MULTIMODAL INVESTMENT CHOICE ANALYSIS

VOLUME I: PHASE I

by

Rhonda Young   Jennifer Barnes
Graduate Research Assistant   Graduate Research Assistant

G. Scott Rutherford
Professor and Chair
Department of Civil and Environmental Engineering
University of Washington, Box 352700
Seattle, Washington 98195

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

Washington State Department of Transportation
Technical Monitor
Charles Howard, Director
Planning and Policy Office

Prepared for

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

June 2002

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 547.1	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE MULTIMODAL INVESTMENT CHOICE ANALYSIS Volume I: Phase I		5. REPORT DATE June 2002	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Rhonda Young, Jennifer Barnes, G. Scott Rutherford		8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO.	
		11. CONTRACT OR GRANT NO. Agreement T1803, Task 36	
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370 Project Manager: Doug Brodin, (360) 705-7972		13. TYPE OF REPORT AND PERIOD COVERED Final research report	
		14. SPONSORING AGENCY CODE	

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

The Multimodal Investment Choice Analysis (MICA) project is developing a computer-based tool to assist the Washington State Department of Transportation (WSDOT), the Washington State Transportation Commission, and the Washington State Legislature in making state transportation funding decisions.

The function of MICA is to summarize the multimodal budgetary tradeoffs that will result from varying funding allocation and priority scenarios. MICA's methodology is based on benefit-cost and goal achievement analyses.

The project has completed the first phase of research. The purpose of this two-volume report is to document the analysis methodology contained within the MICA program, as well as general findings from the first phase of this research effort. This document is also designed to serve as a User's Manual for operating the MICA program. While challenges still exist, the results of the Phase I research effort indicate that development of a multimodal analysis tool is feasible.

17. KEY WORDS Statewide programming, prioritization, multimodal	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616		
19. SECURITY CLASSIF. (of this report) None	20. SECURITY CLASSIF. (of this page) None	21. NO. OF PAGES	22. PRICE

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Acknowledgment

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How to Use This Document

The following document serves two primary purposes. The first purpose is to document an extensive research effort by the University of Washington on the development of a methodology for multimodal project analysis. The document's second purpose is to serve as a User's Manual for the prototype computer program that was developed through this research effort.

Chapters 1 and 2 focus on the research effort and the overall analysis methodology. Chapter 3 describes the general operation of the program. The document is then divided by transportation mode into Chapters 4 through 12. These chapters provide background into the existing analysis methodologies and project types as well as in-depth information of the assumptions and calculations contained in the program. Future research work in each of these modal areas is also discussed. Chapter 13 describes the optimization programming that selects the project lists for funding. The document concludes in Chapter 14 with the lessons learned through this research effort and outlines the next steps in the research effort.

The Appendices of the report provide additional background into the research effort. Volume II, Program Code, provides the actual code contained in the program.

Executive Summary

Introduction

The Multimodal Investment Choice Analysis (MICA) project is a Washington State Department of Transportation (WSDOT) research project being done at the University of Washington. Launched in 1999, MICA is a computer-based tool being developed to assist WSDOT, the Washington State Transportation Commission, the Governor's Office and the Washington State Legislature when making state transportation funding decisions. The function of MICA is to summarize the multimodal budgetary choices that will result from varying funding allocation and priority scenarios. MICA's methodology is based upon a combination of benefit-cost and goal achievement analyses.

Below is a summary of the full scope of this project.

Completed Work

- Assess the state-of-the-practice in statewide multimodal investment choice procedures

- Assess the most appropriate methods for performing multimodal investment choice analysis

- Describe in detail a proposed process for analysis

- Develop and document methods to apply multimodal investment choice analysis for seven modal/program divisions

- Create prototype program

Future Work

- Refine modal/program division methodologies

- Apply the multimodal investment choice analysis methods to next biennium project lists

- Assess how well the process works

- Move the MICA program from an Access database to a web based format

- Work with modal/program divisions to collect the additional data to further refine the analysis methodology

State-of-the-Practice

The initial project task was to survey State Departments of Transportation (DOTs) in order to assess the state-of-the-practice in multimodal transportation planning and to utilize as much existing work as possible. This survey was implemented in 1999. The survey results showed that although some states are interested in multimodal analysis, none had discovered tools they could use to perform such analysis (2, 3). A few states reported that they were in the early stages of

developing an analysis tool. Other states responded that they were uninterested in a multimodal analysis tool for three primary reasons:

- State DOT deals primarily with highway projects and very few modal tradeoff opportunities exist.

- The state governing body (such as a Transportation Commission) makes subjective decisions based on available data.

- Multimodal planning responsibilities are shifted to metropolitan planning organizations.

In 2000, a NCHRP report looked extensively at the progress of multimodal planning. This report concluded that there is considerable work being done on the analysis tools that make multimodal tradeoffs possible but there are institutional obstacles to implementation. These institutional obstacles include funding restrictions and fragmented departmental structures.

The results of this review indicated that MICA's objective of developing a working program to perform multimodal evaluation of actual Washington State projects was unique among both current practice and research efforts in this field.

Inventory of WSDOT Analysis Methods

The next major task in the MICA project was to inventory the current analysis methods and available data within WSDOT. The intention was for MICA to utilize existing WSDOT methodologies as much possible, and this step provided the starting point for achieving that goal. Additionally, the inventory of current methods provided the basis for identification of data and analysis gaps among the individual modal divisions.

The inventory was completed for each of the program divisions that were to be included in the initial launch of MICA. The Mode Categories included in MICA represent either actual modal divisions within WSDOT (Ferry, Highway, Rail, Non-Motorized, and Transit) or unique project types that may involve several modes but have similar project level analysis methods (Intelligent Transportation Systems, Travel Demand Management).

The information found was summarized in matrix form (found in Appendix A), allowing researchers to readily see the range of assumptions, data availability, and impact methodologies. One overall result of this task was the realization that there was more information available than previously thought. In addition, the matrix showed where research efforts should be focused. Another interesting result of the matrix was the variability of the values of certain assumptions such as discount rate and value of time.

A major benefit that emerged from this process is that it involved the WSDOT staff people in the project from the outset. The success of MICA is highly dependent on the cooperation of the managers and analysts within the WSDOT divisions. Additionally, ongoing collaboration with the WSDOT divisions should help foster a more widespread acceptance of the final product.

MICA Program Structure

MICA is being developed as a database program. Ultimately the goal is to transfer the program to a web-based format, which will ease the administration of program updates, and allow users have uniform access to the centralized program and project lists. The program is also being developed to be compatible with the Geographical Information System (GIS) used by WSDOT. Future

versions of MICA will utilize this compatibility to create a graphical interface and display of projects. The overall structure of the program is the same regardless of the computer program platform. The program can be broken into three main components:

1.   Global assumptions

2.   Project level analysis

3.   Scenario level analysis

These components are described in the following sections.

Global Assumptions

Global assumptions are those variables that must be the same for evaluation of all project types, in order to ensure that projects across all modes are analyzed on an equal basis. Typical global assumptions include discount rate, value of in-vehicle time, accident rates by mode or highway classification, and societal costs of various types of accidents. Global assumptions such as these are directly used at the project analysis level for estimation of the project impacts and the calculation of cost-effectiveness measures. Any changes in the global variables results in the recalculation of impacts for all projects, using the new values. Global variable definition also impacts scenario level analysis, since the values of the assumptions can have significant effect on the relative values of the measures for projects being compared.

The default values for the global assumptions are primarily based on policy decisions within the Department of Transportation. Most values incorporated into the current version of the MICA program have long been established at WSDOT. However, the MICA platform provides some advantages with respect to the definition of these variables. First, since they are consistently defined and clearly presented, users can readily view the assumptions on which analysis results are based. Second, updates of the global assumption values can easily be adopted since once they are changed in MICA, analyses of all projects in the database are automatically updated to reflect those changes. Finally, while policy dictates that these global assumption values not be changed frivolously, MICA provides a structure that lends itself to sensitivity analysis of these variables. One can easily test how changing the value of an assumption will impact project level and scenario level results. These impacts can be used as the basis to affect a policy change in global variable definition, or reconfirm the validity of an established value.

Project Level Analysis

The project level analysis methodology is created around the concept of "building blocks" or uniform measures. While the different analysis methods are unique to the project or program type, the output from the analysis is standardized. Each project building block contains monetary and non-monetary impact estimates, project costs, cost-effectiveness measures, and seventeen outcome objective scores. These measures are described in the following sections.

Monetary Measures

Benefit, cost, and cost-efficiency measures are calculated for each project. Three main categories are considered for estimation of monetary benefits. First, **user operating impacts** include changes in user travel time and user costs (such as vehicle operating costs and/or user fares) that are estimated to result from the proposed project. Second, **environmental impacts** include (1) changes in vehicle emissions that are estimated to result from the proposed project, and (2) the benefits that result from specific environmental retrofit projects that are common at WSDOT.

This category may include additional impacts in later versions. Finally, **safety impacts** consist of the increase or decrease in societal cost of accidents that is estimated to result from a proposed project.

Monetary benefits can be either positive or negative. For example, a highway project that increases capacity may allow vehicles to travel faster, resulting in a positive benefit of travel time savings. However, increased traffic that results from that project will have higher emissions, resulting in a negative value for environmental impacts. Additionally, monetary impacts may be direct or indirect. The highway example just cited illustrates impacts that would directly result from a proposed highway improvement. However, a common approach for modes that are alternative to highway is to estimate the impacts on highways that would result if the alternative did not exist. For example, an improvement to freight rail may allow freight that would otherwise be carried by truck to be carried by rail. In addition to possible direct impacts on rail travel, the project may indirectly benefit highways by taking trucks off of the road.

For certain modes or project types, some impacts within the building block categories are considered negligible. In these instances the impacts are programmed to default to zero. For other modes or project types, certain impacts could not be assumed to be negligible, but methodologies for estimating them did not previously exist. In these cases, simplified methods or assumptions that would yield reasonable results have been employed until more detailed techniques can be developed (and the need for the more detailed technique is documented as a long term analysis gap).

By employing the concepts of positive or negative impacts, direct or indirect impacts, and negligible or significant impacts, widely varying analysis methods that are unique to each project type result in a common set of project impact measures that make up the building block components.

The cost categories include **capital**, **operation and maintenance**, and **environmental retrofit costs**. Costs are also itemized as WSDOT costs, local or private share costs, and federal share costs. Once the net present values of benefit and cost measures are calculated, they are used to compute cost-efficiency measures such as benefit-cost ratio.

Non-Monetary Measures
The User Operating, Environmental, and Safety Impacts are additionally calculated in non-monetary terms so that cumulative estimates such as total change in number of fatal accidents or carbon monoxide emissions can be included in the scenario level analysis.

Outcome Objectives represent the seventeen outcome areas that were developed as part of the Washington Transportation Plan (WTP) update by the WSDOT Planning Office. The WTP Policy Framework reflects WSDOT's move toward performance-based planning, and is presented as a four-tiered framework. The first tier is the overall Vision that includes three subcategories: Communities, Economic Development, and Environment. The next tier consists of Outcome Areas that are statewide and multimodal. Service objectives make up the third tier. Each service objective is a specified "measurable target" and is associated with a specific outcome area. The final tier consists of Action Strategies, which are methods for reaching the particular service objectives.

The MICA program contains Outcome Objective worksheets with questions that correspond to the service objectives that have been identified for the seventeen Outcome Areas. Scores are calculated for each of the seventeen areas based on the responses to the questions with possible scores between 0 and 100, with 100 being the best score. Future research work involves incorporating values from the project input forms and calculations to refine the outcome objective

score and to better differentiate between projects. The Outcome Objective measures represent the goal achievement portion of MICA. This component allows the decision-maker to identify projects for funding that have attributes that are hard to capture in the benefit-cost analysis but nevertheless represent WSDOT goals.

Scenario Level Analysis

Monetary and non-monetary data from the project level is standardized into its building block components and passes to the Scenario Level Analysis portion of the program. It is the scenario analysis function that allows for multimodal tradeoffs between different budget and priority scenarios. Although the impact estimation methodology varies between different modes and programs, the outputs are in standardized form, allowing for cross-modal comparisons. The Scenario Level Analysis input consists of:

- Standardized output from the building blocks of the project level analysis

- Additional user inputs required to create funding scenarios

Once project level analysis has been completed for all projects that are to be included in the evaluation, the following steps are required to create a scenario:

The user selects the projects that should be considered for the particular scenario. Since project level analysis is complete, building block measures based on a uniform set of global assumptions will have been calculated for all projects on the list. The user has the additional options of selecting projects only of a specific mode and/or from a specified geographic region. In addition the user can further specify minimum threshold values for the building block variables. For example, the user may only want to consider only highway projects that have positive environmental benefits for a particular region of the state.

The user supplies a budget level. The budget may be either completely unconstrained or allotted by region and/or by program.

The user selects prioritization categories, as well as the relative weights of the selected categories (i.e. benefit cost ratio at 65 percent and tourism outcome objective scores at 35 percent). The user may also modify the project list to specifically include or exclude particular projects if desired.

All of these inputs are identified in the individual scenario reports.

The user can create multiple scenarios to test budgetary tradeoffs across modes and programs. Once multiple scenarios have been created, the program provides a mechanism by which these scenarios can be compared. The scenario comparison allows for the user to examine the relative consequences of varying budget levels and spending priorities. For example, by running two scenarios with identical priorities but different budget levels the user can see what the additional money "buys" in terms of minutes of travel time savings, vehicle emissions, and accident savings. By utilizing the outcome objective scores, the user can prioritize spending on projects that may not be the most cost-effective in terms of traditional benefit-cost values, but that may address a particular WSDOT concern. By running this type of scenario against one in which benefit-cost ratios are prioritized, the user can see the relative differences in both monetary and non-monetary terms.

The foundation of the scenario analysis is that there is no "right" answer. Changes in priorities yield different project lists. The idea behind MICA is that there is not one absolute list of projects that should be funded, but instead the program is designed to provide data to aid the decision-

makers in making tradeoff decisions. The program has the additional advantage that priority definitions are explicitly presented along with analysis results.

Future Work

From the beginning, the MICA project has progressed with full realization that the obstacles and analysis gaps that arise are an inherent component of multimodal analysis research. Rather than allowing these impediments to stall the progress of the project, the philosophy behind MICA has been to clearly identify them and move on. In the case of some analysis gaps, simplified methods or assumptions that would yield reasonable results have been employed until more detailed techniques can be developed.

The future research work for the MICA project are broken down into three categories; improvements to the modal analysis, improvements to the optimization process, and general program improvements.

Improvements to Modal Analysis

Long and short term analysis gaps have been identified and discussed in each of the modal chapters. They have been compiled and summarized into the list below.

Ferry System

- Refine the use of WSF's travel demand results.

- Determine if ferry boat emissions and accident rates are negligible. Add to calculations if found to be significant.

- Add calculations into code to handle isolated island route calculations.

- Refine the modeling of trip-making behavior during long-term service disruptions.

- Investigate whether a non-linear relationship would be more appropriate for modeling the probability of service failure of vessels and terminals based on condition ratings.

- Incorporate available information on freight travel.

Highway Improvements

- Add induced demand calculations.

- Consider changes in pollution emissions.

Highway Preservation

- Work with WSDOT pavement group regarding the use of the HDM-4 program for P1 project analysis.

- Work with WSDOT structures group to incorporate output from Bridge Maintenance System.

- Add safety component to P1 analysis if affects found to be significant.

Multimodal Investment Choice Analysis

- Look at the affects of roughness on freight cargo and quantify freight benefit is affects found to be significant.

- Consider the addition of P3 projects.

Highway Safety

- Add five additional safety project types not currently included.

- Investigate the relationship between highway improvement and highway safety projects to determine if the separation of project types within the program is necessary.

Intelligent Transportation System

- Update the IDAS program database to reflect the regional instead of national estimates of ITS project impacts.

- Compare the analysis results of projects analyzed in IDAS and in SCRITS and modify or adjust as necessary so that analysis is consistent across project type.

Non-Motorized

- Investigate the safety impacts of shoulder improvements for rural bicycle touring.

- Obtain better localized data on the affects of improving bicycle routes on automobile travel.

Rail

- Continued refinement of all rail project analysis methodology to reflect the planning level of project analysis.

Transit

- Incorporate SPASM calculations directly into MICA.

- Derive regional numbers for transit impacts to improve estimation methodology.

Transportation Demand Management

- Refine CTR survey questions to better isolate travel behavior factors.

- Areawide TDM projects need to have more detailed information and the analysis methodology improved to utilize this additional information.

Improvements to the Optimization Process

Further study on the optimization process within MICA will involve more sensitivity analysis with larger project lists, particularly in the area of criteria weighting. As the project lists gets lengthy, computational efficiency will become more of an issue and it may be a useful exercise to study

the efficiency of different formulations. Theoretically, the final formulation achieved through this research effort and discussed in the previous section does not limit the number of projects.

As mentioned earlier, it would be important to model the preferences of the decision makers through the use of a Delphi analysis, Analytic Hierarchy Process, or Conjoint Analysis in order to derive suitable weights for the funding scenarios under consideration. From the results of this additional analysis, the sensitivity of the program to changes in these weights would provide valuable insight.

Through the use of MICA by DOT officials additional functionality may be necessary to address unforeseen issues.

General Program Improvements

Also should be noted that additional efforts will be necessary to move the program from its prototype phase into a implemented, multi-user program. The prototype version of the program is designed to serve two crucial purposes. The first is to test the analysis methodologies and to ensure that the projects are being compared accurately and fairly. The second purpose is to serve as a starting point for discussions on the user-interface of the program. During the prototype phase it is important that the future users of the program determine what features work well, don't work well, or are missing from the program so that the final version of the program serves all potential users.

The prototype program's architecture within the Microsoft Access software platform does not easily lend itself to a multi-user environment. The ability for multiple users to access the program and project lists is extremely important for a program such as MICA that has been developed to bridge the program divisions of WSDOT. Users must be able to have access to the latest project lists and global variable settings to ensure that equivalent analyses are being performed. The Access platform was selected by the research team because of its widespread use and ease of programming. The majority of the research work involved the program code and methodologies behind project and scenario analyses which is directly transferable to other software platforms. Future work will involve moving the program to a web-based or network database structure such that all users have access to the same information. Most likely the user interface portion of the program will be web-based with the data being stored on central network computers.

In addition to user interface and program architecture changes there is another area where additional programming work will be necessary. This involves how the program deals with the different modal divisions. Currently the program is structured to be modally discrete, that is, that project types are associated with one particular mode. Ideally future versions of the program would allow project types to be associated with more then one mode or for composite projects to be created. An example would be Intelligent Transportation System projects. Instead of being a separate mode it might be more useful for it to be associated with multiple modes such as highway or transit projects. An example of composite projects would be a highway capacity improvement that also involved a Transportation Demand Management component.

Chapter 1 - Introduction

The Multimodal Investment Choice Analysis (MICA) project is a computer-based tool developed to assist the Washington State Department of Transportation (WSDOT), the Washington State Transportation Commission, the Governor's Office and the Washington State Legislature when making state transportation funding decisions. The function of MICA is to summarize the multimodal budgetary choices that will result from varying funding allocation and priority scenarios. MICA's methodology is based upon a combination of benefit-cost and goal achievement analyses.

Background

The State of Washington has been grappling with transportation funding tradeoff issues for many years. Limited available revenue for transportation projects results in two major categories of funding competition:

1. Competition between different transportation modes

2. Competition between geographic regions within the state – particularly between urban and rural areas

The traditional solution has been for the Legislature to allocate the transportation budget so that all of the different modal divisions receive some share of the available funding. Then it is up to each division to determine the specific projects that should proceed, addressing geographic equity and based upon the actual funding they receive. However, Washington State decision makers would prefer to be able to take a more integrated approach to these funding decisions, which is the primary motivation behind the MICA project.

Successful development of an integrated multimodal analysis method requires that some significant obstacles be overcome. These include:

*   Analysis methods utilized by the different modal divisions are not consistent with each other.

*   Data needed for analysis is more readily available for some modes than for others.

*   Each modal division tends to define benefits in a way that focuses on that mode's particular strengths. When determining measures to be applied across all modes, the definition of what constitutes a benefit may implicitly favor some modes over others.

Even if a multimodal analysis method is developed that addresses these obstacles, the equity issues are still quite relevant. Thus, the approach must remain flexible enough to accommodate the political realities of the budget allocation process.

In 1990, the Capital Construction Program division of WSDOT initiated a project with University of Washington researchers to overhaul the process they use to evaluate highway projects being considered for funding. This project resulted in the Mobility Project Prioritization Process (MPPP). The MPPP utilizes a spreadsheet program to evaluate the benefit-cost of highway capacity improvements, as well as non-monetary measures that are not included in the benefit-cost calculations. The benefit-cost analysis accounts for 65 percent of the project score with the remaining 35 percent coming from the non-monetary criteria (Reed et al. 1995).

Though only developed for highway capacity improvement projects, the MPPP provided a starting point for the more broad-sweeping MICA project, in that MICA incorporates the MPPP's highway

benefit-cost methodology. MICA also incorporates non-monetary measures into the evaluation process through the use of outcome objective scores. Although they do share some similarities, MICA's outcome objectives represent a broader set of criteria than the non-monetary measures used in the MPPP.

The MICA project was coordinated with the National Cooperative Highway Research Program (NCHRP) Project 8-36, Task 7. The goal of the NCHRP 8-36, Task 7 project was to develop a framework for undertaking multimodal tradeoff analysis as well as preparing several case applications of the framework. Ideally this work would have preceded the MICA project but the timelines of the two projects required that they proceed in parallel. Periodic updates of the MICA project were given to the NCHRP 8-36 (7) expert panel as work on the two projects progressed.

Prior to the development of the MICA program, two major tasks were completed:

1. Conduct of a literature review and survey State Departments of Transportation to assess the state-of-the-practice.

2. Inventory and assess the current analysis methods used by different modal divisions within WSDOT.

The results of these tasks are summarized in the following sections.

State-of-the-Practice

In 1999, State Departments of Transportation (DOTs) were surveyed in order to assess the state-of-the-practice in multimodal transportation planning. The survey results showed that although some states are interested in multimodal analysis, none had discovered tools they could use to perform such analysis (Rutherford and Shafizadeh 1999, Rutherford and Young 2000). A few states reported that they were in the early stages of developing an analysis tool. Other states responded that they were uninterested in a multimodal analysis tool for three primary reasons:

- State DOT deals primarily with highway projects and very few modal tradeoff opportunities exist.

- A state governing body (such as a Transportation Commission) makes subjective decisions based on available data.

- Multimodal planning responsibilities belong to a metropolitan planning organization (MPO) rather than the state DOT.

In 2000, a NCHRP report prepared by Henry Peyrebrune looked extensively at the progress of multimodal planning (Peyrebrune 2000). This report concluded that there is considerable work being done on the analysis tools that make multimodal tradeoffs possible but there are institutional obstacles to implementation. These institutional obstacles include funding restrictions and fragmented departmental structures.

The results of this review indicated that MICA's objective of developing a working program to perform multimodal evaluation of actual Washington State projects was unique within current practice as well as within research efforts in the field.

Inventory of Existing WSDOT Analysis Methods

Existing analysis methods and available data within each of the modal programs at WSDOT were inventoried, with the intent that MICA would utilize existing WSDOT methodologies as much as

possible. Additionally, the inventory of current methods provided the basis for identification of data and analysis gaps among the individual modal divisions.

The inventory was completed for each of the program divisions that were to be included in the initial launch of MICA. Table 1-1 summarizes these program divisions and the program types that are included in each division. All modes and project types shown in this table were subsequently included in the MICA program. The Mode Categories shown in the table represent either actual modal divisions within WSDOT [Ferry, Highway, Rail, Non-Motorized, and Transit] or unique project types that may involve several modes but have similar project level analysis methods [Intelligent Transportation Systems (ITS), Travel Demand Management (TDM)].

The information found was summarized in matrix form, allowing researchers to readily see the range of assumptions, data availability, and impact methodologies (See Appendix A). The matrix illustrated wide variability in the values used for certain assumptions, such as discount rate and value of time. This provided the starting point for determining standard values for the variables that would need to be uniform for evaluation across modes (identified as "global variables"), as well as providing a basis for those determinations. In addition, the matrix showed the areas in which further research would be required to establish consistent evaluation procedures among the different programs. Overall, however, completion of this task indicated more information available than was originally speculated.

