigma p_{jk}U_{3jk} - \Sigma p_{jk}U_{6jk}]$$

These values are shown below

Consequence	D_j
Cost	8.41
Safety	-0.20
User	-2.53
Institutional	3.75

Table 12. Sensitivity Analyses-Weights

A. Weight

Consequence	Sensitivity Analysis No. 1	2	3	4	5 Even
Cost	36 (+25)	32 (+10)	26 (-10)	22 (-25)	
Safety	9 (-25)	11 (-10)	13 (+10)	15 (+25)	
User	28 (+25)	25 (+10)	21 (-10)	18 (-25)	100/6=
Institutional	11 (-25)	13 (-10)	17 (+10)	19 (+25)	16.67
Economic & Social	9 (-25)	11 (-10)	13 (+10)	15 (+25)	
System	7 (-25)	8 (-10)	10 (+10)	11 (+25)	

Note: ( ) indicates approximate percent change in weights

B. Utility

	Alternative					
1.	Do Nothing	12.55	15.02	19.72	22.19	21.67
2.	23N	17.11	21.99	29.15	34.03	41.35
3.	24N	26.13	30.63	36.73	41.24	49.82
4.	25N	18.01	21.58	26.93	30.50	38.67
5.	23N + 24N	13.83	21.77	29.21	34.94	46.43
6.	23N + 25N	19.78	25.35	32.66	38.23	50.35

Economic & Social	-3.00
System	-1.76

(2) Define the threshold and eliminate consequences whose absolute value is less than

$$a = \frac{33.68 - 29.01}{6} = 0.78$$

where 33.68 and 29.01 are the total utilities of alternatives 3 and 6 respectively from Table 11.

(3) Rank order the remaining consequences

Consequence	D_j
Cost	8.41
Institution	3.75
Economic & Social	3.00
User	-2.53
Systems	-1.76

This rank ordering indicates that the higher ranking of alternative 3 (24N) is due to its lower costs. The four non-cost consequences, in aggregate favor alternative 6 (23N & 25N). The dominant influence of the weights assigned to the cost consequence category in the decision process was also demonstrated by the sensitivity studies. Table 12 indicates a virtual tie between the alternatives when the effect of the large weight assigned to costs is eliminated from the analysis.

9.3 COST-UTILITY ANALYSIS

In view of the dominant role of the cost element a cost-utility analysis was made. Since costs are on a ratio scale and not on an interval scale, costs were recomputed in relative terms as the ratio of the cost of each alternative to the highest cost alternative. The total utility for each alternative was recomputed after re-normalizing weights so that the weights for all non-cost consequences summed to 100. The results of this analysis are shown below.

Alternative	Relative Costs	Utility
1. (Do Nothing)	0.25	34.45
2. (23N)	0.73	63.30
3. (24N)	0.68	72.75
4. (25N)	0.68	59.47
5. (23N & 24N)	1.00	72.23
6. (23N & 25N)	1.00	78.09

Alternatives 4 (25N), 2 (23N) and 5 (23N & 24N) are all dominated by alternative 24N which yields a higher total utility at a lower or equal cost.

10. RECOMMENDATIONS

The results of the case study evaluation as shown in Table 11 indicate that, on the basis of the consequence categories selected for analysis and on the basis of the assessments made, the construction of a single rest area at location 24N is preferred to the other alternatives considered. This recommendation is further strengthened by the three separate analyses summarized in Section

9 given that there are no major changes in the relative weights assigned to the different consequence categories. Downgrading "costs" relative to the other consequence categories would make Alternative 6, the construction of rest areas at locations 23N and 25N, more viable.

The evaluation was limited to a single, uniform time frame. That is, the rest areas for all alternatives were assumed to open concurrently and to remain in operation continuously for the entire analysis period. The option of stage construction of alternatives 5 and 6, the construction of two rest areas each, was not considered.

A stage construction scheme consisting of implementing rest area 23N immediately and adding rest area 23N after eight years can be expected to have a total non-cost utility of approximately 72.17 (i.e., (63.30 x 8 + 78.09 x 12)/20) equal to that of alternative 3 (24N).