Completion of the inventory of WSDOT projects and procedures provided the critical foundation needed to begin development of the MICA procedures. Namely, it allowed:

- Identification of specific program areas and project types to be included in MICA

- Identification of uniform project measures to be calculated across programs and modes

- Assessment of the adequacy and gaps in existing procedures to calculate uniform measures within programs and modes

- Identification of global variables that would need to be consistent for evaluation across programs and modes

With this information in place, the structure of the MICA program was designed, and an integrated series of analysis procedures were developed.

MICA Program Structure

MICA has been developed as a database program. Figure 1-1 illustrates the overall structure of the program, which consists of three major components:

1. **Project level analysis** – Calculates impacts of individual projects.

2. **Scenario level analysis** – Calculates the combination of projects that best meets the priorities defined by the user.

3. **Scenario comparison analysis** – Illustrates a side-by-side comparison of the calculated measures of two or more scenarios.

The remainder of this chapter will provide an overview of the inputs, analyses and outputs that are included within each of these components of the MICA program.

Table 1-1: Summary of WSDOT Mode Categories and Project Types

Mode Category	Sub-Category	Project Types	Utilizes Current WSDOT Analysis Method?
Ferry	Preservation	- Vessel Preservation - Terminal Preservation	No – Extension of current Life Cycle Cost Model
	Construction	- Vessel Construction - Terminal Construction	No – Extension of WSF Travel Demand Model
Highway	Improvements	- Climbing Lane - General Purpose Lane - High Occupancy Vehicle Lane - Interchange - Intersection - Park and Ride Lot - Two-Way Left Turn Lane	Yes
	Preservation	- Pavement Preservation - Structure Preservation	No – Extension of existing Pavement Management System but requires utilization of new HDM-4 program.
	Safety	- At-Grade Intersection - High Accident Intersections - High Accident Locations	Yes
Intelligent Transportation Systems (ITS)	IDAS [1] and SCRITS [1] (IDAS is a post-processor program to travel demand modeling results. SCRITS is a sketch planning level analysis tool.)	-Arterial Traffic Management -Freeway Traffic Management -Advanced Public Transit Systems -Incident Management Systems* -Electronic Payment Collection -Railroad Grade Crossing -Emergency Management* - Traveler Information Systems -Commercial Vehicle Operations -Adv. Vehicle Control & Safety Sys.* -Support Deployments* (*Not available with SCRITS [1] Analysis)	No
Non-motorized		- Pedestrian Accident Locations - Pedestrian Risk Locations - Urban Bicycle Improvements - Rural Touring Bicycle	No – Extension of current ranking system

Mode Category	Sub-Category	Project Types	Utilizes Current WSDOT Analysis Method?
Rail		- Freight car purchase - Grade separation - Modal connections - Passenger train set purchase - Station Improvement - Track Improvement	No – General methodology developed from Rail office studies for specific improvements
Transportation Demand Management (TDM)		- Areawide TDM - Commute Trip Reduction Support	Yes – Adapted from CTR surveys and Areawide reduction factors currently used by WSDOT
Transit	STEAM SPASM (STEAM is a post-processor program to travel demand modeling results. SPASM is a sketch planning level analysis tool.)	-Any transit project that can be analyzed with STEAM[1] or SPASM[1].	No

(1) Note: The following acronyms refer to computer analysis programs: SCRITS = SCReen ITS; IDAS = ITS Deployment Analysis System; HDM-4 = Highway Development and Management System (version 4); STEAM = Surface Transportation Efficiency Analysis Model; and SPASM = Sketch Planning Analysis Spreadsheet Model)

User Inputs

MICA Program

Project Level Analysis

Enter Project Level Data

Project Level Analysis (by mode/program)

Project Level Impact Output

Multiple Projects and Modes

Scenario Level Analysis

Define Scenario Parameters

Scenario Analysis (Multimodal)

Scenario Level Output

Multiple Scenarios

Scenario Comparison Analysis

Choose Scenarios for Comparison

Scenario Comparison Analysis

Scenario Comparison Output

Figure 1-1: Overall MICA Structure

Project Level Analysis

At the project analysis level, analysis methods are unique to the project or program type, but the output from the analysis is standard. Figure 1-2 shows the general procedure that is applied to each project that is entered into MICA.
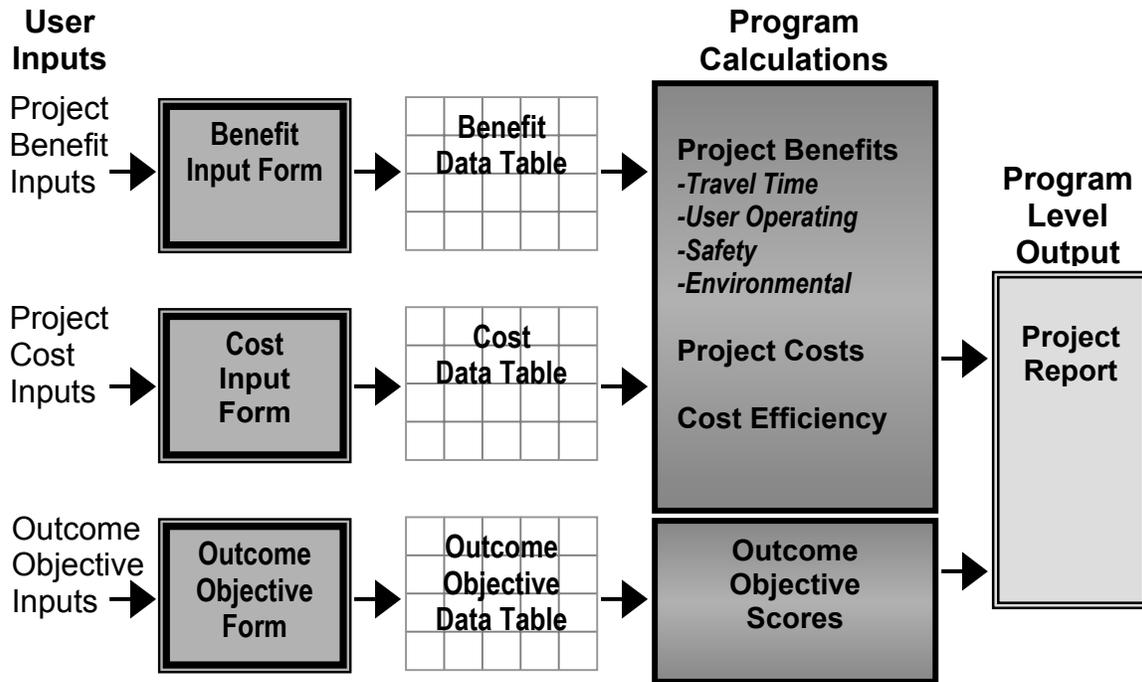
Figure 1-2: Project Level Analysis Component of MICA

While the input forms, required data, and calculations are unique for each project type, the output (consisting of **monetary measures** and **non-monetary measures**) is uniform across all projects within all modes and programs.

The individual project reports include the input data, value of global assumptions used, and the resulting calculated project measures.

<u>**Monetary Measures**</u>

Benefit, cost, and cost-efficiency measures are calculated for each project. Three main categories are considered for estimation of monetary benefits. First, **user operating impacts** include changes in user travel time and user costs (such as vehicle operating costs and/or user fares) that are estimated to result from the proposed project. Second, **environmental impacts** include (1) changes in vehicle emissions that are estimated to result from the proposed project, and (2) the benefits that result from specific environmental retrofit projects that are common at WSDOT. This category may include additional impacts in later versions. Finally, **safety impacts** consist of the increase or decrease in societal cost of accidents that is estimated to result from a proposed project.

Monetary benefits can be either positive or negative. For example, a project that increases capacity may allow vehicles to travel faster, resulting in a positive benefit of travel time savings. However, increased traffic that results from that project will produce more emissions, resulting in a negative value for environmental impacts. Additionally, monetary impacts may be direct or indirect. The capacity improvement example just cited illustrates impacts that would directly result from a proposed project. However, a common approach for modes that are alternative to highway is to estimate the impacts on highways that would result if the alternative did not exist. For example, an improvement to freight rail may allow freight that would otherwise be carried by truck to be carried by rail. In addition to possible direct impacts on rail travel, the project may indirectly benefit highways by taking trucks off the road.

For certain modes or project types, some impacts within the standard categories are considered negligible. In these instances the impacts are programmed to default to zero. For other modes or project types, certain impacts could not be assumed to be negligible, but methodologies for estimating them did not previously exist. In these cases, simplified methods or assumptions that would yield reasonable results have been employed until more detailed techniques can be developed (and the need for the more detailed technique is documented as a long term analysis gap).

By employing the concepts of positive or negative impacts, direct or indirect impacts, and negligible or significant impacts, widely varying analysis methods that are unique to each project type result in a common set of project impact measures.

The cost categories include **capital costs**, **operation and maintenance costs**, **terminal value** and **environmental retrofit costs**. Costs are also itemized as WSDOT costs, local or private share costs, and federal share costs. Once the net present values of benefit and cost measures are calculated, they are used to compute cost-efficiency measures such as benefit-cost ratio.

Non-Monetary Measures

The **User Operating**, **Environmental**, and **Safety Impacts** are additionally calculated in non-monetary terms so that cumulative estimates such as total change in number of fatal accidents or carbon monoxide emissions can be included in the scenario level analysis.

Outcome Objectives represent the seventeen outcome areas that were developed as part of the Washington Transportation Plan (WTP) update by the WSDOT Planning Office. The WTP Policy Framework reflects WSDOT's move toward performance-based planning, and is presented as a four-tiered framework. The first tier is the overall Vision, which includes three subcategories: Communities, Economic Development, and Environment. The second tier consists of Outcome Areas that are statewide and multimodal. Service objectives make up the third tier. Each service objective specifies measurable target and is associated with a specific outcome area. The final tier consists of Action Strategies, which are methods for reaching the particular service objectives. Table 1-2 presents the seventeen outcome areas, as they have been categorized by WSDOT into critical, very important, and important priority categories (WSDOT 2000).

The MICA Outcome Objective worksheets contain questions that correspond to the service objectives for the seventeen Outcome Areas. Scores between 0 and 100 (with 100 as best) are calculated for each of the seventeen areas based on the responses to the questions in addition to calculated values from the impact estimation. The Outcome Objective measures represent the goal achievement portion of MICA. This component allows decision-makers to identify projects for funding that achieve WSDOT policy objectives, but that are difficult to monetize into traditional benefit-cost analysis.

Table 1-2: WSDOT Outcome Objectives – Categorized by Priority

Critical	Very Important	Important
• Safety	• Freight Movement	• Special Needs Transportation
• Maintenance and Operation	• Economic Prosperity	• Improved Security
• Preservation	• Congestion Relief	• Collaborative Decision-Making
	• Seamless Connections	• Support for Tourism
	• Increased Travel Options	• Maintain Air Quality
	• Effective Community Based Design	• Meet Water Quality Standards
		•Maintain Habitat and Watershed
		•Minimize Use of Resources

Scenario Level Analysis

Figure 1-3 illustrates the scenario analysis component, which determines the combination of projects (with project level analysis completed) that best meets priorities defined by the user. Varying sets of priorities can be analyzed by running different scenarios. Although the impact estimation methodologies vary between different modes and programs, the standardized outputs of project level analysis allow cross-modal evaluation.
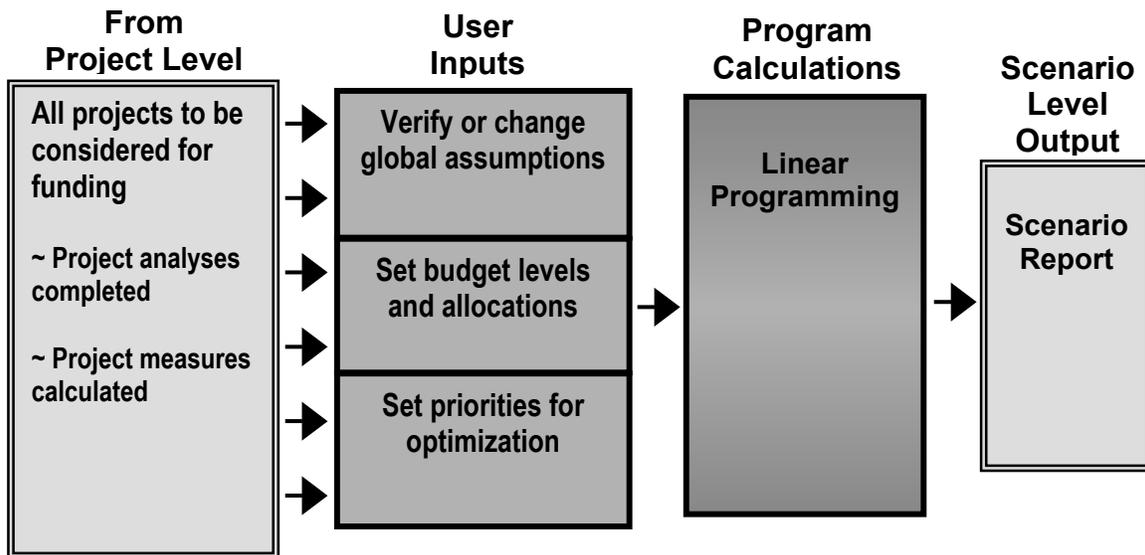
Figure 1-3: Scenario Analysis Component of MICA

The Scenario Level Analysis input consists of:

- Standardized output from the project level analysis

- Additional user inputs required to create funding scenarios

Once project level analysis has been completed for all projects that are to be included in the evaluation, the following steps are required to create a scenario:

1. The user selects the projects that should be considered for the particular scenario. Since project level analysis is complete, uniform measures based on a consistent set of global assumptions will have been calculated for all projects on the list. The user has the additional options of selecting projects only of a specific mode and/or from a specified geographic region. In addition the user can further specify minimum threshold values for the project measures. For example, the user may only want to consider highway projects that have positive environmental benefits, or have benefit-cost ratios greater than 1.0.

2. The user supplies a budget level. The budget may be either completely unconstrained or allotted by region and/or by program.

3. The user selects prioritization categories, as well as the relative weights of the selected categories (i.e. benefit cost ratio at 65 percent and tourism outcome objective scores at 35 percent). The user may also modify the project list to specifically include or exclude particular projects if desired.

MICA utilizes linear programming to determine the specific combination of projects, out of all possible projects, that best satisfy the defined parameters. Each set of scenario calculation also includes composite measures of the group of selected projects. Examples of composite measures include overall benefit-cost ratio, total travel time savings, total change in emissions, total reduction in accidents, and average outcome objective scores.

All of these inputs, the resulting list of selected projects, and the composite measures for the scenario are identified in the individual scenario report.

Scenario Comparison

Once multiple scenarios have been created, the program provides a mechanism by which these scenarios can be compared. Figure 1-4 illustrates the scenario comparison component, which allows for the user to examine the relative consequences of varying budget levels and spending priorities. For example, by running two scenarios with identical priorities but different budget levels the user can see what the additional money "buys" in terms of minutes of travel time savings, vehicle emissions, and accident savings. By utilizing the outcome objective scores, the user can prioritize spending on projects that may not be the most cost-effective in terms of traditional benefit-cost values, but that may address important WSDOT concerns. By running this type of scenario against one in which benefit-cost ratios are prioritized, the user can see the relative differences in both monetary and non-monetary terms.

The scenario comparison report presents side-by-side comparisons of the project list selections and composite scenario measures, for each of the scenarios under consideration.
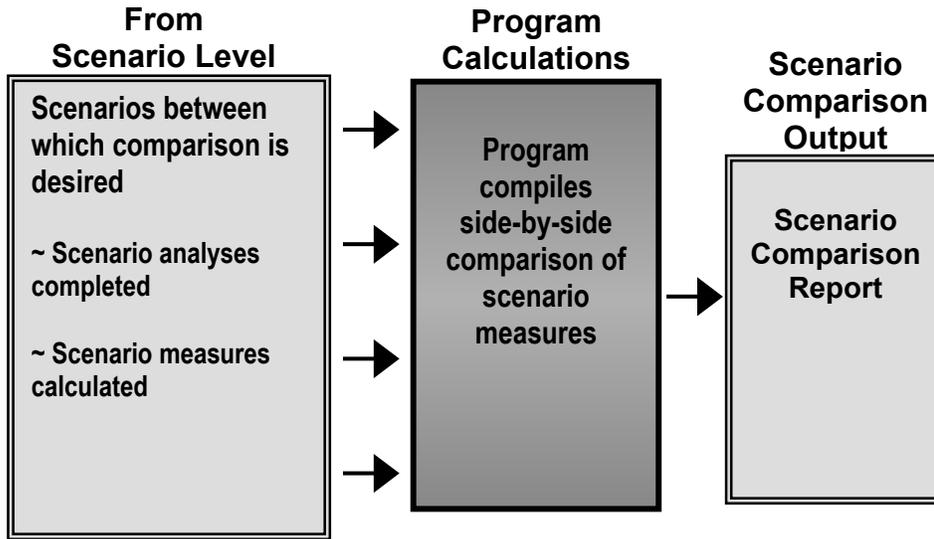
Figure 1-4: Scenario Comparison Component of MICA

The MICA approach is based entirely upon the concept that there is not one absolute list of projects that should be funded. The MICA program does not provide one "right" answer, but instead serves as a tool to aid decision makers in making funding decisions. Different priorities will yield different project lists. MICA includes several features that should enhance the traditional transportation funding decision-making process. Namely,

1. It provides a platform that ensures that all projects under consideration, regardless of program or mode, have been evaluated in a consistent manner.

2. It provides composite measures of the overall effectiveness of a group of projects, based upon transportation policy and priorities of Washington State.

3. It explicitly presents the priorities that are defined to produce a given project list.

While funding choices ultimately rest on the judgment of decision makers, these stated advantages of MICA can add clarity and consistency to the decision process.

References

Peyrebrune, H. Multimodal Aspects of Statewide Transportation Planning. NCHRP Synthesis 286, Transportation Research Board, National Research Council. Washington, DC. 2000.

Reed, Tracy L., D.A. Niemeier, and G. Scott Rutherford. Prioritization of Capacity Improvements. Prepared for the Washington State Department of Transportation. Report No. WA-RD 295.1. Washington State Transportation Research Center. Seattle, WA. 1995.

Rutherford G.S. and K. Shafizadeh. Budgetary Tradeoffs: The State-of-Practice in Statewide Multimodal Transportation Planning. University of Washington. June1999.

Rutherford, G.S. and R.K. Young. Budgetary Tradeoffs: The State-of-Practice in Statewide Multimodal Transportation Planning – Report Update. University of Washington. May 2000.

WSDOT (Washington State Department of Transportation). Washington Transportation Plan Update. Olympia, WA. 2000.

Chapter 2 - Project Measures

Figure 2-1 illustrates the measures that are calculated for analysis at the project level. As the figure shows, **global variables** are determined independently, and are used in the calculations of project-specific measures. Project-specific measures can be categorized as **project benefits**, **project costs**, **cost effectiveness**, and **outcome objectives**. This chapter will describe each of the measures that are included within these major categories.
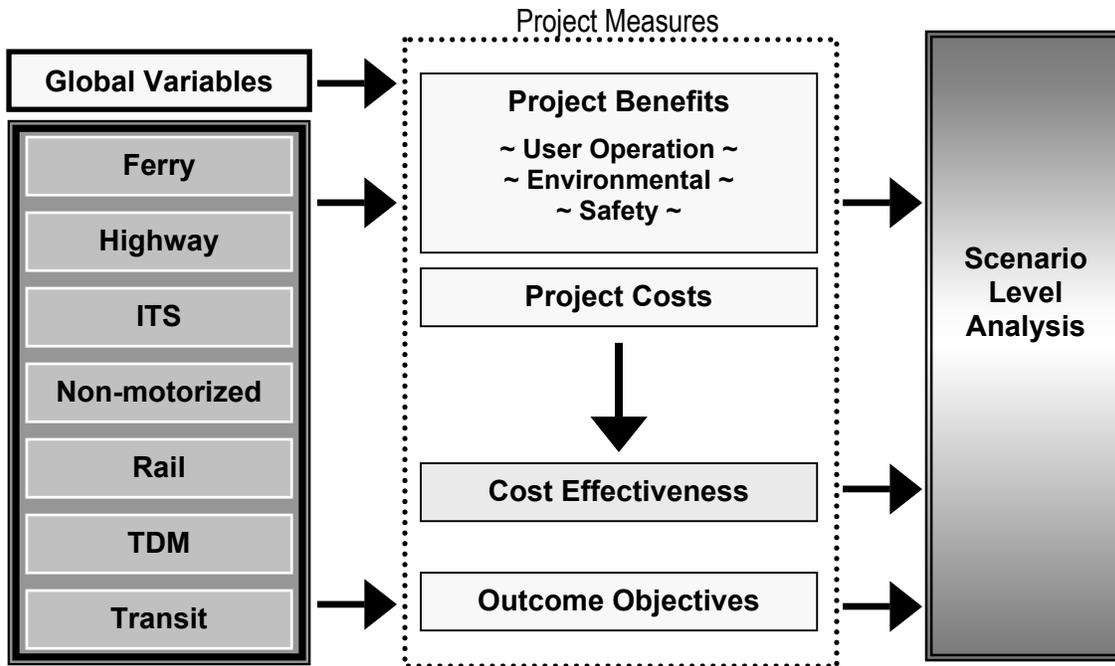
Figure 2-1: Measures Calculated at Project Level Analysis

Global Variables

Global assumptions are those variables that must be the same for evaluation of all project types, in order to ensure that projects across all modes are analyzed on an equal basis. They are directly used at the project analysis level for estimation of the project impacts and the calculation of cost-effectiveness measures. Any changes in the global variables result in the recalculation of impacts for all projects, using the new values. Global variable definition also impacts scenario level analysis, since the values of the assumptions can have significant effect on the relative values of the measures for projects being compared.

The default value for each of the global variables is based upon one of three possible sources. Many variables have values that have long been established through independent research at WSDOT, and have been adopted as policy. For variables that are not established by WSDOT policy, values that have been established through other studies within the State of Washington (typically representing statewide averages) are used. Finally, where no statewide values are available, values established through national studies have been assumed.

The global variable default values represent the best data that is available to date. Future research, or simply changing times, will necessitate the periodic update of these values. Updates of the global assumption values can easily be adopted since once they are changed in MICA, analyses of all projects in the database are automatically updated to reflect those changes. While good practice dictates that they not be changed frivolously, MICA provides a structure that lends itself to sensitivity analysis of the global variables. One can easily test how changing the value of an assumption will impact project level and scenario level results. These impacts can be used as the basis to affect a policy change in global variable definition, or reconfirm the validity of an established value.

The MICA platform provides transparency in the use of global assumptions. Since they are consistently defined and clearly presented, users can readily view the assumptions on which analysis results are based. Table 2-1 summarizes all of the assumptions and variables that are considered to be global in MICA.

Table 2-1: Summary of Global Variables

Assumption Category	General Variable Description	Variable Category
Economic Assumptions	Discount Rate	
	Annual / Daily Benefit	
	Value of Time	- Person, Freight Truck, Freight Rail
		- In-Vehicle Time, Out-of-Vehicle Time
	Full Cost v. Direct Cost Analysis	
	Vehicle Operating Costs	- Auto, Truck, Bus, Rail
		- Per Mile, Per Hour
	Average Vehicle Occupancy	
	Environmental Retrofit Benefits	- Fish Barrier, Storm water Retention, Noise Barrier
Safety Assumptions	Societal Costs of Accidents	- Fatality, Injury, Property Damage
	Accident Rates	- Fatality, Injury, Property Damage
		- Auto, Truck, Bus, Rail
Pollution Assumptions	Percent of Trips with Cold Starts	- Auto
	Emission Rates	- CO, NOX, VOC, PM-10
		- Auto, Truck, Bus, Rail
		- Warm engine travel, Cold starts
	Societal Costs of Pollution	- CO, NOX, VOC, PM-10
Freight Assumptions	Tons of freight carried per truck	- Twelve freight types
Non-motorized Assumptions	Percent Diverted from Auto	- Bicyclists, Pedestrians

The following sections describe in detail each of the global variables and how their values were determined.

Economic Assumptions

Discount Rate

The MICA program utilizes a "constant dollar" economic approach to monetary calculations. The discount rate is a major component in these calculations and represents the opportunity cost of capital to the taxpayer. A constant dollar approach expresses cost and benefits in terms of price levels found at a particular date – typically the time the project is being analyzed or the beginning of the first biennium being considered. The alternate "current dollar" approach expresses costs and benefits at the time they are incurred and requires the use of an average rate of inflation. The constant dollar approach removes the estimation of future inflation by using only the real cost of capital (Dowling Associates et al. 2000).

The default value for the discount rate is currently **4 percent**. This value has been in use for several years at WSDOT, and its derivation is documented in Appendix B. All monetary calculations within MICA utilize the discount rate.

Annual/Daily Benefit

The annual/daily benefit variable represents the typical number of weekdays in an average year. The default value for this variable is **260 weekdays per year** (Dowling Associates et al. 2000). Many of the project impacts are initially calculated for a typical average weekday, and multiplying them by this factor converts them into annual benefits, which is required for benefit-cost analysis. For some project types, benefits are also shown to accrue on weekend days. The number of annual weekend days is assumed to be the difference between 365 and the annual/daily benefit factor (currently defaults to **105 weekend days per year**). The average benefits for a weekend day are converted to annual benefits by multiplying by the annual number of weekend days.

Value of Time

The value-of-time variables are divided into two components: the overall value of time, and the percent of that value that is applied to the various elements of travel.

Value of Travelers Time

The value of traveler's time represents the average hourly wage rate in Washington State. The default value of time is **$18.36 per hour for auto travelers**, which represents an average wage rate across regions and user groups within Washington State. The default value of time is **$20.22 for freight truck drivers**, which was calculated with consultation from the Teamsters Union, and is based upon the average hourly wages and benefits for a truck driver. These values were established by the Mobility Programming Process and have been adopted as WSDOT policy (Dowling Associates et al 2000).

Value of In-Vehicle Time as Percent of Wage Rate

Value of travel time for various types of travel is expressed as a percentage of the overall value of travel time. Table 2-2 illustrates the value of time factor as a function of trip purpose.

The project impact calculations typically do not differentiate between trip purposes so the lower personal travel time value for local travel was utilized for all travel. Thus, MICA uses a value of **50 percent of the wage rate for auto travelers**. Since in-vehicle time is always working time for freight operators, MICA utilizes a value of **100 percent of the wage rate for truck drivers**.

Value of Out-of-Vehicle Time as % of Wage Rate

This variable is similar to the previous variable and is applied to all out-of-vehicle travel time including wait, walk, and transfer times. Ferryboat wait times are also considered out-of-vehicle travel time. The default value used by MICA is **100 percent of the wage rate for all travelers**.

Table 2-2: Value of travel time for various time elements

Time Element	Value of Time as Percent of Wage or Compensation
In-Vehicle Personal (Local)	50%
In-Vehicle Personal (Intercity)	70%
In-Vehicle Business	100%
Excess (waiting, walking, or transfer time) Personal	100%
Excess (waiting, walking, or transfer time) Business	100%

(USDOT 1997)

Full Cost v. Direct Cost Analysis

This variable is set by the user to instruct the program to either use **full operating costs -OR- direct operating costs** for automobile use. Direct vehicle operating cost variable includes the incremental vehicle operating costs of gasoline, vehicle maintenance, and tire wear, but excludes ownership costs. Full vehicle operating cost includes automobile ownership costs, in addition to the components included in direct operating costs.

Traditionally, only direct costs have been used for analysis that involves automobile operations. However, all other modes (trucks, buses, rail, trains) already utilize full operating costs in their analyses. Thus, this global variable is only applicable to automobile analysis. When "full cost" is set, calculations involving automobiles utilizes operating costs that are consistent with the other modes. When "direct cost" is set, the lower but less complete operating costs are utilized for automobiles (while the other modes continue to be analyzed with full cost values).

Vehicle Operating Costs

Vehicle operating costs are needed for all modes included in analysis. In addition to the full cost and direct cost issue described in the previous section, different forms of operating cost are required for different calculations. Table 2-3 summarizes the vehicle operating cost values that have been established for use within MICA.

Note, operating costs have been estimated per mile of travel and also per hour of travel. This is due only to the different units that are required for various calculations.

Direct and full automobile operating costs were derived from the cost elements that are summarized in Table 2-4. The costs shown in this table are based on data for a popular model of each vehicle type listed, with ownership costs based on the assumption that the car is replaced after 60,000 miles. The final estimated auto operating costs represent an average over all types of vehicles, assuming travel of 15,000 miles per year. Direct cost value includes gasoline, oil, maintenance and tires. The full cost value includes all categories shown in Table 2-4.

These values are based upon national averages. Future work could incorporate statewide information on vehicle fleet make-up and average miles driven to further refine this number to better represent the State of Washington.

Table 2-3: Summary of Vehicle Operating Costs

Mode		Cost Per Mile	Cost Per Hour*
Automobile	Direct	$0.11	$5.50
	Full	$0.59	$29.50
Truck	-----	$0.66	$33.00

*Converted from cost per mile, assuming average vehicle speeds of 50 mph

Table 2-4: Automobile Operating Cost Elements

Category	Small Car	Midsize Car	Large Car	SUV	Van
Operating Costs (cents per mile)					
Gasoline & Oil	4.8	5.7	6.3	6.5	5.8
Maintenance	3.1	3.4	3.5	3.7	3.5
Tires	1.3	1.6	2.2	1.4	1.3
Subtotal	9.2	10.7	12.0	11.6	10.6
Ownership Costs (cost per year)					
Insurance	1,012	885	1,012	1,316	972
License, registration, taxes	175	223	279	410	392
Depreciation	2,871	3,355	4,084	3,648	3,468
Finance charge	603	812	1,070	958	890
Subtotal	4,661	5,275	6,445	6,332	5,722
Memo: Depreciation for excess mileage (per 1000 miles > 15,000 miles annually)	151	161	168	129	157
Total Annual Cost					
10,000 miles per year	4,826	5,526	7,036	6,416	5,783
15,000 miles per year	6,041	6,880	8,245	8,072	7,313
20,000 miles per year	7,256	8,219	9,685	9,297	8,628
Total Cost per Vehicle Mile (cents per mile)					
10,000 miles per year	48.3	55.3	70.4	64.2	57.8
15,000 miles per year	40.3	45.9	55.0	53.8	48.8
20,000 miles per year	36.3	41.1	48.4	46.5	43.1

(AAA et al 1999)

For ferry, rail and transit modes, any changes in operating costs that are expected to result from a proposed project are included in the project cost analysis. Thus operating costs for these modes do not need to be assumed. However, analysis for these modes often includes the number of

auto or truck miles that will be diverted to the alternative modes. These calculations incorporate the auto and truck operating costs presented in this section.

Average Vehicle Occupancy

The average vehicle occupancy (AVO) is not actually a global variable, since it can vary between different projects. Most project-specific analyses allow the user to input the appropriate AVO. However, when this value is unknown, the default values presented in Table 2-5 can be used. These values were determined for the State of Washington by the MPPP Technical Advisory Committee, based upon data from the U.S. Census Bureau, the National Personal Transportation Survey, Puget Sound Regional Council travel surveys, and high occupancy vehicle (HOV) lane monitoring studies.

Table 2-5: Average Vehicle Occupancy Default Values

Region, Vehicle, and Lane Type	Average Vehicle Occupancy
General purpose traffic within federally designated urbanized areas (Populations > 200,000)	1.30
General purpose traffic – other	1.10
Truck traffic statewide (Assumes one paid professional driver)	1.00
HOV lane traffic	Requires site specific data

(Dowling Associates et al. 2000)

Environmental Retrofit Benefits

Benefits are considered for three major types of environmental project: fish barrier removal, storm water retrofit, and noise barriers. Rather than separately calculate the benefits of the retrofit projects, benefits are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio. The benefit-cost ratios applied to retrofit projects, as established by WSDOT, are shown in Table 2-6.

Table 2-6: Benefit-Cost Ratios for Environmental Retrofit Projects

Retrofit Project Type	Benefit-Cost Ratio
Fish Barrier Removal Project	4.3
Storm Water Retrofit Project	1.0
Noise Barrier Project	1.0

(WSDOT 2001)

The fish barrier removal value is based upon independent research performed at WSDOT (cite). The value of 1.0 for the other two projects is based upon the assumption that at the very least, retrofit will not have a negative impact on the environment – conditions are brought back to pre-construction levels. Future research may determine that these projects have additional positive benefit to the environment, at which time the values can easily be updated in MICA.

Safety Assumptions

Safety benefits are a function of the change in accidents that are estimated to result from a proposed project. The safety calculations utilize two categories of global variables: the societal costs of accidents, and average accident rates by mode.

Societal Costs of Accidents

Table 2-7 shows the default values for the societal cost of accidents by accident type, as determined by WSDOT for the Mobility Programming Process (Dowling Associates et al. 2000) and adopted as policy. The estimated change in number of each accident type is multiplied by its corresponding societal cost to calculate a safety benefit for each project.

Table 2-7: Accident Costs

Accident Type	Societal Accident Cost (cost per accident)
Fatality Accident	$800,000
Disabling Injury Accident	$800,000
Evident Injury Accident	$62,000
Possible Injury Accident	$33,000
Property Damage Only (PDO) Accident	$5,800

Not all modes estimate changes in accidents for all five accident categories. Some methodologies are only able to estimate changes in overall number of accidents or accidents in three of the five accident categories (fatality, injury, property damage). When this is the case, the methodology described in the mode specific sections of this report explicitly state what accident types are estimated in the calculations. Within MICA, "Injury" accidents are considered the same cost as evident injury accidents.

Accident Rates

Accident rates are a function of miles traveled for a particular mode. The travel modes include automobile, freight truck, bus, and rail. In addition, automobile and truck rates are also based on the highway classification of the roadway (Class 1 through 6). The default rates are based on the Highway Safety Performance report from the Federal Highway Administration for the year 1992 and are given for fatality, injury, and property damage only accidents (FHWA 1995). Table 2-8 shows the accident rates by accident type and highway classification for automobile and truck travel. Table 2-9 lists the accident rates for bus and rail travel by accident type.

While the current accident rate values are based upon national statistics, WSDOT has detailed accident data available that may provide a more accurate statewide model for auto and truck accident rates. It is also possible in the future for the program to differentiate between accident rates in rural and urban areas. Once developed, these refinements can easily be incorporated into the MICA program.

Table 2-8: Automobile and Truck Accident Rates

Fatality Rate (Fatalities/100 Million VMT)						
Highway Classification	*1*	*2*	*3*	*4*	*5*	*6*
Automobile	0.62	0.84	1.65	1.21	0.94	1.78
Truck	0.62	0.84	1.65	1.21	0.94	1.78
Injury Accident Rate (Accidents/Million VMT)						
Highway Classification	*1*	*2*	*3*	*4*	*5*	*6*
Automobile	61.6	101.11	227.09	219.17	178.78	278.91
Truck	61.6	101.11	227.09	219.17	178.78	278.91
PDO Accident Rate (Accidents/Million VMT)						
Highway Classification	*1*	*2*	*3*	*4*	*5*	*6*
Automobile	304	304	304	304	304	304
Truck	182	182	182	182	182	182

Table 2-9: Bus and Rail Accident Rates

Accident Type	Bus	Rail
Fatality (Fatalities / 100 million VMT)	1.21	0.00
Injury (Accidents / Million VMT)	179.40	0.50
Property Damage Only (Accidents / Million VMT)	182.00	1.00

Pollution Assumptions

The pollution assumptions currently only apply to air pollution impacts, though future work may add noise and water pollution impacts to the program. Air quality impacts are determined by the change in vehicle emissions that are estimated to result from proposed projects. Emission rates are currently programmed for Carbon Monoxide (CO), Nitrous Dioxide (NOx), and Particulate Matter – 10 microns (PM_{10}). Future work will add Volatile Carbons (VOC) rates, and may change PM_{10} to $PM_{2.5}$ to reflect new Federal regulations. VOC rates and costs have been programmed into MICA but all values are currently set to zero. The air quality global variables can be categorized into three components: cold start emissions, emission rates based on warm engine travel, and societal cost per ton of emission pollutants. The sources cited below for default values came from the program documentation for the Surface Transportation Efficiency Analysis Model (STEAM) developed by the Federal Highway Administration (FHWA 1999).

Cold Start Emissions

Cold start emission estimates are based on two calculations: (1) the percentage of trips that begin with a cold engine and (2) the amount of additional emission pollutants resulting from an engine cold start.

Percent of Trips that Begin with a Cold Start

The default values for the percent of trips beginning with an engine cold start is **60 percent for automobile trips** and **0 percent for freight truck trips**. These values are based on analysis of the Nationwide Passenger Transportation Survey to estimate the average start modes for trips (Venigall et al. 1994).

For some project types, if the number of trips cannot be estimated, or if the change in the number of trips is insignificant, the cold start emissions are not considered in the calculations. When this applied, the assumptions are explicitly mentioned in the methodology for the particular mode or project type.

Cold Start Emission Rates

Vehicle emission rates per cold start are in grams of pollutant. Table 2-10 lists the emission rates for CO, NOx, and PM_{10} pollutants per cold start for auto and truck travel. The emission rates per cold start are based on research performed for the EPA using the EPA's Mobile 5A model (Dulla 1993).

Table 2-10: Emissions per Cold Start

Pollutant	Auto (grams)	Truck (grams)
CO	60.20	0.00
NOx	0.86	0.00
PM_{10}	0.00	0.00

The program currently assumes cold start emissions only for automobiles. For freight trucks, the default values for cold start emissions are set to zero, but this component has been incorporated into the calculations so that it may be easily added at a future time.

Emission Rates for Warm Engine Travel

The default values for emission rates for CO, NOx, and PM_{10} are based on the Environmental Protection Agency's Emission Trends Report (cite).

The emission rates for a warm engine (also referred to as the hot stabilized mode) are shown in Table 2-11 and Table 2-12. The tables list the default emission rates for CO, NOx and PM_{10} for auto, truck, bus, and rail travel. All emission rates are in grams of pollutant per mile traveled. CO and NOx rates are based on average running speed for automobiles and trucks, but are not dependent on speed for buses or rail. Rates for PM_{10} are independent of average running speed for all modes under consideration.

Societal Costs of Emissions

Estimated emission reduction amounts are converted from grams to tons and multiplied by the monetary value for each pollutant. Positive emission benefit values represent a net reduction in emissions.

The costs per ton of emissions for NOx and CO are based on research by Wang and Santini and the PM_{10} values represent lower bounds from Delluchi's research (Wang and Santini 1995, Delluchi 1997).

Table 2-11: CO and NOx Emission Rate per Mile

MPH	CO Emissions (g/mile)		NOx Emissions (g/mile)	
	Auto	Truck	Auto	Truck
5	40.94	29.16	1.14	10.80
10	24.81	20.11	1.00	8.96
15	19.43	14.54	0.96	7.70
20	16.44	10.96	0.94	6.86
25	12.54	8.66	0.97	6.33
30	9.94	7.16	0.98	6.05
35	8.08	6.20	0.99	6.00
40	6.68	5.62	1.00	6.16
45	5.60	5.33	1.01	6.55
50	5.06	5.29	1.07	7.22
55	5.06	5.49	1.22	8.24
60	7.39	5.97	1.36	9.78
65	9.71	6.79	1.51	11.96
Transit	**Bus**	**Rail**	**Bus**	**Rail**
	14.51	0.00	7.70	0.00

Table 2-12: PM_{10} Emission Rate per Mile Traveled

Mode	PM_{10} Emissions (g/mile)
Auto	0.03
Truck	0.32
Bus	0.32
Rail	0.00

Table 2-13: Societal Costs of Emissions

Pollutant	Cost ($ / ton)
CO	$3,889
NOx	$3,731
PM_{10}	$11,066

Freight Assumptions

Much of the benefit of freight rail is determined by the number of freight trucks that would be required to carry its load, if rail were not operating. In addition to the lower operating cost of rail, taking trucks off of the highways saves pavement degradation. Table 2-14 shows the average tons of freight carried per truck, for the major types of freight that are transported in the State of Washington. When a freight rail project is proposed, these values are used to determine the equivalent number of trucks the project would take off of the highways. Note, if the exact type of freight is not known or if numerous types of shipments will be carried, the "General Freight" value is used, which consists of average of all major freight types.

Table 2-14: Tons of Freight Carried Per Truck

Type of Freight	Average Tons Carried Per Truck
Agricultural/farm products	26.55
Lumber/wood products	25.25
Mixed shipments	15.33
Chemicals	26.30
Food and kindred products	25.60
Paper and pulp products	25.19
Petroleum or coal products	26.34
Waste or scrap material	25.90
Stone/clay/glass products	26.52
Primary metal products	24.81
Transportation equipment	20.00
General freight*	25.00

(HDR et al. 2000)

Nonmotorized Assumptions

For nonmotorized projects, one benefit that is difficult to quantify is the number of bicyclists and pedestrian travelers that would otherwise be driving automobiles if the project were not constructed. In additional to saving automobile operating costs, projects that shift travelers out of automobiles have safety and environmental benefits. Table 2-15 shows average the average rate of auto trips that are displaced by bicycle and pedestrian trips, based upon a national bicycling and pedestrian study (FHWA 1993).

Table 2-15: Average Auto Trips Displaced by Nonmotorized Modes

Mode	Trip Purpose				
	Commute/Personal	Commercial	Recreation	Children	Average
Bicycle	62.5 %	62.5 %	50.0 %	29.0 %	38.0 %
Pedestrian	50.0 %	33.0 %	21.0 %	19.0 %	26.0 %

Calculated Project Measures

Figure 2-2 illustrates the general categories of project measures that are considered in MICA.

Uniform project measures, as summarized in Table 2-16, are calculated for every project under consideration. While calculation procedures vary among modes and project types, the final values are presented in consistent units, and are based upon consistent assumptions.

The following sections provide a general description of the uniform project measures. The actual procedures for calculating the measures will be described in detail in the mode-specific chapters in this report, since they are unique for the different project types.

BENEFIT CATEGORIES

User Operating Benefits ◆◆ – Travel Time Savings – Vehicle Operating Costs –

Environmental Benefits ◆◆ – Changes in Emissions – Environmental Retrofit –

Safety Benefits ◆◆ – Changes in Accidents –

COST CATEGORIES

Project Costs ◆◆ – Capital – Operation & Maintenance – Terminal –
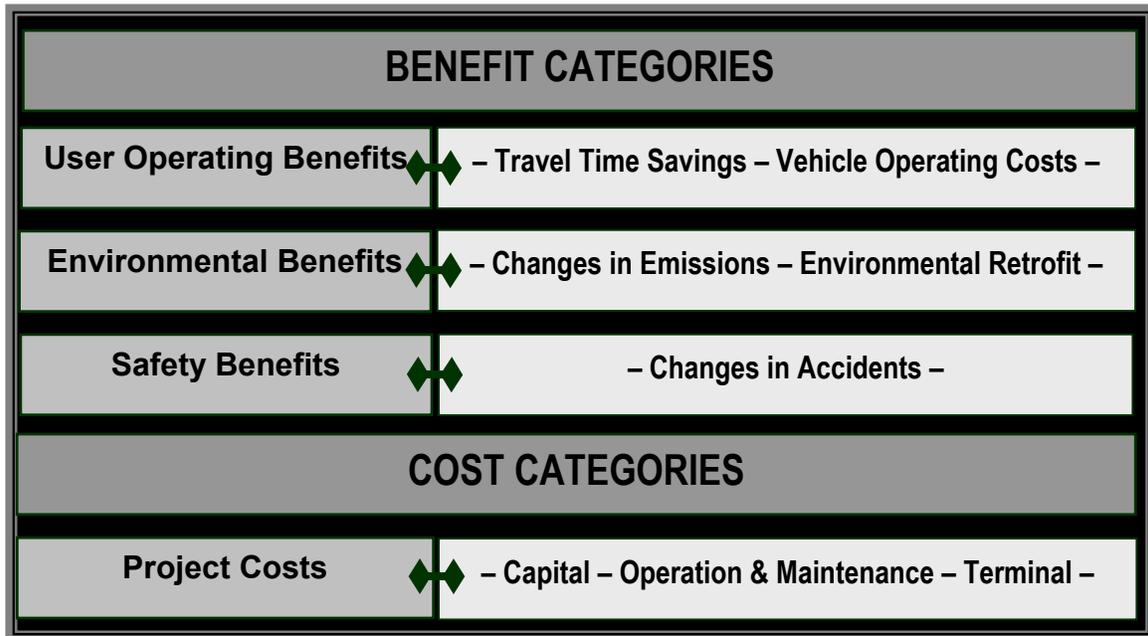
Figure 2-2: Benefit and Cost Categories

Table 2-16: Summary of Uniform Project Measures

Benefit Measures		Cost Measures	Cost Efficiency Measures	Outcome Objective Measures
(Non-Monetary)	(Monetary)	(Monetary)		
• Δ Vehicle Miles Traveled	• User Operating Benefits	• Total Project Cost	• Total Benefit-Cost Ratio	• System Operation
• Δ User Travel Time	• Environmental Benefits	• WSDOT Project Cost	• WSDOT Benefit-Cost Ratio	• System Preservation
• Δ CO Emissions	• Safety Benefits			• Congestion Relief
• Δ NOx Emissions				• Travel Options
• Δ PM$_{10}$ Emissions				• Seamless Connections
• Δ VOC Emissions				• Safety
• Δ Fatality Accidents				• Security
• Δ Injury Accidents				• Community Basis
• Δ Property Damage Only Accidents				• Collaboration
				• Freight Movement
				• Economic Prosperity
				• Tourism Support
				• Air Quality
				• Water Quality
				• Habitat Maintenance
				• Use of Resources

Benefit Measures

Several benefit components are added together to produce the total project benefit measure, namely:

1.   User operating benefits

2.   Environmental benefits

3.   Safety benefits

The majority of project analyses calculate the change in vehicle-miles-traveled (∆VMT) that is expected to result. ∆**VMT** is a very illustrative non-monetary measure in itself, but it also very valuable for other subsequent benefit calculations. The following descriptions will show that many of the estimated impacts are a function of the ∆VMT. Generally, a reduction in VMT results in positive benefits, while an increase in VMT results in negative impacts.

Note, most project benefit measures have positive values, but they can also be negative in value. For example, if a project results in increased automobile traffic, the levels of emissions might also increase. In this case, the change in emissions would be positive, with the monetary value of the change actually representing a disbenefit. Thus it would be a negative value in the total benefit calculation.

The total monetary benefits are calculated as:

TOTAL_BENEFITS = [User_Operating_Benefits] + [Environmental_Benefits] + [Safety_Benefits]

User Operating Benefits

User benefits are those that directly impact the travelers who will be utilizing the WSDOT project. The monetary User Operating Benefits for a project are calculated as:

User_Operating Benefits = [Travel_Time_Benefits] + [Vehicle_Operating_Benefits]

Travel Time Benefits

Travel time savings result when a project (1) allows travel speeds to increase, or (2) provides a new alternative that is shorter or faster than existing alternatives.

The non-monetary measure ∆**User_Travel_Time** consists of the total hours of travel time that are estimated to be saved by users, over the life of the project. The monetary benefit measure is calculated as:

Travel_Time_Benefits = [∆User_Travel_Time] * [Value_of_Time]

The travel time benefits are calculated for both passenger and freight travel, utilizing the values presented in the "Value of Time" description under *Global Assumptions*.

Vehicle Operating Benefits

Vehicle operating savings result when a project (1) results in reduced VMT (2) speeds up traffic so that less time is spent in vehicles for the same trip. Vehicle operating benefits are calculated as:

Vehicle_Operating_Benefits = [∆VMT] * [Vehicle_Operating_Cost (per mile)]

OR

Vehicle_Operating_Benefits = [∆Travel_Time] * [Vehicle_Operating_Cost (per hour)]

The change in vehicle operating costs is calculated for each mode that is impacted by the project: automobile, truck, bus and rail. Note, if mode shifts are expected to result from a project, the VMT may increase for one mode and decrease for the other mode. For example, addition of a passenger train will result in increased VMT for rail. However, for new passengers that would otherwise drive automobiles, the addition of the train will result in decreased VMT for auto. The total vehicle operating savings will be the difference between the two. In another example, a project results in a shift from auto to existing transit service. In this case, the auto VMT would decrease but transit VMT would remain unchanged, since new passengers utilize existing capacity. Thus, the vehicle operating savings would be a function only of reduced auto VMT.