Cost estimates for such a staged construction alternative are somewhat more difficult since these costs must be evaluated over different time periods. The necessary computations are shown below using standard engineering economy techniques and an equivalent interest rate of 7.5 percent.

Present Value of costs of 23N for 20 years	11.85C
Present Value of costs of 25N for 12 years starting in year 9	4.72C
Less Present Value of remaining useful life of 25N at end of 20 years	0.09C

Present Value of stage construction alternative 16.48C

The Uniform Annual Costs corresponding to this Present Value are 1.62C leading to a relative cost, as discussed in Section 9.3, of 0.70.

A cost-utility comparison thus yields the following:

	Relative Costs	Utility
Alternative 3	0.68	72.75
Staged Implementation of Alternative 6	0.70	72.17

Given the accuracy and resolution of the computations used in these analyses, there are no significant differences between these values.

The recommendation of the case study is, therefore, to implement one of the following two alternatives:

- Construct a rest area at location 24N now.
- Construct a rest area at location 23N now together with a firm commitment to construct another rest area at location 25N at the end of eight years.

Whether such a commitment can be made, and kept, given the applicable administrative and political environment, must be decided on a higher administrative level.

APPENDIX C

SAFETY BENEFIT ANALYSIS CALCULATIONS

This appendix contains the detailed derivations and calculations to estimate the safety benefits of highway rest areas arising from reductions in shoulder stops.

(1) Hauer (1), analyzed all available data and arrived at the following estimate (1981 data) for accidents involving vehicles stopped on the shoulder on the rural interstate system:

Accident Severity	Number	Rate (MVM)
Fatal	309	2.22×10^{-3}
Non-Fatal Injury	4898	3.53×10^{-2}
Property Damage Only	6938	5.00×10^{-2}
All	12145	8.75×10^{-2}

The striking fact about these data is the apparently high average severity of shoulder stop accidents. The ratio for the three accident severities is 1:16:22. The most commonly quoted value for this ratio is based on data assembled by the National Safety Council (2). These ratios are:

1:28:453 for all accidents, and

1: 8:182 for rural Interstate system accidents.

NSC data are, however, not directly comparable since these data lump non-disabling injuries with property damage. An examination of published state accident data shows for those states which disaggregate data to the required extent, the following values for the fatal:injury:PDC ratio for rural interstate accidents:

Illinois	1:26:57
Nebraska	1:27:51
North Carolina	1:20:27
North Dakota	1:24:65
Oregon	1:22:21
South Carolina	1:11:72
Wisconsin	1:46:126
7 States	1:21:53

The differences in the proportion of accidents recorded on Property Damage only is undoubtedly due to differences in reporting thresholds between the states. Hauer's data are corroborated by data from Virginia which reports a 1:16:24 ratio for accidents involving parked vehicles on Interstate routes as compared with 1:48:83 for all (rural and urban) accidents on these routes.

(2) The same study, synthesizing six different data bases, arrived at the following estimate for shoulder stop frequency:

Stops per Million Vehicle Miles

Vehicle Type	Emergency	Leisure	Total
Passenger Cars	74	555	629
Trucks	192	1000	1192

Due to the considerable spread in the available data, Hauer states that "... there is considerable doubt about the miles per stop estimate". There is, however, some corroborative evidence available from the current study. The telephone survey (made as part of the current study) yielded the following data:

Median distance between discretionary stops on long trips not constrained by the availability of gasoline or other services — 100 miles

Proportion of all respondents who prefer a

shoulder stop to other alternatives 5.4 percent

These two figures jointly indicate that a discretionary (leisure) shoulder stop will be made approximately every 1850 miles resulting in 541 leisure shoulder stops per million vehicle miles, an almost exact match with Hauer's estimate.