This is the area where the **full cost/direct cost** option is exercised. If full the analyst selects cost analysis, the full automobile operating costs are applied, which include auto ownership costs in addition to the vehicle operating costs of fuel, maintenance and tire wear. This is consistent with the values that are used for the other modes. If direct cost analysis is selected, only the direct vehicle operating costs are included for automobiles. The full cost operating values are still used for the other modes. While the direct cost method is not based upon consistent definitions between modes, this is how multimodal analysis has traditionally been done.

Environmental Benefits

Currently, the environmental impact benefit calculations consist of air quality impacts, although other environmental measures, such as noise or water quality impacts, may be added at a later date. Additionally, the benefits of environmental retrofit projects are recognized in MICA. Environmental benefits are calculated as:

Environmental_Benefits = [Air_Quality_Benefits] + [Env_Retrofit_Benefits]

Air Quality

Air quality impacts are a function of (1) the change in the number of vehicle trips, and (2) the change in VMT that is projected to result from a project. The non-monetary air quality measures are calculated as:

∆CO_Emissions =[[∆Cold_Starts] * [CO_rate(per start)]] + [[∆VMT] * [CO_rate(per mile)]]

∆NOx_Emissions =[[∆Cold_Starts] * [NOx_rate(per start)]] + [[∆VMT] * [NOx_rate(per mile)]]

∆PM$_{10}$_Emissions =[[∆Cold_Starts] * [PM$_{10}$_rate(per start)]] + [[∆VMT] * [PM$_{10}$_rate(per mile)]]

∆VOC_Emissions =[[∆Cold_Starts] * [VOC_rate(per start)]] + [[∆VMT] * [VOC_rate(per mile)]]

Air quality impacts are calculated for all modes that are affected by a project. The measures are calculated in grams of pollutant. To calculate the monetary air quality measure, the grams of pollutants are converted to tons, and multiplied by the societal costs:

$$Air\_Quality\_Benefits = [[\Delta CO]*[CO\_cost]] + [[\Delta NOx]*[NOx\_cost]] +$$
$$[[\Delta PM_{10}]*[PM_{10}\_cost]] + [[\Delta VOC]*[VOC\_cost]]$$

Environmental Retrofit

Benefits are considered for three categories of environmental retrofit projects:

1. Fish Barrier Removal

2. Storm water Retrofit

3. Noise Barrier Construction

Benefits for these are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio (BCR), as established by WSDOT and shown in Table 2-6 under the *Global Assumptions* description. Environmental retrofit benefits are calculated as:

Fish_Barrier_Benefit = [Fish_Barrier_Project_Cost] * [Fish_Barrier_BCR]

Stormwater_Benefit = [Stormwater_Project_Cost] * [Stormwater_BCR]

Noise_Barrier_Benefit = [Noise_Barrier_Project_Cost] * [Noise_Barrier_BCR]

Env_Retrofit_Benefits = [Fish_Barrier_Benefit] + [Stormwater_Benefit] +
[Noise_Barrier_Benefit]

Safety

Safety impacts are calculated by estimating the changes in the number of accidents that will occur as a result of the project. Changes in accidents are calculated within MICA by one of two separate methodologies (1) direct reductions due to facility improvement, or (2) changes due to shifts in VMT.

The first method requires that historical accident data be available for the facility under analysis. Typically in WSDOT procedures, the average number of accidents over three years is determined for each accident type – fatality, injury, and property damage only (PDO). These averages are assumed to be the typical number of accidents that will occur during each year of the project's life. Then, reduction factors are applied to calculate the number of these accidents that will be reduced as a result of the project. Using this methodology, the non-monetary measures of reduction in accidents are calculated as:

ΔFatality_Accidents = [Total_Fatality_Accidents]*[Fatality_Accident_Reduction_Factor]

ΔInjury_Accidents = [Total_Injury_Accidents]*[Injury_Accident_Reduction_Factor]

ΔPDO_Accidents = [Total_PDO_Accidents]*[PDO_Accident_Reduction_Factor]

The source of the reduction factor varies with project type. When this methodology applies, the source is identified in the project-specific methodology descriptions.

The second methodology is based on estimated changes in VMT for all modes that are impacted by the project. In this case, the accident rate per mile is applied to the change in miles traveled, as follows:

Δ**Fatality_Accidents = [ΔVMT]*[Fatality_Accident_Rate(per mile)]**

Δ**Injury_Accidents = [ΔVMT]*[Injury_Accident_ Rate(per mile)]**

Δ**PDO_Accidents = [ΔVMT]*[PDO_Accident_ Rate(per mile)]**

If mode shifts are expected to result from a project, the estimated number of accidents may increase for one mode, and decrease for the other mode. The total change in accidents will be the difference between the two. In cases where shifts occur from a higher risk mode to a lower risk mode of travel, the reduction in the total number of estimated accidents should result. Certain projects may be expected to increase the number of accidents, typically by inducing more travel or a shifting of travel to less safe modes. In these cases the accident reduction values would be negative resulting in a negative safety benefit for that project.

Regardless of the method that is used to calculate the change in the numbers of accidents, the method monetary safety benefit is calculated as:

Safety_Benefits = [[ΔFatality_Accidents]*[Fatality_Accident_Cost]] +
[[ΔInjury_Accidents]*[Injury_Accident_Cost]] +
[[ΔPDO_Accidents]*[PDO_Accident_Cost]]

Note, some project types separate Injury Accidents into the more detailed categories of Disabling Injury, Evident Injury, and Possible Injury. The general approach is the same, but societal costs are more detailed. The mode-specific descriptions will identify the project-types in which the more detailed injury categories are considered.

Cost Measures

Several cost components are added together to produce the total project cost measures, namely:

1. **Capital Costs** – include all costs of engineering, construction, and right-of-way acquisition. The program allows input of capital costs over five bienniums (10 years).

2. **Operation and Maintenance (O&M) Costs** – include the annual costs involved with operating and maintaining the project, after construction is complete. Currently, the program assumes that this is a uniform annual cost over the analysis life of the project.

3. **Terminal Value** – consists of the value of the project at the end of the analysis life. Sometimes referred to as "salvage value", the terminal value recognizes that a project most likely will still operate beyond the period in which it is being analyzed, and thus still has a value beyond the forecast year. At this time, MICA is designed with the terminal value as one input that is independently determined by the analyst, outside of the program. It does not perform calculations to determine what that value should be.

The user inputs the amounts of Capital and O&M Costs according to their source. Sources recognized by MICA are WSDOT, Federal, and three "Other", which are identified by the analyst. Other sources of funding can include City, County, Private, or non-WSDOT state funding. MICA calculates two cost measures:

TOTAL_COST = [Sum of all Capital Costs and all O&M Costs] – [Terminal Value]

WSDOT_COST = [Sum of WSDOT Capital Costs and WSDOT O&M Costs] –
[Terminal Value]

User Transfer

User transfer refers to money that changes from one group to another, and thus constitutes neither a cost nor a benefit. For example, public tolls or transit fares represent out-of-pocket costs to travelers that directly result from use of transportation facilities. However, the revenue that is generated by fares and tolls is collected by the controlling agency, representing a benefit. Since this money simply transfers, it is not included in either the cost or the benefit calculations. However, user transfer sums are calculated for projects to which they apply, and are identified in the project reports.

Cost Efficiency Measures

As mentioned previously, the economic calculations in the MICA program utilize a "constant dollar" approach to economic analysis. Calculation of Net Present Value (NPV) consists of converting all monetary impacts (costs and benefits) to current dollar values, using the global discount rate. The conversion of monetary impacts to NPV is accomplished through the use of the following basic economic equations.

Net Present Value Conversion Factor Equations

Present Value of a Future Sum: $\qquad P/F = (1+i)^n$ **(Equation 2-1)**

Present Value of a Uniform Annual Series: $\qquad P/A = \dfrac{(1+i)^n - 1}{i(1+i)^n}$ **(Equation 2-2)**

Present Value of a Uniform Gradient Series: $\qquad P/G = \dfrac{\left(e^{(r-i)n} - 1\right)}{(r-i)}$ **(Equation 2-3)**

Where, P/F = factor for converting a future sum to present value

             P/A = factor for converting a uniform annual series to present value

             P/G = factor for converting a uniform gradient series to present value

             i = discount rate

             n = analysis period

             r = annual growth rate = Year_n Sum / Year_1 Sum

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These factors are applied to convert all monetary impacts that accrue over the analysis life of the project into a current dollar lump sum value of monetary benefits, and a current dollar lump sum value of project costs. The following NPV sums are calculated:

NPV$_{\text{Benefits}}$ = Net Present Value[TOTAL_BENEFITS]

$$NPV_{Total\_Cost} = Net\ Present\ Value[TOTAL\_COST]$$

$$NPV_{WSDOT\_Cost} = Net\ Present\ Value[WSDOT\_COST]$$

Once these NPV values are determined, they are used to calculate MICA's two cost-efficiency measures.

The Benefit-Cost Ratio (BCR) is calculated as:

$$BCR = [NPV_{Benefits}] / [NPV_{Total\_Cost}]$$

The BCR indicates the proportion of dollars returned for every dollar spent on a project, representing its cost efficiency. A project is considered to be efficient if its BCR exceeds 1.0.

The WSDOT Benefit-Cost Ratio (WSDOT_BCR) is calculated as:

$$WSDOT\_BCR = [NPV_{Benefits}] / [NPV_{WSDOT\_Cost}]$$

The WSDOT_BCR does not represent true cost efficiency, since it does not consider the project costs shouldered by other public and private partners. Since it only considers the WSDOT portion of project costs but considers all benefits, a project with a BCR less than 1.0 (which is thus inefficient) could have a WSODT_BCR that is greater than 1.0. However, the WSDOT_BCR does provide a measure that captures the advantages of partnering in projects. By sharing the cost burden with others, State transportation improvements can amass substantial benefits with minimal investment of WSDOT dollars.

Outcome Objectives

While the benefit and cost measures include as many elements as is feasible, some State goals and priorities simply cannot be captured in this way. The seventeen outcome areas were developed as part of the Washington Transportation Plan (WTP) update (WSDOT 2000a). The seventeen areas are divided into three subcategories: Communities, Economic, and Environment, which correspond to the vision model adapted for the developed of the WTP. illustrates how the three components work together to provide balance and livability (WSDOT 2000a).
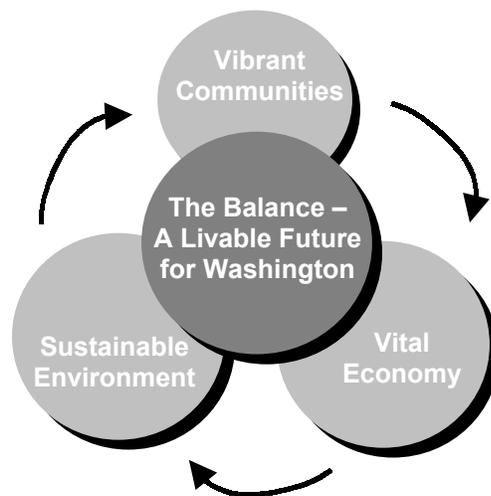
Figure 2-3: Washington Transportation Plan Vision Model

The seventeen outcome areas and their associated service objectives are summarized in Table 2-17. As the table shows, eight of the outcome areas have been designated as emphasis areas for data gathering efforts. These eight goal areas were selected from the 17 since they represent 85 percent of the transportation systems needs as identified in the WTP planning process. (Bremmer 2001)

Table 2-17: WTP Policy Framework

Outcome No.	Outcome		Service Objective
1*	**Essential Mobility: System Operation and Maintenance**	1	Maintain the effective and predictable operations of the transportation system to meet customer's expectations.
	The transportation system operates effectively, efficiently, and predictably	2	Increase the efficiency of operating the existing systems and facilities.
		3	Maintain vital transportation services in the event of a natural disaster.
2*	**Essential Mobility: System Preservation**	4	Preserve transportation infrastructure to achieve the lowest life cycle cost and prevent failure.
	Transportation facilities are in sound operating condition		
3	**Essential Mobility: Special Needs Transportation**	5	Meet all basic transportation needs for special needs population.
	Transportation system provides all citizens access to basic services		
4*	**Enhanced Mobility: Congestion Relief** WTP corridors operate with minimal delay for people and freight and with continual reduction in the societal, environmental and economic cost of congestion	6	Reduce person and freight delay on WTP Corridors.
		7	"Travel time" Service Objective to be developed in future updates.
		8	"Reliability" Service Objective to be developed in future updates.
5	**Enhanced Mobility: Increased Travel Options**	9	Improve existing Travel Options. (Travel Options is defined as new options and better quality of existing options based on market demand)
	Throughout the state, travelers have viable alternatives to the privately-owned automobile for their trips		
6	**Enhanced Mobility: Seamless Connections**	10	Create links and remove barriers between transportation facilities and services.
	The transportation system offers easy connections between different services throughout the state		
7*	**Improve Safety: Continuously Reduce Injury, Fatalities & Risk**	11	Reduce and prevent deaths and the frequency and severity of disabling injuries, and societal costs of accidents.

Outcome No.	Outcome		Service Objective
	A safe transportation system without deaths or disabling injuries and with continuous reductions in societal cost of accidents		(Focus on the rate of frequency and severity)
8	**Improve Safety: Increased Security** Customers are safe and secure while using the transportation system	12	Improve transportation facilities with state-of-the-art safety and security features.
		13	Improve security of all transportation facilities.
9	**Livable Communities: Effective Community-based Design** Integrated community design, land use and transportation investments improve quality of life	14	a) Reduce impact on communities and their resources with the development and implementation of transportation projects b) Increase integration of state and local interests in the development and implementation of transportation services and facilities c) Balance state and local needs in the development and implementation of multi-modal transportation projects.
10	**Livable Communities: Collaborative Decision Making** Collaboration occurs between federal, tribal, state, regional, local and private sector partners	15	Increase early and continuing involvement of community stakeholders, partners and WSDOT in actions that impact transportation systems.
11*	**Effective Competitive Freight Movement** Freight movement is reliable* and transportation investments support Washington's strategic trade advantage* (see congestion relief)	16	Reduce barriers that delay the effective and reliable movement of freight.
		17	Maintain the ability to move freight and goods in the even of alterations to the Columbia/Snake River system as a transportation right of way.
12*	**Support General Economic Prosperity** Transportation supports general economic prosperity	18	Support statewide economic development through targeted transportation investments.
		19	Support economic development in distressed areas through targeted transportation investments.
13	**Support for Tourism** Recreational travelers have convenient and inviting access to tourist destinations	20	Increase traveler information to tourist destinations.
		21	Improve the quality of tourists' related travel experiences in Washington.
14*	**Maintain Air Quality** Transportation services and facilities help maintain air quality by meeting air quality health standards	22	Reduce the impact of transportation facilities and services on air quality in conformance with the State Implementation Plan for Air Quality.
15*	**Meet Water Quality Standards** Transportation services and facilities help maintain water quality by meeting water quality standards	23	Reduce water quality impacts caused by transportation facilities and services to comply with federal and state water quality requirements.

Outcome No.	Outcome		Service Objective
16*	**Maintain Habitat & Watershed Quality & Connectivity**	24	Reduce the impacts of past projects and avoid or minimize impacts to watershed and habitat from current and future transportation activities.
	Transportation services and facilities help to maintain the quality of, and contribute to the recovery of the ecological functions of watersheds and habitats		
17	**Reuse and Recycle Resource Materials**	25	Minimize the use of resources and increase the use of recycled material.
	Transportation services and facilities prudently use, reuse and recycle resource materials		

*These are the emphasis areas for gathered data

The questions within each of the outcome areas correspond to the service objectives that have been identified for that area. Scores are calculated for each of the seventeen areas with possible scores between 0 and 100, 100 being the ideal best score.

Currently the program code contains calculations for the outcome objectives based on the user's answers to each question. Future program revisions will utilize values from the project input forms and calculations to refine the outcome objective score and to better differentiate between projects. Significant work will be required to refine these calculations so that an accurate comparison across modes can be made.

This component allows the decision-maker to identify projects for funding that have attributes that are hard to capture in the benefit-cost analysis but nevertheless represent WSDOT goals.

Other Variables

The MICA program utilizes three additional variables for identifying projects in key locations. These variables include WTP Corridor, Freight Goods Transportation System, and Air Quality Classification. Each of these variables is discussed in the following sections.

WTP Corridor

Washington Transportation Plan (WTP) Corridors were developed by WSDOT, in collaboration with regional and metropolitan transportation planning agencies, to identify key facilities that link people and freight movement between major regional and statewide destinations. WTP Corridors consider all transportation modes, facilities, and services between destinations. The Corridors were developed to move the planning decisions from mode and segment specific projects to a broader vision with regards to congestion relief strategies and modal tradeoffs between major nodes. WTP Corridors are categorized as either Statewide or Regional Corridors.

For highway facilities, Statewide Corridors are designated a Highways of Statewide Significance (HSS) and/or as part of Strategic Freight Network. Rail Facilities are considered Statewide Corridors if they are part of the Strategic Freight Network. WTP Regional Corridors include the following:

Locally-owned National Highway System (NHS)

- Connectors to Transportation Facilities and Services of Statewide Significance (TFSSS)

- NHS fright connectors

- Primary access to tribal lands

- Non-HSS state highways

WTP Corridor designation serves the following planning functions:

- Provides an area in which to analyze multiple travel patterns and land uses

- Sets general physical boundaries for identifying mobility deficiencies

- Enables WSDOT, Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Organizations (RTPOs) to more readily link segments of transportation facilities with mobility needs, and enable a broader approach to developing solutions to address these needs

- Provides an area to develop transportation strategies that integrate modal solutions and coordinate with local land use plans and decisions.

Each project type within MICA assigns a variable to designate whether that project is within a designated WTP Corridor. This variable is currently used in the Outcome Objective calculation to assign higher priority to these projects. Future program revisions may include identification of projects within particular designated corridors and the ability to tabulate impacts for corridor versus non-corridor projects (WSDOT 2000b).

Freight and Goods Transportation System

The Freight and Goods Transportation System (FGTS) is a classification system used by WSDOT to identify the extent of the freight and goods network within Washington State, in compliance with RCW 47.05.021 and the Federal Highway Administrations requirements under the *Highway Performance Monitoring System* (WSDOT 2001). State law requires the Transportation Commission to designate a freight and goods transportation system that includes state highways, county roads, and city streets.

The tonnage classifications that have been adopted by WSDOT and the Transportation Commission for designating the FGTS are as follows:

Table 2-18: Tonnage Classification for Washington State Highways

Tonnage Classification	Freight Tonnage Transported
T-1	> 10 million tons per year
T-2	4 to 10 million tons per year
T-3	300,000 to 4 millions tons per year
T-4	100,000 to 300,000 tons per year
T-5	20,000 tons per 60 days

State highways, county roads and city streets are classified according to the tons of freight that are carried each year. The Strategic Freight Corridors, sometimes also referred to as the Strategic Freight Network, are those routes that carry four million tons or more of freight annually (T-1 and T-2 classifications).

A key element in the development of the FGTS is the approximate freight tonnage by vehicle type. The classifications are determined by using the estimates for facilities average annual daily traffic, truck percentage, truck type, and working days per year. Table 2-19 summarizes the average weights by vehicle type were used in the development of the FGTS.

Table 2-19: Average Weights of Freight Vehicle Type

Truck Type	Average Weight	Truck Description
Single Unit	7 tons	Any single unit vehicle including dump trucks and mixers.
Double Unit	27 tons	A double unit vehicle, normally a truck and trailer, generally 4-6 axles. Basically any truck up to 80,000 lbs.
Trains	42 tons	Normally a tractor and 2 trailers. Basically any truck rated from 80,000 to 105,000 lbs.

The FGTS is used by the MICA program to determine the relative importance of a roadway facility with regards to the movement of freight. All roadway project types require the user to input the FGTS classification. If the roadway is not classified, "None" is selected from the pull-down list. Currently MICA utilizes the FGTS classification for Outcome Objective scoring. Future revisions may include benefit estimates for congestion relief based on valuation of goods carried by a particular project.

Air Quality Designation

Air Quality Designation is classification given to regions by the Environmental Protection Agency (EPA) based on federal and state Clean Air Act (CAA) legislation. The designation categories are Attainment, Maintenance, Non-Attainment, and Unclassifiable (EPA 2001). The EPA has established a National Ambient Air Quality Standard (NAAQS) for six pervasive air pollutants including ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. Attainment areas meet the national primary or secondary ambient air quality standard for the particular pollutant. Maintenance areas are those that previously did not meet the air quality standards but current do. Non-Attainment areas do not meet the standards. Unclassified areas are those that cannot be classified on the basis of available information.

The MICA Program uses air Quality Designation in Outcome Objective scoring. to Additional points are given to projects with positive air quality benefits in non-attainment and maintenance areas. Currently the program does not differentiate designation by pollutant types and only allows the user to select one designation. Future program revisions may include pollutant valuation based on air quality designation for that particular pollutant.

References

AAA (American Automobile Association) and Runzheimer International. Your Driving Costs, 1999 Edition. 1999.

AASHTO (American Association of State Highway and Transportation Officials). A Manual of User Benefit Analysis of Highway and Bus Transit Improvements. Washington, DC. 1977.

Bremer, Daniela and Keith Cotton. Washington's Transportation Plan: Innovations and Challengers in Transportation Planning. Washington Department of Transportation, Olympia, WA. 2001

Delluchi, M. The Annualized Social Cost of Motor Vehicle Use in the U.S., 1990-1991: Summary of Theory, Data, Methods, and Results. Institute of Transportation Studies, Davis, CA. 1997.

Dowling Associates, Inc., Kittleson & Associates, ECONorthwest, and Rao Associates. WSDOT Mobility Project Prioritization Process: Benefit/Cost Software User's Guide. Prepared for the Washington State Department of Transportation. Olympia, WA. May 2000.

Dulla, Robert C. "Treatment of Start Emissions in TCM Modeling." Letter from Sierra Research to Philip Lorang of the Environmental Protection Agency. February 9, 1993.

EPA (Environmental Protection Agency). National Air Quality and Emissions Trends Report. 1995.

EPA (Environmental Protection Agency). "EPA's Updated Clean Air Standards" Environmental Protection Agency Website. www.epa.gov . 2001

FHWA (Federal Highway Administration). Highway Safety Performance – 1992. January 1995.

FHWA (Federal Highway Administration). National Bicycling and Walking Study (Case Study 15: The Environmental Benefits of Bicycling and Walking). Publication No. FHWA-PD-93-015. U.S. Department of Transportation. Washington, DC. January 1993.

Federal Highway Administration and Cambridge Systematics. STEAM User Manual. Federal Highway Administration Website. http://www.fhwa.dot.gov/steam/ users_guide.htm October 1999.

HDR Engineering, Inc. and Denver Tolliver & Associates. Benefits of Rail Freight Transportation in Washington. Prepared for the Washington State Department of Transportation. Olympia, WA. December 2000.

Morely, Kimberly. Mobility Programming Criteria and Evaluation Procedures. Washington Department of Transportation. WA-RD 453.1. June 1998.

Pechan, E.H. Emission Trends Report. Environmental Protection Agency.

USDOT (U.S. Department of Transportation). The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations. Washington D.C. 1997.

Venigalla, Mohan, Miller, and Chatterjee. "Start Modes of Trips for Mobile Source Emissions Modeling." Transportation Research Record No. 1432. Transportation Research Board. 1994.

Wang, M. and Santini, D. "Monetary Values of Air Pollutant Emissions in Various U.S. Areas". Transportation Research Record No. 1475. Transportation Research Board. 1995.

WSDOT (Washington State Department of Transportation). Freight and Goods Transportation System Update. Washington State Transportation Commission. June 2001.

(WSDOT) Washington Department of Transportation. "Washington Transportation Plan." Washington Department of Transportation Website. Planning and Programming Service Center. 2000(a). http://www.wsdot.wa.gov/PPSC/WTP.htm

(WSDOT) Washington Department of Transportation. "WTP Corridor Designation." Washington Department of Transportation Website. Planning and Programming Service Center. 2000(b). http://www.wsdot.wa.gov/PPSC/WTP/Priority%20Projects/Corridors%202000v3.htm

Washington Traffic Safety Commission. Informational Guide for Highway Safety Improvements. 1978 Edition.