(3) The number of shoulder stops prevented by highway rest areas can be estimated from the responses to both surveys. Based on these responses, the proportion of drivers who would make a shoulder stop if the rest area were not available is as follows (recomputed to eliminate "don't know" answers):

Interview Data -	Passenger Cars	11.2 percent
	Trucks & RVs	22.9 percent
	All	12.8 percent
Telephone Survey Data		14.7 percent

Somewhat greater weight will be given to the rest area data, mainly because these respondents had recently been exposed to signing, standard in most states, to the effect that shoulder stops are only permitted in emergency (MUTCD Standard Signs R8-4 and R8-7). The figures which will be used in further calculations are:

Passenger Cars	12.5 percent
Trucks and RVs	22.9 percent

(4) The average proportions of the total main line traffic stream that will enter a rest area can be approximated, on the basis of available data, as:

Passenger Cars	10 percent
Trucks and RVs	15 percent

(5) The potential shoulder stops that are prevented by the rest area would, presumably, occur at some point between the rest area and the next downstream rest area. The national average Interstate rest area spacing is 44 miles.

(6) The proportion of the traffic stream that will <u>not</u> stop on the shoulder is given by:

Proportion entering rest area x Proportion would stop on the shoulder

Passenger Cars: 0.1 x 0.125 = 0.0125

Trucks and RVs" 0.15 x 0.229 = 0.0344

(7) Based on the proportions computed in (6), the rate for prevented shoulder stops, given a 44 mile average rest area spacing is:

Passenger Cars: $0.0125 \times 10^6/44$ = 284 per million vehicle miles

Trucks and RVs: $0.0344 \times 10^6/44$ = 782 per million vehicle miles

(8) Therefore, if rest areas were <u>not</u> available discretionary shoulder stops could increase by the following percentages:

Passenger Cars: 284/555 = 51 percent

Trucks and RVs: 782/1000 = 78 percent

(9) It has been postulated that rest areas may also prevent forced (emergency) shoulder stops (most of which are due to vehicle failure) by offering an opportunity of detecting incipient vehicle failure. Little data on this point is available. It may be

assumed that at least 10 percent of all rest area users who checked their vehicle, or its load, during a rest area stop thereby avoided a subsequent emergency shoulder stop. The percentages of rest area users are (see Table 7 of the main report):

Passenger Cars	8.9 percent
Trucks and RVs	18.0 percent

(10) Based on these assumptions and using the same procedures as before, the proportional increase in forced (emergency) stops prevented by rest areas is given by:

Proportion Entering Rest Area x Proportion Checking Vehicle or Load x 0.1 (from assumption in (9)) x $10^6/44$ x 1/Number of Emergency Stops

Passenger Cars: $0.1 \times 0.089 \times 0.1 \times 10^6/44 \times 1/74 = 0.27$

Trucks and RVs: $0.15 \times 0.18 \times 0.1 \times 10^6/44 \times 1/192 = 0.32$

(11) The total percentage increase in shoulder stops that would occur if rest areas were not available is then given by the weighted sum of the proportions in (8) and (10):

Passenger Cars: $100 \times 0.51 \times 555 + 0.27 \times 74)/(555 + 74)$

$= 48$ percent

Trucks and RVs: $100 \times (0.78 \times 1000 + 0.32 \times 192)/(1000 + 192$

$= 71$ percent

(12) For 1987, the last full year for which disaggregate data are available, vehicle miles of travel for the rural interstate system were as follows (3):

Passenger Cars and 2-axle-4-Tire Trucks	138558×10^6	80.9%
All other trucks	32812×10^6	19.1%
All vehicles except buses	171370×10^6	100.0%

(13) Using the data on disaggregated VMT in (12) to weight the percentages in (11) the best estimate of the total increase in shoulder stops prevented by rest areas is:

$48 \times .809 + 71 \times .191 \approx 52$ percent

(14) It is reasonable to assume that a 52 percent increase in shoulder stops frequency would produce a 52 percent increase in accidents involving vehicles on shoulders. Applying this percentage increase to the accident rates cited in (1) and to the VMT data cited in (12) yields the following estimates for shoulder stop accidents prevented by rest areas:

Fatal Accidents	$2.22 \times 10^{-3} \times 171,370 \times 0.52 = 198$
Non-Fatal Injury Accidents	$3.53 \times 10^{-2} \times 171,370 \times 0.52 = 3,146$
Property Damage Only Accidents	$5.00 \times 10^{-2} \times 171,370 \times 0.52 = 4,456$
Total Accidents	$8.75 \times 10^{-2} \times 171,370 \times 0.52 = 7,797$

REFERENCES

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