Chapter 3 – Operation of the MICA Program

MICA is an Access database program that consists of two modules:

1. In the **PROJECT MODULE**, the user inputs project-level data, and the uniform project measures are calculated for each project that is entered. Figure 3-1 shows the starting screen for the Project Module, which is the screen that appears when MICA is launched. The mode-specific windows are opened from this window by clicking on the appropriate mode button.

2. In the **MICA MODULE**, the user defines the multimodal investment scenarios, and the scenario measures are calculated for each scenario that is entered. Additionally, comparison analysis of two or more scenarios is performed in this module. Figure 3-2 shows the starting screen for the MICA Module of the program.

As the figures show, the user may switch between the two modules by clicking on the button in the upper right corners of the screens.
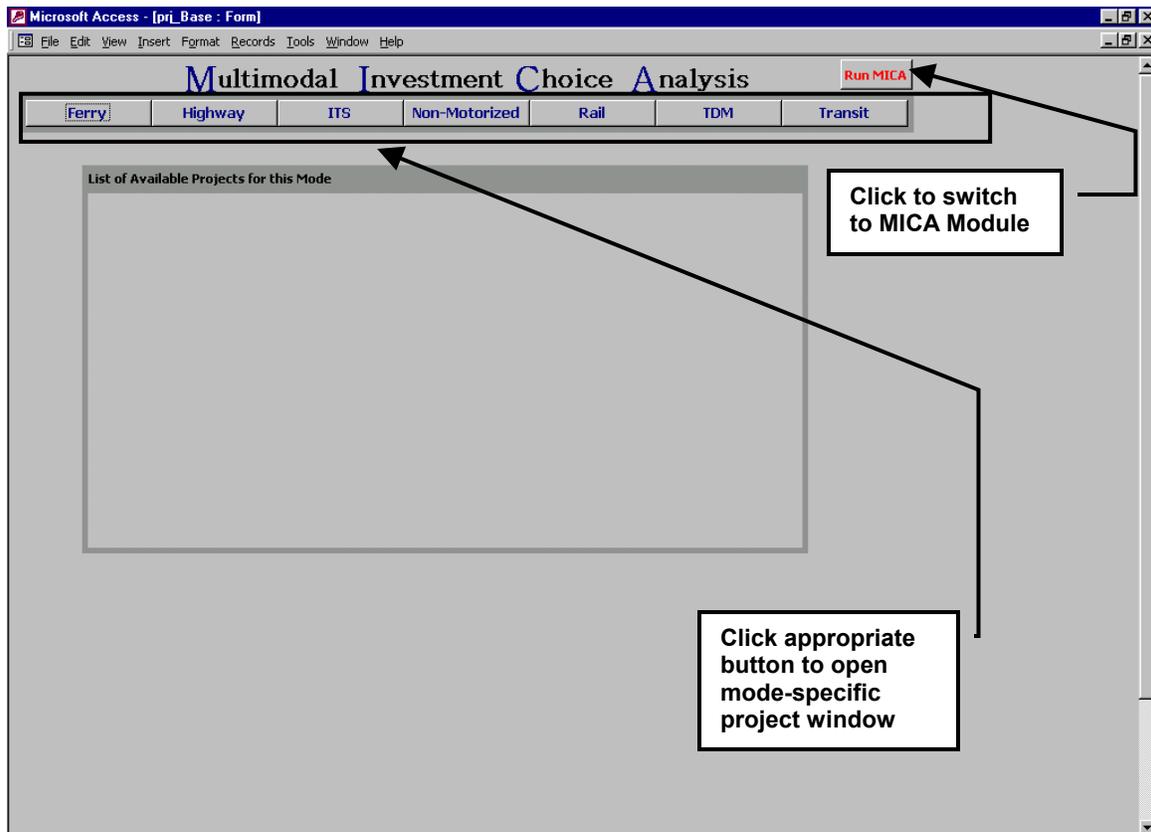
Figure 3-1: Starting Screen for Project Module
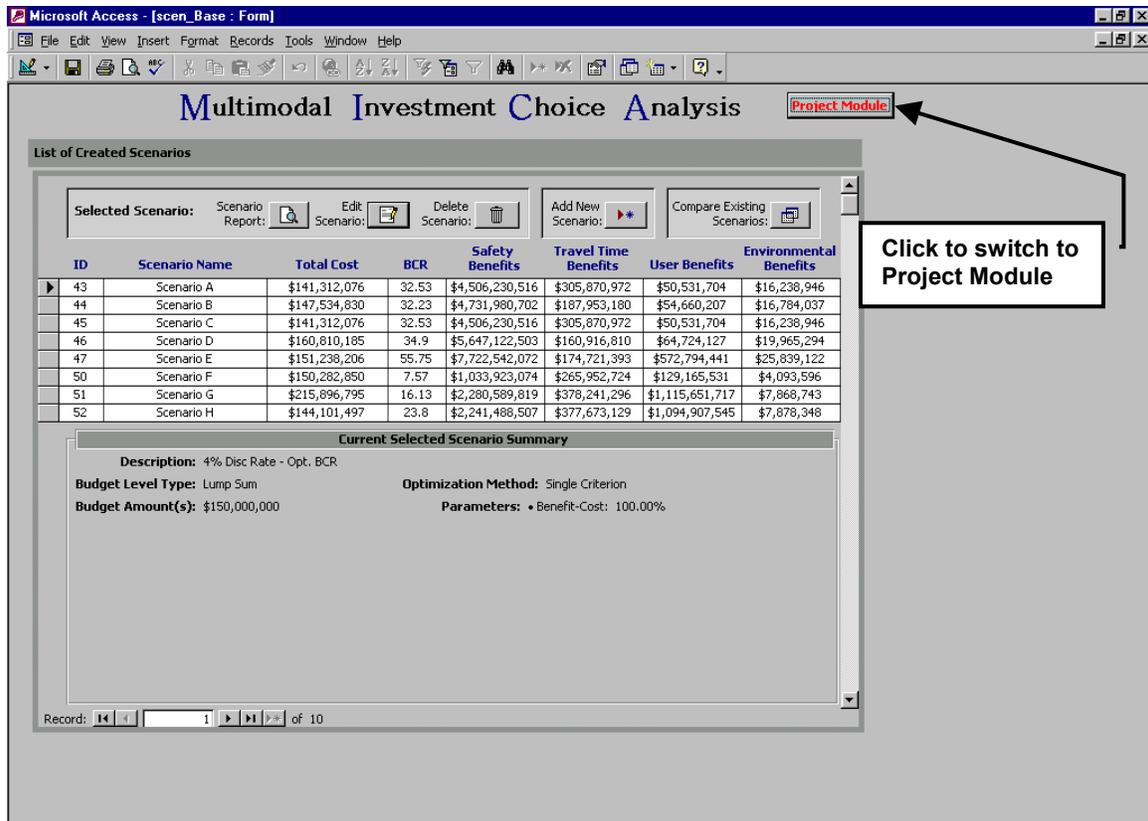
Figure 3-2: Starting Screen for MICA Module

This chapter describes the user inputs and general procedures employed by the MICA program. The project-specific inputs and procedures will be described in the subsequent mode chapters of this report.

Project Module

Opening Screen for Project-Level Analysis

All project-level data are input, and analyses completed in the Project Module. Figure 3-3 shows a representative starting screen for project-level analysis. The figure shows the window that opens for Rail project analysis, but all mode-level opening screens have the same features shown in the figure. These features are:

Description of projects in database – Lists all of the projects that have been either completely or partially entered into the database for that mode. This summary listing indicates the Project Title, Project Type, and the Region of Washington State in which it is located.

Input status – Indicates whether or not the data that is required for analysis is complete, for each project listed. If the required input data is complete, the box is checked. If any piece of data required for project analysis is missing, the box is not checked. Note, only the projects with complete input status are brought into the MICA module for multimodal analysis.

Project selection status – Displays an arrow next to the project on the list that is currently selected. Only one project at a time may be selected. In the Figure 3-3 example, the third project on the list is shown as selected. The user can select a different project by clicking anywhere on the row of the description for that project, in which case the arrow would move to the new selection.

Sub-category button – Indicates which sub-category of the mode is active. In the Figure 3-3 example, only one sub-category (Improvements) is available. However, for other modes more than one sub-category is present. Sub-categories will be described in the mode-specific chapters when they are applicable.

Project entry buttons – Each button launches one of the four possible actions that the user can perform in project-level data entry and analysis. The user clicks the **Add** button to enter a new project. The other three actions, **Edit**, **Preview** and **Delete**, are performed on projects that already exist within the database. In this case, the user first selects the project and then clicks the button for the appropriate action. The four project entry actions are described in the following sections.
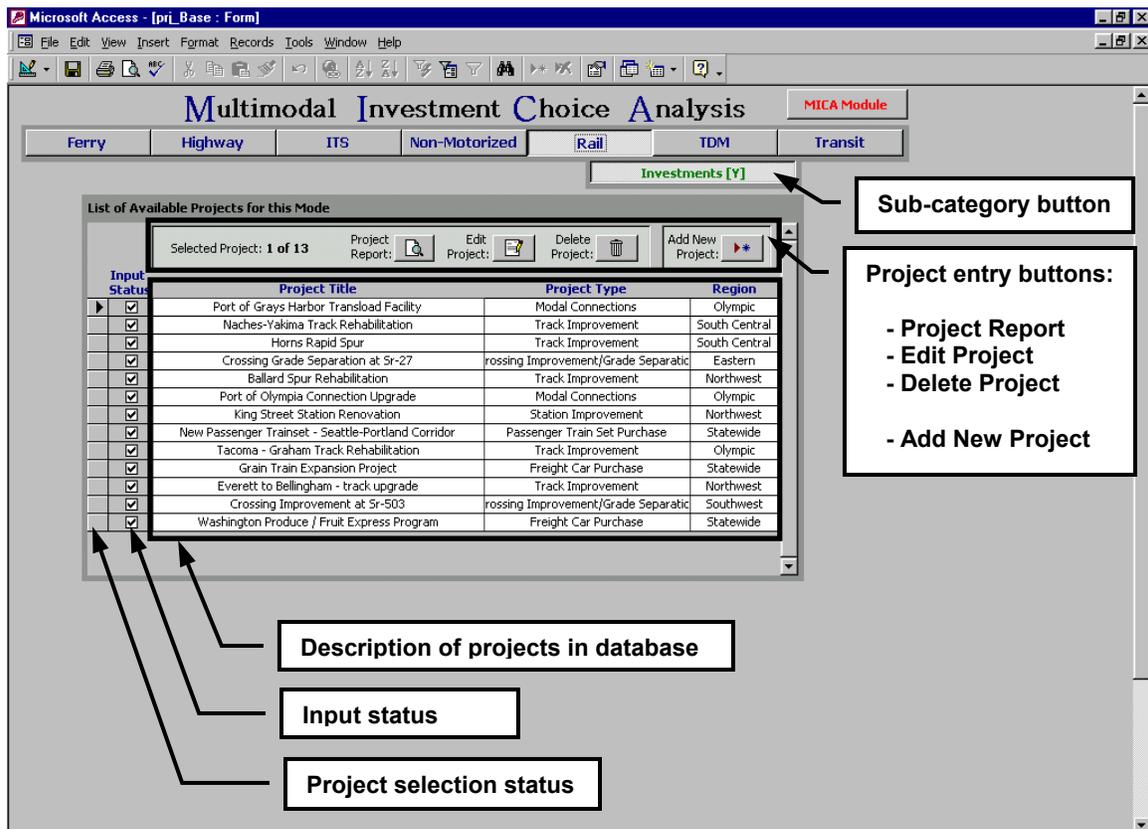
Figure 3-3: Example of Starting Screen for Project-Level Analysis

Add a New Project

The **Add** button is selected when the user wants to add a completely new project to the database within the active mode. Figure 3-4 shows the first page of a representative Input Form for adding a new project. The figure shows the window that opens for Ferry construction projects, but all mode-level opening screens have the same features shown in the figure.

For all modes and projects in the database there are four components of data requirements, each presented on a separate "page" of the Project Input Form:

- General Project Information

- Project Benefits

- Outcome Objectives

- Project Costs

The user can access each of the four pages by clicking on the appropriate tab at the top of the Project Input Form. Alternatively, clicking on the **Continue** button at the bottom of the screen will advance the user to the next page of the Input Form.


Figure 3-4: Example of Project Input Form, General Information

<u>**General Project Information**</u>

This component contains of descriptive data for the project. All projects in all mode categories require the following descriptive information:

- **Project Title –** Descriptive title of the project

- **Project Identification Number –** Identifier that is unique to the project

- **Project Type –** Specific type of project, selected from a pull down list specific to the mode. The project types for each mode category are summarized in Table 1-1, and are described in detail in each of the mode chapters of this report.

- **Biennium** – Biennium in which the project is to be considered for funding

- **Region –** WSDOT Region in which the project is located. A pull down menu provides the six region options: **Eastern**, **North Central**, **Northwest**, **Olympic**, **South Central** and **Southwest**. Two additional options are presented: **Statewide** should be selected if the project is located in multiple regions, and since they are not considered within regional constraints, **Ferry** should be selected for all Ferry projects.

- **Legislative District –** State Legislative District in which the project is located.

- **Air Quality –** Air quality designation, as identified by the Clean Air Act. A pull down menu provides the options of **Attainment Area**, **Non-Attainment Area**, **Maintenance Area,** or **Unclassifiable** (as described in the Project Measures chapter of this report).

- **WTP Corridor –** Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). A pull down menu provides the options of **Yes** or **No**.

- **Strategic Freight Network –** Identifies the Freight Goods Transportation System (FGTS) Classification. A pull down menu provides the options of **T-1**, **T-2**, **T-3**, **T-4**, **T-5**, or **None** (as described in the Project Measures chapter of this report).

Different modes may have additional required descriptive data within the General Project Information component. For modes to which this applies, the additional requirements are described in the mode chapter.

<u>**Project Benefits**</u>

The benefits input worksheet collects all data needed to calculate the **User Operating**, **Environmental**, and **Safety** benefits. Each project type within each mode has a unique procedure for calculating benefits, and each procedure is quite involved. All benefits calculation procedures are described in detail in the mode chapters of this report.

Outcome Objectives

The MICA outcome objective worksheets are broken down into the three major components of the overall vision – Vibrant Communities, Vital Economy, and Sustainable Environment. The following paragraphs describe how the 100 possible points are distributed within each outcome objective question. The question numbers correspond to the outcome areas shown in Table 2-17.

Vibrant Community Outcomes

Figure 3-5 shows the input screen for the Vibrant Community outcome objectives.

The Vibrant Community outcomes are scored as follows:

Outcome 1 – System Operation and Maintenance
Parts A, B, and C are worth 34, 33, and 33 points respectively. Points are assigned if the user selects a yes answer for each part. The user must select the strategy associated with Part B.

Outcome 2 – System Preservation
A score of 50 points is assigned if the user answers yes to question 2. The user must also select a preservation strategy from the pull-down list. An additional 50 points is assigned if the project type for the particular project is classified as a preservation project.

Outcome 3 – Special Needs Transportation
A score of 75 points is assigned if the user answers yes to question 3. The user must also select a strategy from the pull-down list. An additional 25 points is assigned if the project type for the particular project is associated with Special Needs Transportation.

Outcome 4 – Congestion Relief
Points are only assigned if the project is located within an identified WTP Corridor (see General Project Information). If the calculated travel time savings is positive then a score of 100 points is assigned. If the travel time savings is equal to zero, 50 points are assigned. Finally, if the travel time minutes is estimated to be negative then 0 points are assigned.

Outcome 5 – Increased Travel Options
Parts A and B are each worth 50 points. Points are assigned if the user selects a yes answer for each part.

Outcome 6 – Seamless Connections
Parts A and B are each worth 50 points. Points are assigned if the user selects a yes answer for each part.

Outcome 7 – Safety
If the calculated safety benefits are greater then zero a score of 80 points is assigned. If the calculated safety benefits are equal to zero then a score of 40 points is assigned. Finally, if the safety benefits are negative then a score of 0 points is assigned. An additional 20 points are assigned if the user selects a yes answer.

Outcome 8 – Security
A score of 100 points is assigned if the user answers yes to question 8.

Outcome 9 – Community Based Design
20 points is given for each of the five livable communities strategies utilized by the project.

Outcome 10 – Collaborative Decision Making
Parts A and B are each worth 50 points. Points are assigned if the user selects a yes answer for
part A and if the number of partnerships entered is greater then 0 for part B.

OUTCOME OBJECTIVE QUESTIONS

Instructions: Please enter in the appropriate values below.

☑ **Community**   ☑ **Economic**   ☑ **Environment**

1. Does the proposed project increase the transportation system's operation by:

   addressing an existing maintenance deficiency? (Project area
   currently does not meet a minimum threshold value as defined in the   Yes ▾
   service objectives.)

   utilitzing existing resources more efficiently?   Yes ▾

   If yes, how?   Signal Timing/Coordination   ▾

   maintaining services in the event of a disaster?   No ▾

2. Does the proposed project preserve the existing transportation
infrastructure?   Yes ▾

   If yes, how?   Structural Failure   ▾

3. Does the proposed project increase the number of basic transportation
needs being met?   Yes ▾

   If yes, how?   Increase Service/Accessibility for Special Needs Population ▾

4. Does the proposed project provide congestion relief by reducing person and   No ▾
freight delay on a designated WTP Corridor?

5. Does the proposed project improve viability of alternatives to privately-
owned automobile trips by providing:

   new alternatives?   No ▾

   better quality of existing alternatives?   Yes ▾

6. Does the proposed project provide easier connections between different
services by:

   decreasing the number of barriers?   Yes ▾

   increasing the ease of transfer?   No ▾

7. Does the proposed project reduce and prevent deaths, disabling injuries,   No ▾
and societal costs of accidents?

   Does the project area currently not meet threshold rates as defined in the   No ▾
   service objectives?

8. Does the proposed project improve the safety and security of the   Yes ▾
transportation system?

   If yes, how?   Establish Emergency Plans   ▾

9. Does the proposed project support livable communities and increase community satisfaction
with the development and implementation of transportation services by: (Check all that Apply)

   Compatible with Community's Vision   ☐

   Address Existing Noise Impacts   ☐ Address Existing Traffic Impacts   ☑

   Minimize Noise Impacts   ☑ Minimize Traffic Impacts to Communities   ☑

10. Does the proposed project support livable communities through effective   No ▾
collaborative decision-making?

   How many partnerships are involved with the project?   Text203:   12

Figure 3-5: "Vibrant Community" Outcome Objective Inputs

Vital Economy Outcomes

Figure 3-6 shows the input screen for the Vital Economy outcome objectives.

Figure 3-6: "Vital Economy" Outcome Objective Inputs

The Vital Economy outcomes are scored as follows:

Outcome 11 – Freight
Points are assigned according to the level of FGTS Classification with T-1 classification warranting a score of 90 points, and T-5 classification warranting a score of 54 points. T-2, T-3 and T-4 classifications warrant scores of 81, 72, and 63 respectively. Part B is worth an additional 10 points, which are assigned if the user selects a yes answer.

Outcome 12 – Economic Prosperity
Parts A and B are each worth 50 points. Points are assigned if the user selects a yes answer for each part.

Outcome 13 – Tourism
Parts A and B are each worth 50 points. Points are assigned if the user selects a yes answer for each part.

Sustainable Environment Outcomes

Figure 3-7 shows the input screen for the Sustainable Environment outcome objectives.

Figure 3-7: "Sustainable Environment" Outcome Objective Inputs

Outcome 14 – Air Quality
Air quality points are assigned based on the calculated value of environmental benefits and the air quality classification of the project region. Positive environmental benefits in a non-attainment area scores 80 points while in a maintenance area it would score 60 points. Positive environmental benefits in an attainment or unclassifiable area would score 40 points. If the environmental benefits equaled zero the scores for non-attainment, maintenance, and attainment or unclassifiable would be 70, 50, and 40 respectively. If the environmental benefits were negative, the scores for the non-attainment, maintenance, and attainment or unclassifiable categories would be 0, 20, and 40 respectively. Part B is worth an additional 10 points if the user selects a yes answer.

Outcome 15 – Water Quality
Parts A, B, and C is worth 34, 33, and 33 points respectively. Full points are assigned if the user selects a yes answer for each part. Half points are assigned if a N/A is selected for an answer for each part.

Outcome 16 – Habitat
  Questions A through D are each worth 5 points and the points are assigned if the user selects a yes answer for each part. Part E is worth up to 40 points with the full points assigned for zero impact. 20 or 10 points are assigned for the next two levels of impact and 0 points are assigned for the highest level of impact. Part F is also worth up to 40 points with the full points assigned for

zero impact. 20 or 10 points are assigned for the next two levels of impact and 0 points are assigned for the highest level of impact

Outcome 17 – Use of Resources
A score of 50 points is assigned if the user answers yes to question 17.

Project Costs

The cost inputs and calculations are uniform for all projects within all modes in MICA. Figure 3-8 illustrates the input screen for project costs, which include these components: **Capital Costs** (out of which Environmental Retrofit Capital Costs are distinguished), **Operation and Maintenance Costs**, and **Terminal Value**. Additionally, the cost components are input according to their source: WSDOT, Federal, and three "Other" sources that are named by the user. Other sources could include city, county, private, and non-WSDOT state funding.

Figure 3-8: Cost Input Form

Capital Costs
The program allows Capital Costs of a project that span up to five bienniums (10 years) to be considered. To calculate the net present value (NPV) of capital costs, MICA calculates the *Present Worth of a Future Su*m for each biennium, and sums the NPV value for each biennium to calculate the total capital cost.

$$NPV_{Cap\_Cost} = \sum_{b=1}^{5} Cap\_Cost_b * (1+i)^{(2*b-1)}$$

Equation 3-1

Where, NPV_{Cap_Cost} = Net Present Value of the Capital Cost

b = biennium number

Cap_Cost_b = Capital Cost entered for biennium "b"

i = discount rate

$(2 * b - 1) = n$ = midpoint of the biennium = analysis period

This calculation is performed for each funding source, and the various sources are summed to calculate the total capital cost of the project.

The *Environmental Retrofit* section asks that the user identify the amount from the capital cost that will be spent on the three environmental retrofit projects: Fish Barrier Removal, Storm Water Retrofit, and Noise Barrier. The same calculation is used to determine the NPV of these costs. The environmental retrofit costs are singled out simply so that the benefits of these projects may be estimated. Once the NPV_Cost is calculated, the benefit-cost ratio for the project type is applied to estimate the NPV_Benefit (as described in the *Project Measures* chapter).

Operation and Maintenance Costs
The operation and maintenance (O&M) cost values that are input are assumed to occur annually for the duration of the analysis period. Thus, the MICA calculates the NPV of O&M costs by using the Present Worth of a Uniform Annual Series equation.

$$NPV_{O\&M\_Cost} = O\&M\_Cost_{ann} * \left(\frac{(1+i)^n - 1}{i(1+i)^n} \right)$$

Equation 3-2

Where, $NPV_{O\&M\_Cost}$ = Net Present Value of the Operating and Maintenance Costs

$O\&M\_Cost_{ann}$ = Annual O&M cost entered by user

i = discount rate

n = analysis period

This calculation is performed for each funding source, and the various sources are summed to calculate the total O&M cost of the project.

Terminal Value
The terminal value is input as a single value that represents the residual value of the project at the end of the analysis period. To calculate the NPV of the terminal value, the *Present Worth of a Future Su*m is calculated.

$$NPV_{Term\_Value} = Term\_Value * (1 + i)^n$$ **Equation 3-3**

Where, NPV_{Term_Value} = Net Present Value of the Terminal Value

$Term\_Value$ = Terminal Value entered by user

i = discount rate

n = analysis period

Edit an Existing Project

Selecting the **Edit** button, as shown in the Project Level Analysis starting screen in Figure 3-3, allows the user to add or change data for a selected project that has previously been partially or completely entered. The project to be edited must first be selected from the project list. Then clicking the **Edit** button will open the same series of windows that are used when adding a project. The previously entered data will be displayed in the input fields, and the user can change or add to it as needed.

Preview an Existing Project

Selecting the **Preview** button, as shown in the Project Level Analysis starting screen in Figure 3-3, initiates MICA's calculation of the project measures for the selected project, and then displays a print-ready project report. The project report summarizes all of the calculated project measures, as well as the input data and global assumptions that were used in the calculations.

The project measure calculations can only be performed if the input data is complete. If the data is incomplete, an error message stating that there is missing information will appear when the **Preview** option is selected. However, a project report will still generate that summarizes the entered input data, with no project measures displayed.

Delete an Existing Project

Selecting the **Delete** button, as shown in the Project Level Analysis starting screen in Figure 3-3, allows the user to completely remove a selected project from the MICA database. To remove a project, the user must simply select the project, and then click the **Delete** button. A message box will appear to confirm that the user wants to delete the selected record (the term record refers to the selected project).

MICA Module

In the MICA module, individual scenarios are defined and multiple scenarios are compared. Figure 3-9 shows the starting screen for the MICA module.

Opening Screen for Scenario-Level Analysis

The major functions of the Scenario-Level Analysis screen, as shown in Figure 3-9, are described as follows.

<u>**Description of scenarios in the database**</u> – Lists all of the scenarios that have been previously defined. The summary listing indicates the scenario identification number, scenario name, the total costs of all projects funded in the scenario, and the cumulative safety, travel time, user, and environmental benefits for the scenario.

<u>**Description of selected scenario**</u> – Lists the details of the scenario that is currently selected from the list of scenarios in the database. The pencil icon to the far left of the scenario list indicates the current scenario.

<u>**Selected Scenario action buttons**</u> – Each button launches one of the three possible actions that the user can perform with existing scenarios in the database. The three actions are **Scenario Report, Edit Scenario**, and **Delete Scenario**. The three scenario action buttons are described in the following sections.

<u>**Add New Scenario**</u> – The **Add New Scenario** button creates a new scenario in the database. The steps involved in adding a new scenario are described in the following section.

<u>**Compare Scenarios**</u> - The **Compare Scenarios** button compares the selected scenarios. The check box located to the left of the Scenario Name indicates whether the particular scenario will be included in the comparison.
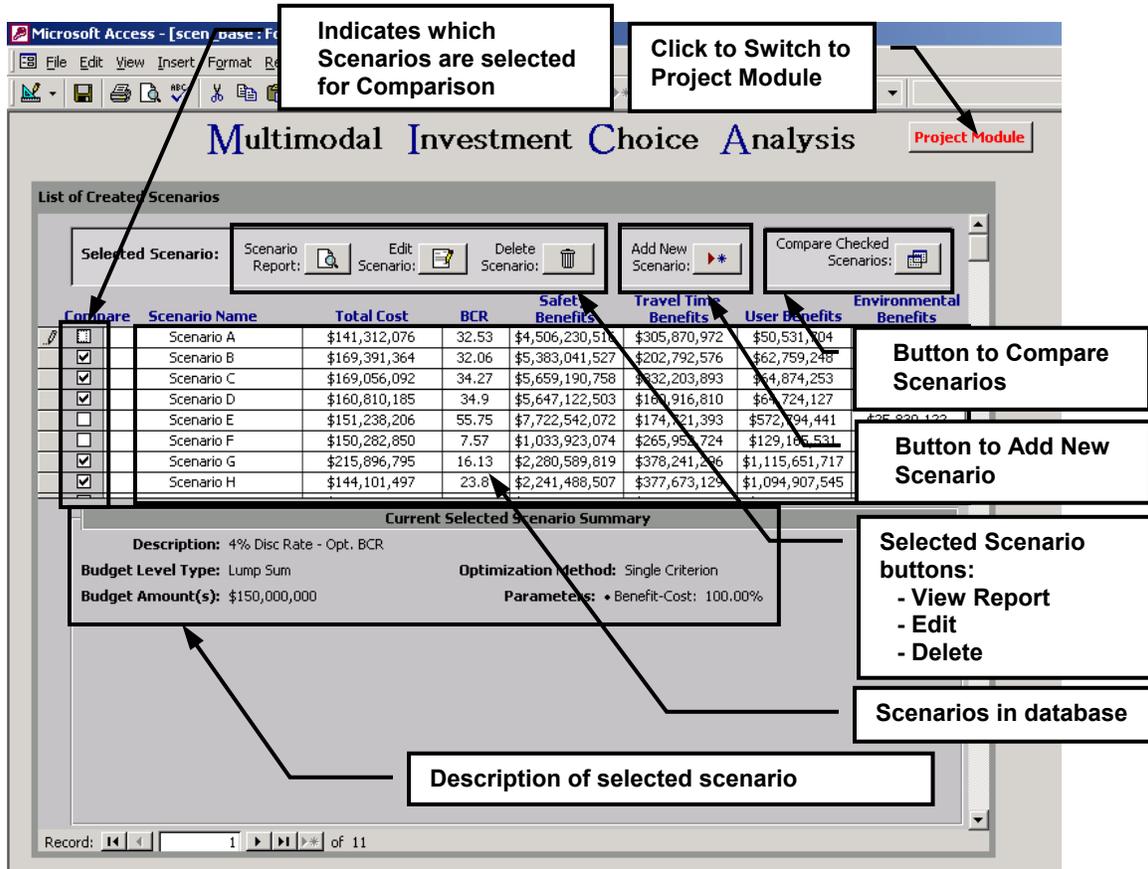
Figure 3-9: MICA Level Analysis Screen

Add New Scenario

The **Add** button is selected when the user wants to add a completely new scenario to the database. Figure 3-10 shows the first page of the Scenario Input Form.

There seven steps to entering a new scenario with each step presented on a separate "page" of the Scenario Input Form:

1. Scenario Info

2. Assumptions

3. Budget Levels

4. Select Projects

5. Project Criteria

6. Optimization Method

7. Generate Scenario

The user can access each of the seven pages by clicking on the appropriate tab at the top of the form.

Scenario Info

The first step of generating a scenario is to enter the descriptive date for the new scenario. All scenarios require the following descriptive information, as shown in Figure 3-10:

Scenario ID – Identifier that is unique to the scenario

Scenario Name – Name of the scenario

Description – Description of the scenario

Author – Name of user creating the scenario

Date Created – Date the scenario was created

Figure 3-10: Scenario Input Form, Scenario Info

Assumptions

The Assumptions Screen, which is shown in Figure 3-11, shows the values of the global variables that are currently being used by the program. The *Project Measures* chapter contains a discussion of these global variables and their default values. The user can (1) accept the variables as they are by moving to the next tab or (2) choose to modify the global variable values. If changes are made to this screen, a message box will appear to confirm that the user would like to make modifications to the values and to warn that this will cause all the projects within the database to be recalculated.

:

Figure 3-11: Scenario Input Form, Global Variables Screen

Budget Levels

In the Budget Levels Screen, shown in Figure 3-12, the user selects the budget period of either **2 Years**, **6 Years**, **10 Years** or **20 Years**. The user enters the appropriate budget amounts for *each* two-year period within the total selected period. Figure 3-12 shows the screen that appears if a two-year (one biennium) budget period is selected. If, for example, the six- year budget period were selected, the user would have to enter a budget amount for three bienniums. In addition, the user has the choice of constraining the allocations to **Budget Per Region** or **Budget Per Mode**.
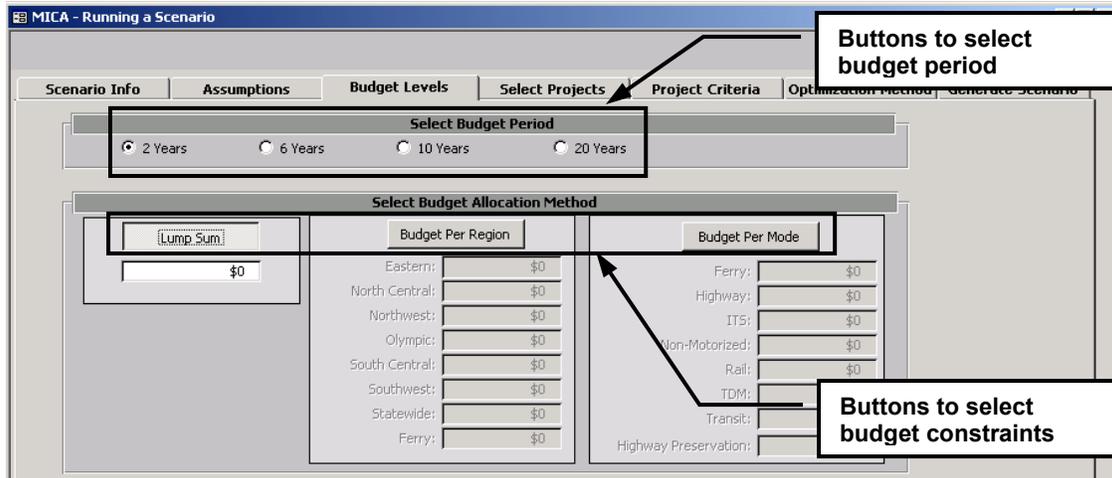
Figure 3-12: Scenario Input Form, Budget Levels Screen

Select Projects

The Select Projects screen, shown in

Figure 3-13, allows the user to select the projects that are to be considered for funding, among the total list of projects. This screen displays a list of all completed projects in the database, along with project information such as identification number, project title, mode and project type, region, and WSDOT project cost. A check in the **Select Proj** box indicates the project has been selected for funding consideration. The user can **Select All** or **Clear All** projects using the buttons above the project list in addition to individually selecting or deselecting projects by clicking on the **Select Proj** box for each project.

The **By Region** and **By Mode** project selection filters can be used to quickly sort through projects by mode or by region. A check box indicates that the region or mode selected will be included in the filtered project list. **Rebuild Completed Project List** will apply the filters to the completed project list shown above.
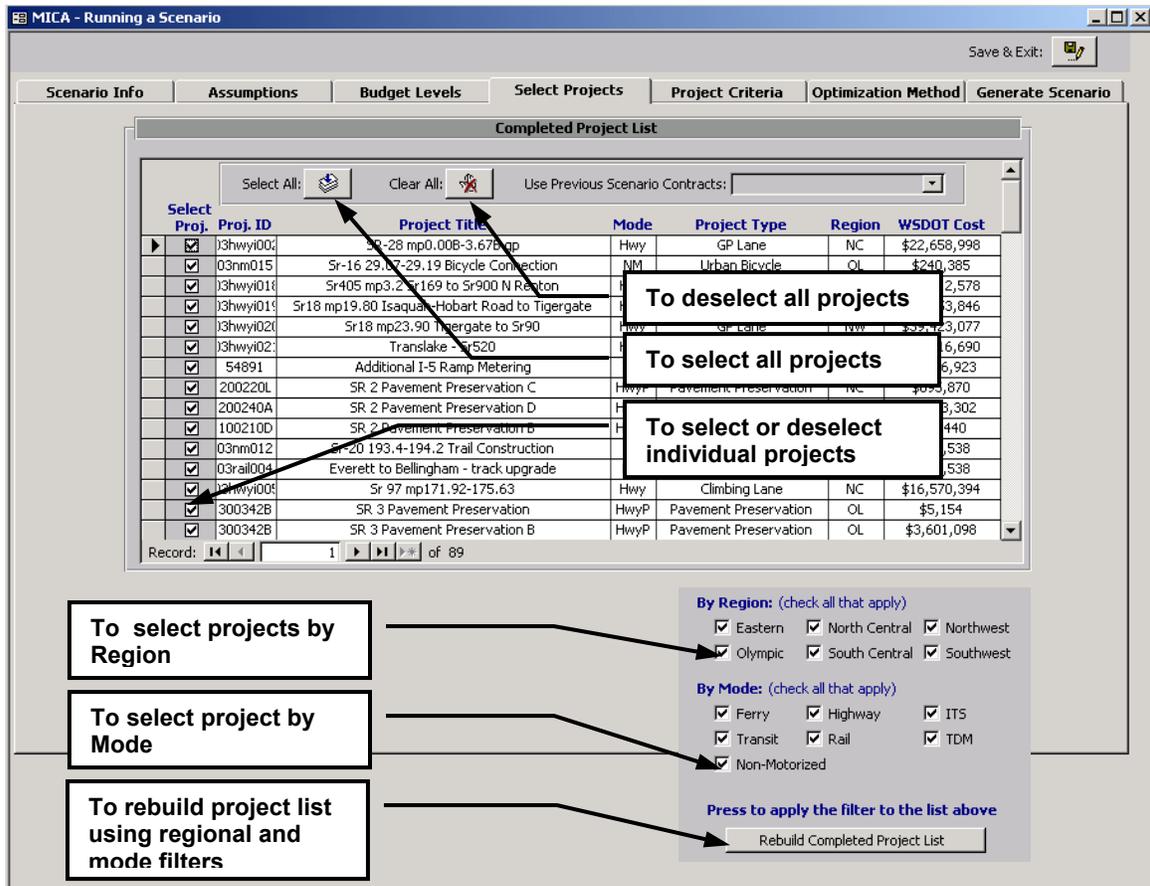
Figure 3-13: Scenario Input Form, Select Projects Screen

Project Criteria

The Project Criteria screen, as shown in Figure 3-14, allows the screening out of projects that do not meet minimum thresholds specified by the user. To do this, the user enters a minimum value for each project criterion the he or she wishes to be screened. For example, the user may only want to consider projects with a benefit-cost ratio greater than 1 and safety benefits greater than 0. By inputting a "1" into the "Benefit Cost Ratio" box and a "0" into the "Safety Benefits" box, unacceptable projects are screened from funding consideration. If all Minimum Threshold boxes are left empty, all projects defined in the previous step (Select Projects) are considered in the analysis. The project criteria consist of 22 categories: the benefit-cost ratio, four estimated benefit categories, and the 17 outcome objective areas.

Figure 3-14: Scenario Input Form, Project Criteria Screen

Optimization Method

In the Optimization Method screen, shown in Figure 3-15, the user sets the optimization priorities for the scenario. Priorities can be based on **Single Criterion**, **Multi-Criteria**, or **Weighted Multi-Criteria**. The project selection criteria are selected from a list of 22 categories (as described in the previous "Project Criteria" step).

Single Criterion Optimization – The user selects one optimization criterion from the pull-down list of 22 categories.

Multi-Criteria Optimization – The user selects as many criteria as desired from the list of 22 categories. The optimization weights each selected criterion equally.

Weighted Multi-Criteria Optimization – The user enters a weighting factors between 0 and 1 for as many criteria as desired from the list of 22 categories. The sum of all the weighting factors must equal 1.0. If they do not, an error message will appear and the scenario analysis will not proceed. The optimization step will use the criteria categories and the entered weights.

Important Note:

When selecting criteria for optimization the user should be aware of issues with "double-counting". Including measures such as benefit-cost ratio *and* safety benefits would count the safety benefits twice since they are already included in the benefit-cost ratio measure. In addition, certain outcome objectives capture the same measures as benefit-cost ratio. For example, due to the nature of preservation projects they tend to score high in the benefit-cost ratio category since typical preservations projects require little capital to maintain the benefits of facility. Therefore using the benefit-cost ratio category and the preservation outcome objective together would place weight on preservation projects. A general rule of thumb is that it is best to use either the benefit categories or the outcome objective categories to avoid issues with double counting. Another rule of thumb is to limit the number of categories included in the optimization to five or six. Beyond that number the optimization program is most likely only utilizing some of the criteria and it is difficult to decipher the which criteria are reflected in the funded projects list for that scenario.
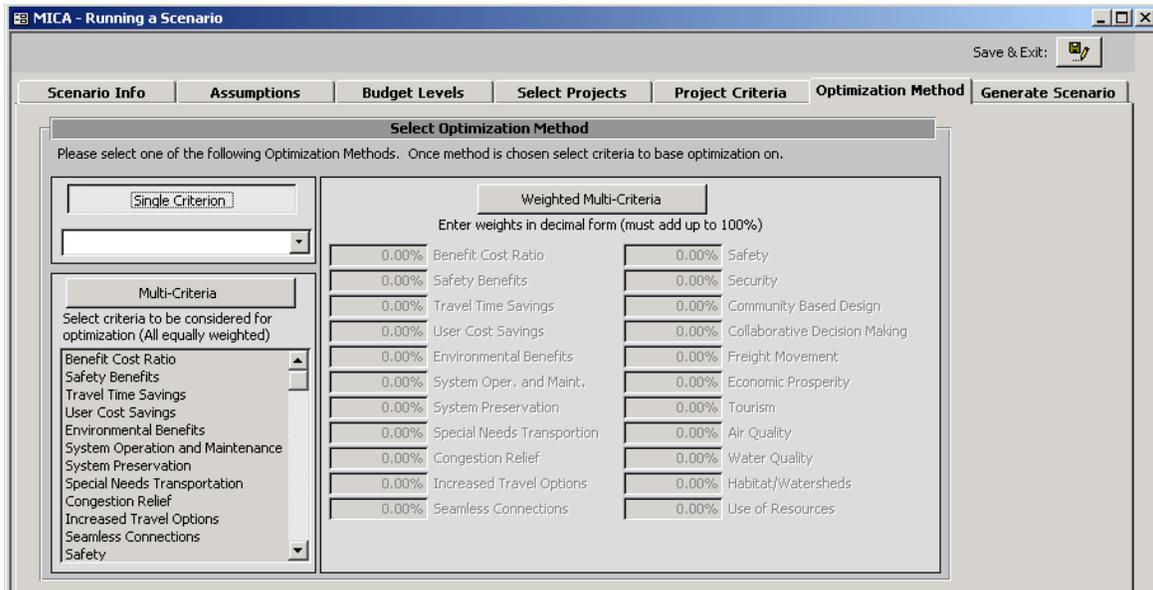
Figure 3-15: Scenario Input Form, Optimization Methods Screen

Generate Scenario

When the user selects the **Generate Scenario** tab the program will *automatically* run the scenario calculations, based upon the optimization criteria and budget levels defined by the analyst in the previous steps. Scenario calculations consist of (1) optimization calculations and (2) selection of a set of funded projects. The scenario inputs of budget allocation, project selection, and optimization method must be completed before the **Generate Scenario** function can be run. If these inputs are incomplete, an error message will appear when the user selects this tab.

Figure 3-16 shows the **Generate Scenario** screen, which displays the results of the scenario analysis. The "Optimization Summary" lists all of the scenario parameters input by the user in the previous screens. The "Funded Project List" identifies the projects selected for funding under the scenario, and summarizes the total WSDOT cost and the total benefit-cost ratio for all funded projects.
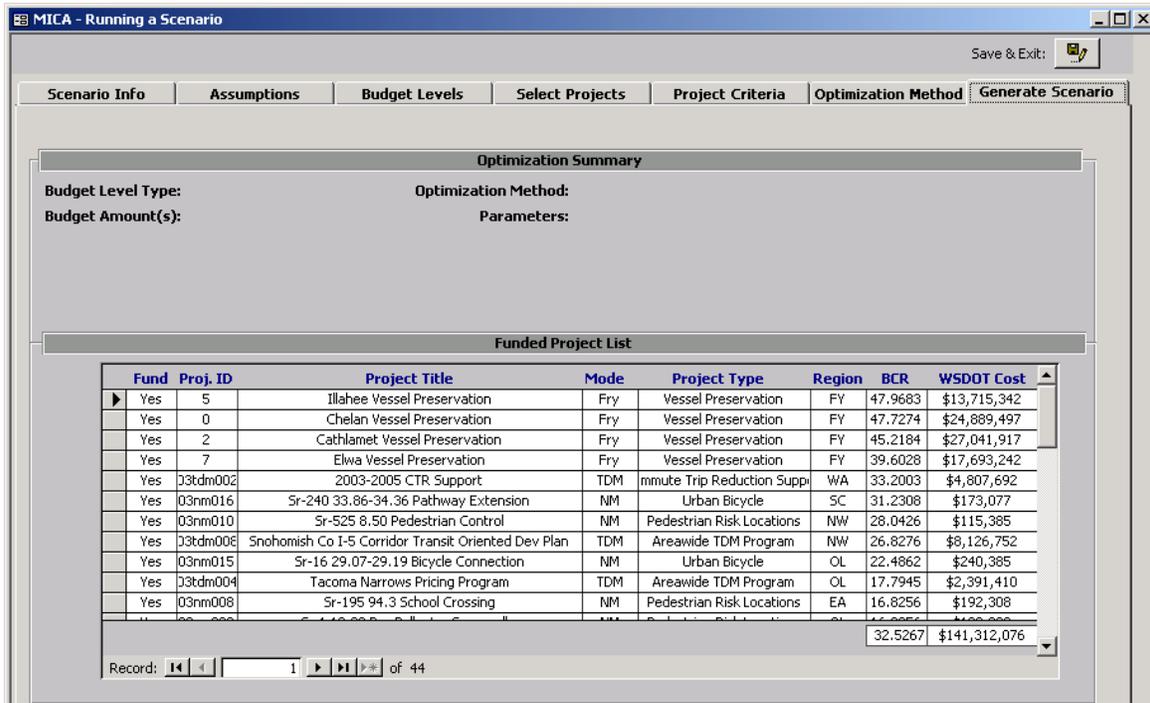
Figure 3-16: Scenario Input Form, Generate Scenarios Screen

Edit an Existing Scenario

Selecting the **Edit** button, as shown in the Scenario Analysis starting screen in Figure 3-2 allows the user to add or change data for a selected scenario that has previously been partially or completely entered. The scenario to be edited must first be selected from the project list. Then clicking the **Edit** button will open the same series of windows that are used when adding a scenario. The previously entered data will be displayed in the input fields, and the user can change or add to it as needed.

Preview an Existing Scenario

Selecting the **Preview** button, as shown in the Scenario Analysis starting screen in Figure 3-2, generates a print-ready scenario report. The scenario report summarizes the scenario input information as well as listing the funded and unfunded projects. In addition, the report provides the Cumulative Scenario Measures of costs and benefits, average outcome objective scores, total benefit-cost ratio, and funding summaries by mode and region.

Delete an Existing Scenario

Selecting the **Delete** button, as shown in the Scenario Analysis starting screen in Figure 3-2, allows the user to completely remove a selected scenario from the MICA database. To remove a scenario, the user must simply select the scenario, and then click the **Delete** button.

Compare Scenarios

Selecting the **Compare** button, as shown in the Scenario Analysis starting screen in Figure 3-9, allows the user to compare multiple scenarios. Figure 3-17 shows the initial form that displays when the **Compare** button is selected. All of the scenarios that were selected in the previous screen (Figure 3-9) are displayed. The tabs across the top of the form list the four comparison information forms. The **Preview Comparison Report** button allows the user to print the current form view. The Close Comparison Window button closes the comparison forms and returns the user back to the Scenario Analysis starting screen (Figure 3-9).

Figure 3-17: Selected Scenarios for Comparison

Figure 3-18 shows the benefit comparison screen for the scenario comparison analysis. The form lists the selected scenarios and tabulates the overall benefit cost ratio, estimated accident reductions by accident types, estimated reduction in pollutants by emission types, in addition to the overall benefits for safety, travel time, user, and environmental benefits. The tabular format allows for quick comparison of the different benefit categories.

Figure 3-18: Scenario Benefits Comparison

Figure 3-19 shows the outcome objectives screen for the scenario comparison analysis. The form lists the selected scenarios and tabulates the average outcome objective score. The tabular format allows for quick comparison of the different outcome objective categories.
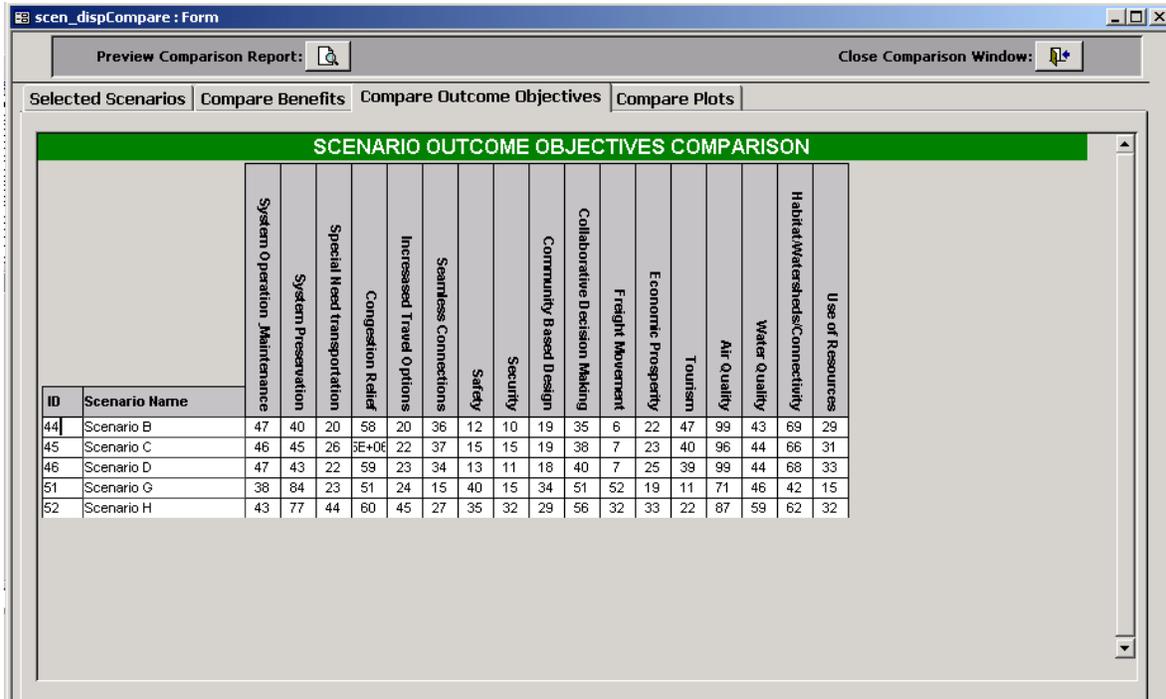
Figure 3-19: Scenario Outcome Objectives Comparison

The final and perhaps most useful screen of the scenario comparison analysis is the Compare Plots form shown in Figure 3-20. This form allows the user to select the categories in which to display the scenario comparison information graphically. The user may manually select the categories to graph from the list on the left side of the screen or use the six buttons above the list to perform common comparison plots. The scenario comparison plots allow the user to graphically see where the gains and losses are between scenarios.

The six common comparison plots listed in the buttons mentioned above are further described below:

Scenario benefits – Graphs the travel time, safety, user, and environmental benefit levels for each of the selected scenarios.

Travel Time Reductions – Graphs the estimated travel time reductions for both all traffic and for just freight traffic. In addition the user transfer estimate is also graphed each of the selected scenarios.

Pollution Reductions – Graphs the estimated emission reductions for CO, NOX, VOC, and PM-10 pollutants for each of the selected scenarios.

Safety Reductions – Graphs the estimated accident reductions for fatality, injury, and property damage only accidents for each of the selected scenarios.

Modal Funding – Graphs the funding by mode for each of the selected scenarios.

Regional Funding – Graphs the funding by region, including statewide and ferry modes, for each of the selected scenarios.
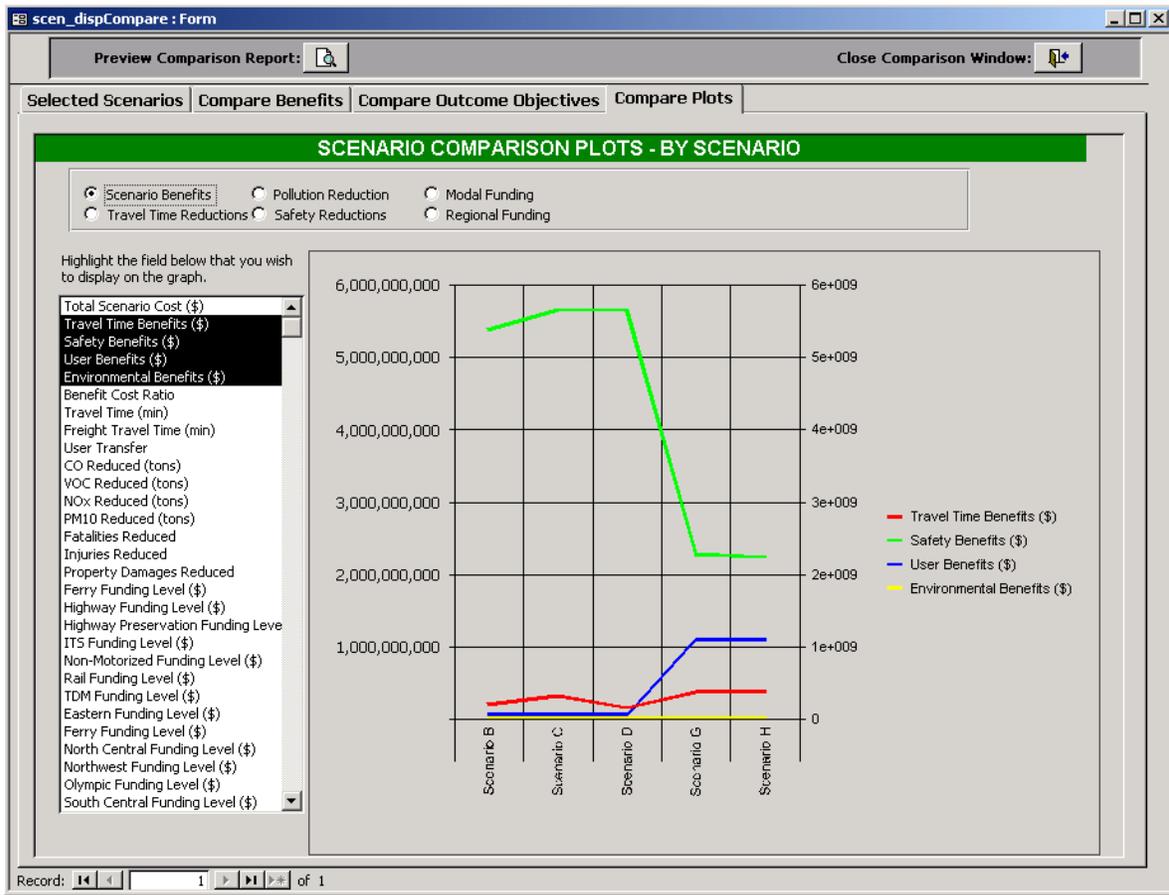
Figure 3-20: Comparison Plots by Scenario

Chapter 4 – Ferry Systems

Projects for the ferry system are broken down into two major categories, construction and preservation programs for both terminal and vessel projects. Preservation projects are the higher priority for the ferry system and the majority of the projects under funding consideration fall into this category. Construction projects are usually identified by forecasted demands of the ferry system. Preservation projects for both vessel and terminal infrastructure are identified through the Washington State Ferry System (WSF) Life-Cycle Cost Model.

Inventory of projects

The current WSF Capital Plan identifies infrastructure needs for 2001-2011 for both the Current Law and New Law cases. The New Law case assumes additional monies available from unsecured future funding sources such as proposed tax or fare increases. The current law program identifies projects 125 projects under the categories of terminal (20 terminal locations), system-wide, and vessel class (10 sub-categories). The Current Law Construction Program is estimated at $163 million for the 2001-2003 biennium, $420 million for the six-year plan, and $693 million for the ten-year plan.

Inventory of current analysis methods

The WSF Life-Cycle Cost Model identifies potential terminal and vessel preservation projects. Each vessel and terminal within the system is analyzed for the upcoming 10-year period using the average life cycle for vital and non-vital elements of the terminal or vessel. Each element in the model is assigned an expected life and a typical cost of replacement. A condition rating for the vital and non-vital systems is assigned based on the number of elements that are operating within their expected life cycle. A vital condition rating of 100 corresponds to a terminal or vessel that has 100 percent of its elements operating within its expected life. The condition rating is determined for each of the five bienniums both with and without the recommended improvements. The recommended improvements, as identified by the life cycle cost model, are reviewed by the ferry system operators and revisions based on first-hand knowledge are made before the final proposed improvements are made. The costs identified by the model include 20% engineering and management contingency and 6% inflation costs.

Terminal and vessel construction projects include both new construction and reconstruction of existing facilities or vessels. Analysis of construction projects utilizes demand forecast modeling to analyze the needs for and the impacts of the proposed project. Typically a design study is performed to research and document these findings. Typically very few construction projects are proposed for a given biennium and the capital expenditures very high so the level of analysis is usually very in-depth.

Identification of analysis gaps

Below is a list of known gaps in the analysis. Long-term gaps represent areas where additional data may be needed. These are areas recommended for further work in future phases of the project.

Construction Projects

- Continue to refine the programs use of the travel demand model results.
- Ferry emission and vessel accident rates are currently assumed to be negligible.

Preservation Projects

- Handle isolated island routes differently since the "drive-around" option is not an alternative. Currently you would just enter a large number into the drive-around times to show that it wasn't a feasible alternative.
- Refine the modeling of driver behavior during long-term service disruptions.
- Investigate whether a non-linear relationship would be more appropriate for modeling the probability of service failure based on condition rating.
- Incorporate available information on freight travel and preferably the tonnage and estimated value of freight goods carried.
- Ferry emission and vessel accident rates are currently assumed to be negligible.

Project worksheets and inputs

Chapter 3 – Operation of the MICA program explains the general functions of the project and scenario levels of the program. The following sections focus on the input forms and calculations specific to the Ferry project types.

Project Information

From the Project Level Screen for Ferry the Project Information Screen shown in Figure 4-1 will be displayed when adding or editing a ferry project. The Ferry Project Information Screen is identical for all project types. The Project Benefits screen (shown on the second tab) is the only ferry input screen that is specific to the project type. From any of the ferry project screens, the three buttons at the top of the screen can be selected to delete the current project, preview the calculation results, and save and exit the current project.

Figure 4-1: Ferry Project Information Screen

Project Title: descriptive title of the project

Program Identification Number: Unique identifier used by WSF and WSDOT to identify project.

Project Type: Select appropriate project type from pull down list. Four choices available: Vessel Preservation, Terminal Preservation, Vessel Construction, and Terminal Construction. The program will not allow the user to continue to the remaining three input forms without first selecting a project type.

Region: WSDOT Region for the project. Lists the 6 regional WSDOT offices in addition to a Ferry and Statewide region for special project types.

Legislative District: State Legislative District. If multiple districts apply choose a *primary* district.

Population Density: Choose either urban or rural. If both apply chose a *primary* density.

Air Quality: Attainment/Non-Attainment/Maintenance/Unclassifiable areas as identified by the Clean Air Act. If multiple areas apply choose a *primary* area.

WTP Corridor: Yes or No. Is the project on an identified WTP Corridor?

FGTS Classification: Is the ferry route on the Strategic Freight Network? If so choose one of the five Freight Goods Transportation System Classification (T-1 through T-5) from the pull-down list. Otherwise choose "None".

Preservation Projects

Preservation projects are sub-categorized as either vessel or terminal preservation projects.

<u>Vessel Preservation Projects</u>

The following descriptions refer to **Figure 4-2**.

Vessel Information:

> **Vessel Name:** Name of Vessel to be preserved

> **Ferry Class:** Select the applicable Ferry Class from the pull-down list

Condition Ratings: (From the WSF Life-Cycle Cost Model)

> **Beginning Biennium Start Year:** First year of first biennium in four digit format

> **Current Condition Rating:** Enter the Vital and Non-Vital Condition Ratings at beginning of analysis period

> **Bienniums:** Enter the Vital and Non-Vital Condition Ratings for each biennium.

>> **Base Case:** Projected Condition Ratings without the improvements

>> **Project Case:** Project Condition Ratings with the improvements

Route Information:

Approximate Drive Around Time: Approximate driving time from terminal to terminal. If there is no available drive around route enter 180 minutes (3 hours)

Average Ferry Travel Time: Includes crossing, loading, and unloading times but <u>not</u> waiting times.

Average Daily Trips: For weekday and weekend. Should be the yearly average and account for seasonal highs and lows.

Fare Information:

Car and Driver: Average fare paid for a car and driver. Should be the yearly average and account for peak seasonal and commuter pricing.

Passenger: Average fare paid for a passenger. Should be the yearly average to and account for peak seasonal and commuter pricing.

Trip Purpose Information: The following inputs can be found from the 1999 Travel Survey results

Work/School Business: Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Medical Appt./Personal Business: Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Social/Recreational: Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Boarding Mode Percent - Vehicle: Route specific boarding mode percent for the three periods should be entered. Numbers represent a percentage of total passengers by boarding mode for the period.

Boarding Mode Percent – Walk-On: Route specific boarding mode percent for the three periods should be entered. Numbers represent a percentage of total passengers by boarding mode for the period

Percent of Daily Ridership in PM Peak Period: Percentage of total daily riders typically traveling in the peak period from 3 to 7 p.m.

Average Boat Wait Times: The following inputs can be found from the 1999 Travel Survey results

0-10 Minutes: Percentage of passengers during each of the three periods with a wait time between 1-10 minutes

11-30 Minutes: Percentage of passengers during each of the three periods with a wait time between 11-30 minutes

31-60 Minutes: Percentage of passengers during each of the three periods with a wait time between 31-60 minutes

61-90 Minutes: Percentage of passengers during each of the three periods with a wait time greater then 60 minutes.

Figure 4-2: Vessel Preservation Input Screen

Terminal Preservation Projects

The following descriptions refer to Figure 4-3.

Terminal Information:

> **Terminal Name:** Name of Terminal

Condition Ratings: (From the WSF Life-Cycle Cost Model)

> **Beginning Biennium Start Year:** First year of first biennium in four digit format

> **Current Condition Rating:** Enter the Vital and Non-Vital Condition Ratings at beginning of analysis period

> **Bienniums:** Enter the Vital and Non-Vital Condition Ratings for each biennium.

>> **Base Case:** Projected Condition Ratings without the improvements

>> **Project Case:** Project Condition Ratings with the improvements

The following information should be entered for each route served by the terminal.

Route Information:

> **Approximate Drive Around Time**: Approximate driving time from terminal to terminal. If there is no available drive around route enter 180 minutes (3 hours)

> **Average Ferry Travel Time:** Includes crossing, loading, and unloading times but <u>not</u> waiting times.

> **Average Daily Trips:** For weekday and weekend. Should be the yearly average and account for seasonal highs and lows.

> Fare Information:

Fare Information:

> **Car and Driver:** Average fare paid for a car and driver. Should be the yearly average and account for peak seasonal and commuter pricing.

> **Passenger:** Average fare paid for a passenger. Should be the yearly average to and account for peak seasonal and commuter pricing.

Trip Purpose Information: The following inputs can be found from the 1999 Travel Survey results

> **Work/School Business:** Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Medical Appt./Personal Business: Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Social/Recreational: Route specific trip purpose information for the three periods should be entered. Numbers represent a percentage of daily trips for each period based on trip purpose.

Boarding Mode Percent - Vehicle: Route specific boarding mode percent for the three periods should be entered. Numbers represent a percentage of total passengers by boarding mode for the period.

Boarding Mode Percent – Walk-On: Route specific boarding mode percent for the three periods should be entered. Numbers represent a percentage of total passengers by boarding mode for the period

Percent of Daily Ridership in PM Peak Period: Percentage of total daily riders typically traveling in the peak period from 3 to 7 p.m.

Average Boat Wait Times: The following inputs can be found from the 1999 Travel Survey results

0-10 Minutes: Percentage of passengers during each of the three periods with a wait time between 1-10 minutes

11-30 Minutes: Percentage of passengers during each of the three periods with a wait time between 11-30 minutes

31-60 Minutes: Percentage of passengers during each of the three periods with a wait time between 31-60 minutes

61-90 Minutes: Percentage of passengers during each of the three periods with a wait time greater then 60 minutes.

Figure 4-3: Terminal Preservation Input Screen

Construction Projects

Construction projects are sub-categorized as either vessel or terminal construction projects.

Vessel Construction Projects

The following descriptions refer to Figure 4-4.

Vessel Information:

Vessel Name: Name of Vessel.

Route: Route number vessel is typically used on or will be used on.

Vessel Improvement: Select if the construction project is for a vehicle or passenger only vessel.

Ferry Class: Select the applicable ferry class from the pull down list.

Vessel Retire: Will the construction of the project result in another vessel being retired from regular service?

Current Terminal Condition Rating: If the vessel retirement question was answered "yes" then enter the vessel condition rating from WSF Life Cycle Cost Model for Vital and Non-Vital Systems for the retiring vessel.

Travel Demand Modeling Results

Initial Analysis Year: Enter four digit number for analysis year.

Forecast Analysis Year: Enter four digit number for analysis year.

Weekday Ridership Numbers:

Auto Access/Egress Travel Time: Total auto travel times for 24-hour period in person-hours. Calculated from the peak hour estimates based on peak hour percentages for the initial and forecast years with and without the project.

Ferry Wait Travel Time: Total ferry wait times for 24-hour period in person-hours.

Ferry In-Vehicle Travel Time: Total travel time on the vessel including load and unload times in person-hours for the 24-hour period.

Average Annual Week Day Ridership: Average ridership for typical weekday that represents an average of the peak and off-peak season ridership numbers.

Week End Ridership Numbers:

Auto Access/Egress Travel Time: Total auto travel times for 24-hour period in person-hours. Calculated from the Sunday estimates the initial and forecast years with and without the project.

Ferry Wait Travel Time: Total ferry wait times for 24-hour period in person-hours.

Ferry In-Vehicle Travel Time: Total travel time on the vessel including load and unload times in person-hours for the 24-hour period.

Average Annual Week Day Ridership: Average ridership for typical weekend day that represents an average of the peak and off-peak season ridership numbers.

Figure 4-4: Vessel Construction Input Screen

Average Fare Paid by Rider: Average fare paid by rider represents an average based on peak and off peak seasonal rates, commuter pricing, and boarding modes.

<u>**Terminal Construction Projects:**</u>

The following descriptions refer to Figure 4-5.

Terminal Information:

> **Terminal:** Name of Terminal.
>
> **Types of Improvements:**   Check all improvement types that apply to the terminal construction project.

Travel Demand Modeling Results

> **Initial Analysis Year:** Enter four digit number for analysis year.
>
> **Forecast Analysis Year:** Enter four digit number for analysis year.

Weekday Ridership Numbers:

> **Auto Access/Egress Travel Time:** Total auto travel times for 24-hour period in person-hours. Calculated from the peak hour estimates based on peak hour percentages for the initial and forecast years with and without the project.
>
> **Ferry Wait Travel Time:** Total ferry wait times for 24-hour period in person-hours.
>
> **Ferry In-Vehicle Travel Time:** Total travel time on the vessel including load and unload times in person-hours for the 24-hour period.
>
> **Average Annual Week Day Ridership:** Average ridership for typical weekday that represents an average of the peak and off-peak season ridership numbers.

Week End Ridership Numbers:

> **Auto Access/Egress Travel Time:** Total auto travel times for 24-hour period in person-hours. Calculated from the Sunday estimates the initial and forecast years with and without the project.
>
> **Ferry Wait Travel Time:** Total ferry wait times for 24-hour period in person-hours.
>
> **Ferry In-Vehicle Travel Time:** Total travel time on the vessel including load and unload times in person-hours for the 24-hour period.
>
> **Average Annual Week Day Ridership:** Average ridership for typical weekend day that represents an average of the peak and off-peak season ridership numbers.
>
> **Average Fare Paid by Rider:** Average fare paid by rider represents an average based on peak and off peak seasonal rates, commuter pricing, and boarding modes.

Capacity and Circulation Improvements

> **Parking Capacity:** The base case (before) and project case (after) parking capacity at the terminal.

Figure 4-5: Terminal Construction Input Screen

Tollbooth(s) Capacity: The base case (before) and project case (after) tollbooth capacity in number of cars able to be served per hour at the terminal.

Holding Capacity: The base case (before) and project case (after) holding capacity at the terminal.

Tollbooth(s) Capacity:

Terminal Offloading Capacity: The base case (before) and project case (after) offloading capacity in number of minutes to offload average ferry.

Parking Nuisance Problems: Check yes to identify that there is existing parking nuisance problems at the terminal.

Holding Area Nuisance Problems: Check yes to identify that there is existing holding area nuisance problems at the terminal.

Outcome Objectives

The Outcome Objectives inputs are the standard questions described in Chapter 3 of this report. While all the input questions remain the same regardless of mode or project type the calculations are project type dependent.   Ferry preservation projects are given an automatic 50 points because of their project type.   The additional 50 points given to the project based on the percentage increase of the Vital and NonVital Condition ratings with the Vital Conditional Ratings being weighted twice those of the NotVital Ratings. Vessel and Terminal Construction Projects can also earn additional points in the Preservation category if the project increased the Condition Rating of an existing vessel or terminal.

Cost Information

The cost input forms and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project.   In some cases this will result in a negative operation and maintenance cost if the improvement will lower the annual cost of operation the facility.

Benefit-cost calculations

Preservation Projects

The benefit-cost calculations for terminal and preservation projects are very similar and are based on the methodology that the lower the vital condition rating of a terminal or vessel the higher the probability of the failure of that facility. The benefits of preservation projects are based on the avoidance of disbenefits. That is, the additional costs in the form of increased travel time, safety risk, automobile emissions, and user operating costs that would incur in the case of a system failure. The only difference between the calculations for vessel and terminal projects is that terminals may serve several routes and therefore all the routes impacted must be considered. Vessel preservation projects assume that the ridership numbers are equally divided between the vessels serving that route.

The following paragraphs describe the methodology of the calculations. The actual calculations contained in the project code, found in Volume II, can be followed along using these descriptions. The paragraph titles in the following descriptions correspond to annotations found in the actual code.

Calculations for weighted weekday percentages for trip purpose and boarding mode
The calculations first convert the peak period estimates into daily estimates by trip purpose and boarding mode. The weekday travel survey work (see references) was performed for the PM hours with the Peak period being define as 3:00 to 7:00 PM and the Non-Peak period being the remaining PM hours. To calculate the percent of daily weekday trips by trip purpose the AM hours were assumed to mirror the PM hours to model the two daily peaks. Therefore the percentage of trips by trip purpose is calculated as the weighted average of peak and non-peak periods with the peak period percentage being twice the PM peak period percentage. This calculation was repeated for the remaining trip purposes. The percentage of trips by boarding mode was calculated in a similar manner with the overall weekday percentage being calculated as the weighted average of peak and non-peak boarding mode percentages.

Calculations for percentage of riders likely to drive around during service failure

The next step was to estimate the number of trips likely to be continued during a service failure. This was calculated as a percentage based on trip purpose. These calculations are based on the assumption that work trips are more likely to be continued during a service failure than personal business trips and social trips. The calculations assume that 100% of work trips will still occur and will be replaced by drive-around trips. 50% of the medical and personal appointment trips and 10% of the social trips will be replaced by drive-around trips. The calculations are based on a long-term service disruption and therefore do not represent the short-term affects of a service disruption where it would be reasonable to assume that a higher percentage of trips would be avoided altogether. These calculations also assume that the diverted trips would become drive-around trips even though most routes are served by more then one vessel. The assumption here is that the disbenefits of the drive-around trip would be equal to the disbenefits of the longer boat-wait times.

Calculations for number of drive around trips during service failure for two-year period
The percentage of trips diverted for weekdays and weekends (Saturday is modeled the same as Sunday travel percentages) is then converted to number of trips by multiplying the percentages by the annual average number of daily trips for the weekday and weekend. The daily number of trips is converted to annual number of trips using the Annual Daily Benefit global variable, whose default value is 260 days per year. The weekend trips are calculated by subtracting the daily benefit variable from 365.

Probability of Vessel Failure for each Biennium for Base Case and Project Case
The probability of vessel failure for each biennium period is calculated as a linear relationship to the vessel's vital condition rating assuming that there is zero probability of failure at a condition rating of 100 and a probability of 1 at a 0 condition rating. Preservation benefits are based on the savings derived from service failures that are avoided and are calculated by multiplying the difference between the Project Case probability and the Base Case probability by the disbenefit assuming a service failure. Disbenefits are calculated assuming a service failure for the entire biennium. [This may seem like a long duration but the assumption is that a decision was made not to invest in the vessel and if a failure were to occur then it is reasonable to assume that emergency money would not be available.]

Average Boat Wait Calculations
The boat wait is determined by taking a weighted average of the boat wait percentages to calculate an average weight time for the peak, non-peak, and Sunday periods. From these averages a daily average weight time is calculated for weekdays and weekends using the same rationale as daily percentages by trip purpose described above.

Travel Time Calculations
The travel time minutes are calculated separately for out-of-vehicle and in-vehicle time since studies have shown that people value their time very differently for these two categories. The out of vehicle time (in this case the wait time) is calculated by multiplying the average weekday wait by the annual number of weekday trips without a service failure. The in vehicle time is calculated as the difference between the drive around travel time and the ferry trip travel time.   The additional travel time is considered a disbenefit and the avoided wait time is considered a benefit.

Travel Time Calculations - Project Case
The estimated travel timesaving in minutes is then multiplied by the difference in service failure probability between the Base Case (no preservation improvements) and the Project Case (with preservation improvements). The avoided disbenefits are assumed to be benefits and avoided benefits are assumed to be disbenefits. For example the avoided additional travel time is considered a project benefit. The total travel timesaving is then tallied.

Travel Time Benefit Calculations
A dollar value is then assigned to both the in vehicle and out of vehicle travel times using the program global variables for Time Value for Vehicle Travel (default value $18.36) and Percent of Time Value for In-Vehicle Travel Time (default value 50%) and Percent of Time Vale for Out of Vehicle Travel Time (default value 100%). The travel time minutes are first converted to hours and then multiplied by the hourly rate and the percent of time value. Once again the avoided disbenefits are treated as positive values and the avoided benefits as negative values.

Freight travel timesavings are not considered to be significant and are therefore assumed to be zero.

Travel Time Benefit NPV Calculation
The travel time benefits for each biennium are brought back to a Net Present Value using the global variable Discount Rate (default value 4%). Benefits (avoided disbenefits) are assumed to occur at the end of each period.

Operating Cost Calculations

The additional vehicle miles traveled are calculated using the in-vehicle travel time and the assumption of a 50 mph average running speed. The total VMT for the five periods is then tallied.

User Cost Benefit Calculations
MICA is structured to consider either the full cost or only the direct cost of travel. The global variable Full Cost (default yes) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the vehicle operating costs per mile is a higher value then the direct cost value. The user cost calculation multiplies the additional VMT for the biennium by the appropriate operating cost to derive a user savings for that period.   (Note that the VMT calculation already includes the probability calculation). The avoided additional costs are considered a benefit. The avoided ferry fare is considered a revenue transfer and is not considered as either a benefit or disbenefit.

User Benefit NPV Calculation
The user operating savings for each biennium are then brought back to a present value using the global variable discount rate (default 4%). The benefits are assumed to occur at the end of each biennium.

Air Pollution - Emissions Calculations for Drive Around Trips
Air pollution emissions are calculated using the estimated additional vehicle miles traveled and global variables for the emission rates per mile (assuming a running speed of 50 mph) resulting in the additional tons released into the air due to a service failure. The emission rates are in g/mile

and must be converted into English tons. The emissions rates are based on a warmed up vehicle engine. To capture the effects of cold-starts the number of new trips is multiplied by the cold start percentage (global variable that estimates the number of trips that begin with a cold start) by the emissions in grams for an average cold start. The resulting value is tallied for each period and the sum value is considered an avoided disbenefit and is treated as a negative value. (Note that the VMT calculation already includes the probability calculation).

Emission Benefit Calculations
The environmental benefit for each period is calculated using the estimated avoided tons released for each pollutant and the global variables for the dollar value for a ton of pollutant released. The environmental benefits for each biennium are brought back to a Net Present Value using the global variable Discount Rate (default value 4%). Benefits (avoided disbenefits) are assumed to occur at the end of each period.

Lost Fare Revenue Calculations
Lost fare revenue is considered a revenue transfer (neither benefit nor disbenefit) but is calculated here for informational purposes. To calculate lost revenue the number of trips with ferry service is multiplied by the average fare based on boarding mode. Only half of the walk on passengers' fares are considered since the fare is only collected in one direction. The lost fare revenue is calculated for each period and multiplied by the probability factor. The lost revenues for each biennium are brought back to a Net Present Value using the global variable Discount Rate (default value 4%). Lost revenues are assumed to occur at the end of each period.

Accident Calculations
The number or accidents is calculated using the estimated additional vehicle miles traveled and global variables for the accident rate per million miles of vehicle travel for the different accident types. The resulting value is tallied for each period and the sum value is considered an avoided disbenefit and is treated as a negative value. (Note that the VMT calculation already includes the probability calculation).

Safety Benefit Calculations
The safety benefit for each period is calculated using the estimated avoided accidents and the global variables for the dollar value for each accident type. The safety benefit for each biennium is then brought back to a present value using the global variable discount rate (default 4%). The benefits are assumed to occur at the end of each biennium.

Cost Calculations
The capital costs for the 10-year period are brought back to a present value using the global variable discount rate (default 4%). The costs are assumed to occur at the end of each biennium. An implicit assumption is that the once the decision is made to preserve the vessel the preservation efforts will continue for the entire 10-year cycle. Each two-year period is not considered independently.

- Assumes that no outside funding is used in Ferry Preservation projects.

- Assumes that no outside funding is used in Ferry Preservation projects.

- Operation and Maintenance costs should be included since the loss of the vessel would lower the system's O&M expenditures.

- Environmental retrofit costs are set at zero for vessel preservation projects.

- A terminal value or salvage value calculation will be added later.

Benefit-Cost Calculations

The Benefit Cost ratio is calculated as the sum of the present value of project benefits over the sum or the present value of project costs. Since outside funding of vessel preservation projects is unlikely the WSDOT Benefit Cost ratio is set equal to the real Benefit Cost ratio.

Construction Projects

The benefit-cost calculations for terminal and construction projects are very similar and are based on the results of travel forecast modeling with and without the proposed project for both current and future forecast year. The only difference between the calculations for vessel and terminal projects is that terminals will ultimately have additional calculations based on landside efficiencies such as reduced emissions effects due to increased efficiencies in the tollbooth facilities.

The following descriptions follow the methodology of the calculations. The actual calculations contained in the code (see later section) can be followed along using these descriptions.

Travel Time Savings per Rider

The travel times for auto travel, waiting and ferry travel time are calculated on a per rider basis for the base and project cases and for the initial and forecast years.

Induced Ridership

Induced travel is calculated for both the initial and forecast years and is the forecasted change in ridership due to the project.

Travel Time Benefits in Minutes –Weekday Yearly Total

Weekday travel time savings for the initial analysis year is calculated for auto travel, waiting, and ferry travel by multiplying the difference in travel time per rider for the project case and base case by the number of riders in the base case (i.e. original riders). Induced rider travel time benefits are calculated the same way except then multiplied by ½. These calculations are repeated for the forecast year travel time savings. Estimated weekday values are converted into minutes and multiplied by the global variable that converts daily savings into annual savings. Estimated weekend values are also converted into minutes and multiplied by 365 minus the annual daily benefit global variable. Positive values represent reduced travel times and negative values represent increased travel times (disbenefits).

Travel Time Benefits in Minutes Total

The estimated travel timesavings in minutes for the entire analysis period is calculated assuming a uniform growth rate between the initial and forecasted years a 0% discount factor. Only monetary calculations use the global variable discount rate (default value 4%).

Travel Time Benefits in Dollars

The travel timesavings are then monetized using the global variables for time value for vehicle travel (default value $18.36/hour). The estimated number of minutes for auto travel, wait time, and ferry travel are multiplied by the time value variable and by a global variable that represents the percent of time value attributed to each period of the journey. Studies have shown that people value their wait time higher then their in-vehicle time therefore reductions in wait times have a greater impact then reductions in in-vehicle travel times. The default global variable values for in-vehicle travel times is 50% and for out-of-vehicle travel times is 100%.

Travel time benefits are calculated for both the initial and forecast years. A uniform growth rate between the two years is assumed and brought back to a net present value using the global variable discount rate (default 4%).

Freight travel timesavings are not considered to be significant and are therefore not separated from the passenger travel. Additional benefits derived from reduced freight travel are assumed to be zero since the magnitude of these benefits are not expected to change to outcome of the project.

Operating Cost Calculations

The change vehicle miles traveled for the initial and forecast years are calculated based on the entered results from the travel demand forecasting model. The annual change in VMT is then multiplied by the global variable that converts daily benefits to annual benefits. The estimated VMT for the entire analysis period is calculated assuming a uniform growth rate and a 0% discount rate. A positive VMT value represents a net increase in vehicle miles traveled.

User Cost Benefit Calculations

MICA is structured to consider either the full cost or the direct cost of travel. The global variable Full Cost (default yes) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the vehicle operating costs per mile is a higher value then the direct cost value and includes cost of ownership in addition to cost of operating. The user cost calculation multiplies the estimated VMT by the appropriate operating cost to derive a user savings for that period. The reduced VMT and therefore the reduced costs are considered a benefit. Any additional ferry fares are considered a revenue transfer and are not considered a benefit or disbenefit. The estimated user costs savings are calculated for the initial and forecast years and assume a uniform growth rate between. Benefits are brought back to a net present value using the global variable discount rate (default 4%).

Air Pollution - Emissions Calculations

The change in emissions levels for the four pollutants included in MICA are calculated from the change in the vehicle miles traveled. The emissions rates are based on global variables for the grams of emissions per mile (assuming a running speed of 50 mph). The emissions rates are based on a warm engine. Cold start emission affects are assumed negligible at this time since the majority of induced ferry trips are most likely diverted highway trips. The resulting estimate for tons of emissions is calculated for the entire analysis period. Positive values represent a net reduction in emission amounts.

Emissions Benefit Calculations

The total emission estimates are multiplied by the global variable for cost per ton for the four types of pollutants considered in the MICA program. The emission benefits are brought back to a present value amount using the global variable discount rate.

Fare Revenue Calculations

Fare revenues are considered a revenue transfer (neither benefit nor disbenefit). The estimated change in revenue to the ferry system is calculated for information only and is not included in the cost-efficiency calculation. Revenue estimates are brought back to a present value using the global variable discount rate.

Accident Calculations

The number or accidents is calculated using the estimated additional vehicle miles traveled and global variables for the accident rate per million miles of vehicle travel for the different accident types.   The resulting value is tallied for the initial and forecast years and the sum value is determined using a uniform growth rate and a 0% discount rate.

Safety Benefit Calculations

The safety benefit calculation uses the global variables for the accident rate per million miles of vehicle travel for the different accident types as well as a global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate and is brought back to present value using the global variable discount rate.

Cost Calculations

Currently the user enters the net present value of the cost components of the project. Future refinements will allow the user to enter future values or annual values and the net present value calculations will be done internally.

Benefit-Cost Calculations

The Benefit Cost ratio is calculated as the sum of the present value of project benefits over the sum or the present value of project costs. The WSDOT Benefit Cost ratio considers all of the project benefits but only the WSDOT portion of the costs.

Project reports

All project level reports are structured similarly with the first section showing the user inputs. The second section shows the results to key calculations such as travel timesavings in minutes and in dollars, benefit-cost ratios, etc. The third section shows the results to the Outcome Objective calculations. The final section shows the Global Variables that were used in the calculations and notes if values differed from the default values.

References

1. Baker, Brent T; Deardorf, Raymond. Development and Application of a Revenue and Ridership Forecasting Model for Ferry Service. Transportation Research Record 1608. 1997.

2. Dehghani, Youssef; Saranthan, Krishnan; and Gihring, Celine. Comprehensive Planning Model for Ferry Ridership Forecasting Analysis in Puget Sound Region. Transportation Research Record 1608. 1997

3. George Washington University. The Washington State Ferries Risk Assessment Final Report. June 1999.

4. Parsons Brinckerhoff. WSF 1999 Travel Survey: Analysis and Results Report. June 2000.

5. Ulberg, Cy. Ferry Pricing Strategies Analysis. WA-RD 193.1. November 1989.

6. Washington State Ferries. Systems Plan for 1999-2018. June 1999.

7. Washington State Ferries. Travel Forecasting Methodology Report. May 1996.

8. Washington State Ferries. WSF Capital Plan, Version 3. September 20, 2000.

Chapter 5 – Highway Improvements

The Highway Improvement Program is included in the Washington State Current Law Budget as Program I-1. The projects included in this MICA category are also referred to as Mobility Improvements, and consist of state highway projects that increase highway capacity. The role of Mobility Improvements includes completing the core HOV lane system in the Puget Sound Region; improving the level of service on rural highways; assisting in mitigation of congestion on urban highways; and access management projects.

Inventory of Projects

The seven project types included for analysis in MICA are simply the project types that have already been defined by WSDOT, and for which analysis methods have already been developed. These are:

1. **Climbing Lane:** Addition of a truck climbing lane to a two-lane highway or to and arterial.

2. **General Purpose Lane:** Addition of a general purpose lane to an arterial, two-lane highway, or a multi-lane highway or freeway.

3. **High Occupancy Vehicle (HOV) Lane:** Addition of an HOV lane to a highway facility.

4. **Interchange:** Addition of a new interchange to an existing facility.

5. **Intersection:** Improvement of an existing intersection.

6. **Park and Ride:** Construction of a new park and ride lot.

7. **Two-Way-Left-Turn Lane (TWLTL):** Conversion of a two-lane undivided facility into a three-lane TWLTL facility; or, median treatments and or access spacing changes.

Inventory of Current Analysis Methods

The analysis methods developed for Highway Mobility Projects served as the starting point for the development for all of the MICA analysis methods for all modes. The existing Mobility procedures are implemented in a set of spreadsheets called the Mobility Project Prioritization Process (MPPP), and they calculate all benefit and cost measures that are needed for MICA (Dowling Associates 2000). Thus, the procedures in the MPPP spreadsheets were simply converted into the program code needed for MICA.

Note, while the MPPP procedures were adopted exactly, project measures calculated in MICA may vary slightly from those calculated in the MPPP spreadsheet, for the same project. The reason for this is that some of the default values adopted for the global variables in MICA are slightly different than those used in MPPP (i.e. the default value of a traveler's time is higher in MICA than in MPPP).

Identification of Analysis Gaps

The current analysis methods for highway mobility projects do not allow for the possibility that a new or improved facility may induce new traffic. User operating impacts are calculated solely on the improved travel speeds that will result from a facility improvement, and assume that the same volume of traffic will use the roadway with or without the improvement. For most improvements,

this is reasonable. If travel times are moderately improved, one can argue that the new traffic due to the improvement has simply shifted from a different route. In this case, the negative impacts gained along the new route would be lost along the old route, resulting in no net gain or loss. However, in cases where an improvement results in a significant gain in travel speeds, it is probable that some people will choose to make trips that they would not have made when the road was difficult to travel. In this case, the additional operating costs and environmental impacts should be considered in analysis. Induced traffic is difficult to predict, and is probably not a significant issue for most Highway Improvement projects that are currently under consideration. However, for a proposed project that includes major capacity improvement, it should be addressed. Induced traffic on new or highly upgraded highways would be a worthwhile topic in future research efforts.

Project Worksheets and Inputs

The highway improvement mode is accessed by clicking on the "Highway" button on the starting screen of the Project Module. Additionally, the user must click on the "Improvement" sub-category to access the specific Highway Improvement project type. Figure 5-1 shows the opening screen for the highway improvement mode. From this screen, the analyst can access existing highway improvement projects in the MICA database, or add a new highway improvement project (note, the general procedures for Project Level Analysis are described in *Chapter 3 – Operation of the MICA Program*).
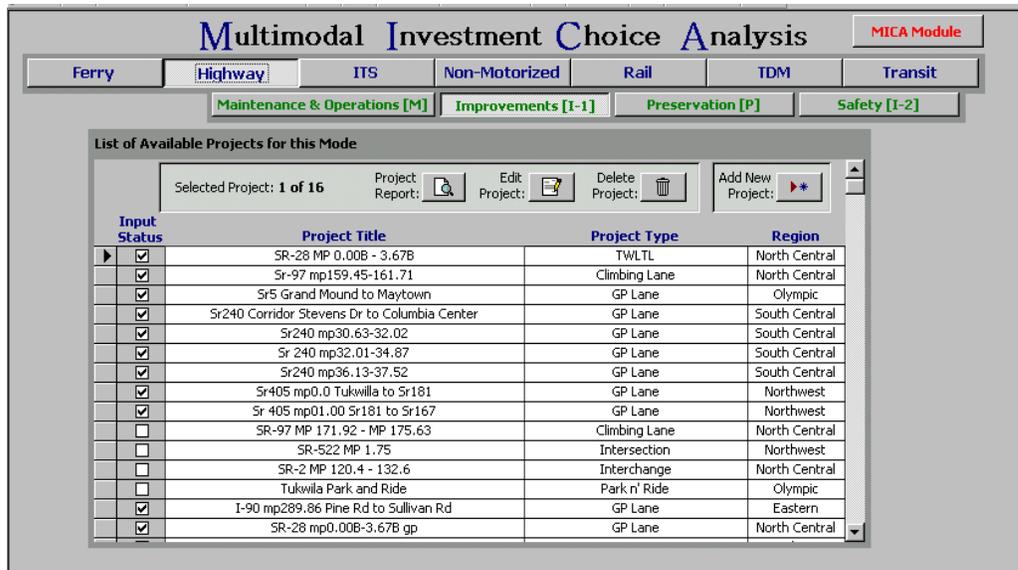
Figure 5-1: Opening Screen for Highway Improvement Mode

Project Information

The Project Information input form, as shown in Figure 5-2, is the first of four screens to be displayed when a highway improvement project is edited or added to the database. The user can navigate through the four screens by clicking on the tab headings. Additionally, the three buttons at the top of the screen can be selected at any time to delete the current project from the database, preview the project report, or save the current data and exit back to the opening screen for highway improvement projects.

Figure 5-2: Highway Improvement Project Information Form

The Project Information component contains the following descriptive information:

        Project Title: Descriptive title of the project

        Project Type: Identifier that is unique to the project

        Project Type: Specific type of project, selected from a pull down list. For the highway improvement mode, the seven project types are:

- **Climbing Lane**
- **General Purpose Lane**
- **High Occupancy Vehicle Lane**
- **Interchange**
- **Intersection**
- **Park and Ride Lot**
- **Two-Way-Left-Turn Lane**

State Route: State Route Designation, if applicable.

Beginning Milepost: Milepost number at beginning of project, if applicable.

Ending Milepost: Milepost number at end of project, if applicable.

Project Length: Length of project (miles), if applicable.

Biennium: Biennium in which the project is to be considered for funding

Region: WSDOT Region in which the project is located. A pull down menu provides eight region options:

- **Eastern**

- **North Central**

- **Northwest**

- **Olympic**

- **South Central**

- **Southwest**

- **Statewide** should be selected if the project is located in multiple regions

- **Ferry** applies only to ferry projects, and would never be selected for highway projects

Legislative District: State Legislative District in which the project is located, if the project fits completely or primarily in one district.

Air Quality: Air quality designation for the project area, as identified by the Clean Air Act. A pull down menu provides the options of:

- **Attainment Area**

- **Non-Attainment Area**

- **Maintenance Area**

- **Unclassifiable**

as described in *Chapter 2 – Project Measures*.

WTP Corridor: Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

Highway System Plan: Identifies whether or not the project is included in the Highway System Plan. Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

FGTS Classification: Identifies whether or not the project is included in the Freight and Goods Transportation System (FGTS) classification system. A pull down menu provides the options of:

- **T-1** (> 10 million tons per year)

- **T-2** (4 to 10 million tons per year)

- **T-3** (300,000 to 4 millions tons per year)

- **T-4** (100,000 to 300,000 tons per year)

- **T-5** (20,000 tons per 60 days)

- **None**

as described in *Chapter 2 – Project Measures*.

Project Specific Benefit Worksheets

The second input screen is the benefit input form, which is unique to the each of the seven types of projects analyzed within the highway improvement mode. The following sections describe the input screens and the data required for each project type. However, first two components will be described that are applied to several or all of the project types within the Highway Improvement category: the Twenty-four Hour Volume Distribution Curves; and, the Accident Reduction Calculation.

Twenty-four Hour Volume Distribution Curves

Several of the highway improvement project types utilize 24-hour traffic data in their calculations. In these cases, the user selects an Annual Daily Traffic (ADT) volume distribution curve for the highway segment under analysis. To display the curve data, the user clicks on this display button
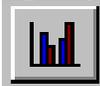
 on the benefit input form.

Figure 5-3 shows the data form for the 24-hour traffic distribution curve that opens when the display button is clicked. The form displays a traffic volume for each hour of the 24-hour period, for each approach of the selected highway segment. The curves are based on 24-hour traffic counts conducted by WSDOT. Currently, the MICA database contains over 1500 curves that have been formulated by WSDOT staff. The curves are listed in ascending numerical order by state road number, and then by milepost number. The appropriate curve is selected by scrolling through the list of available curves under the "Select Curve" field. Alternatively, the user can add a new curve buy selecting the "Add Curve" button, as identified in Figure 5-3.

Selected curves can also be edited and deleted from the database from this window. To delete a curve, the user clicks the "Delete" button as shown in the figure, and the active curve will be removed. To edit a curve, the user simply types the revised volumes directly in the form, and clicks on the "Save" button, as shown in the figure.

The active 24-hour volume distribution can also be view graphically, as shown in Figure 5-4, by clicking on the "View graph" button in the data form. To return to the data form, the user clicks the "View Data" button from the graph form, as shown in the figure. Clicking on the "Close" button from either the data form or the graph form will return the user to the benefit input form.
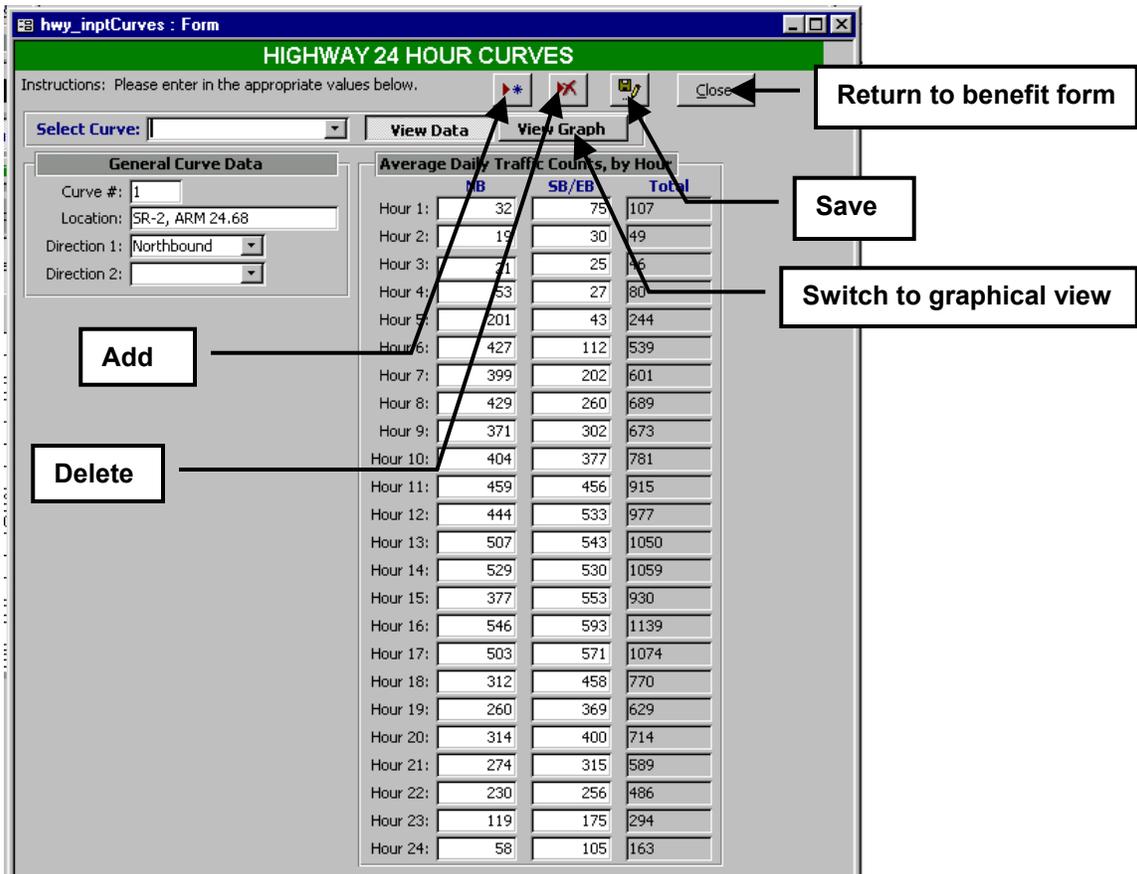
Figure 5-3: Data form for 24-hour ADT Volume Distribution Curve
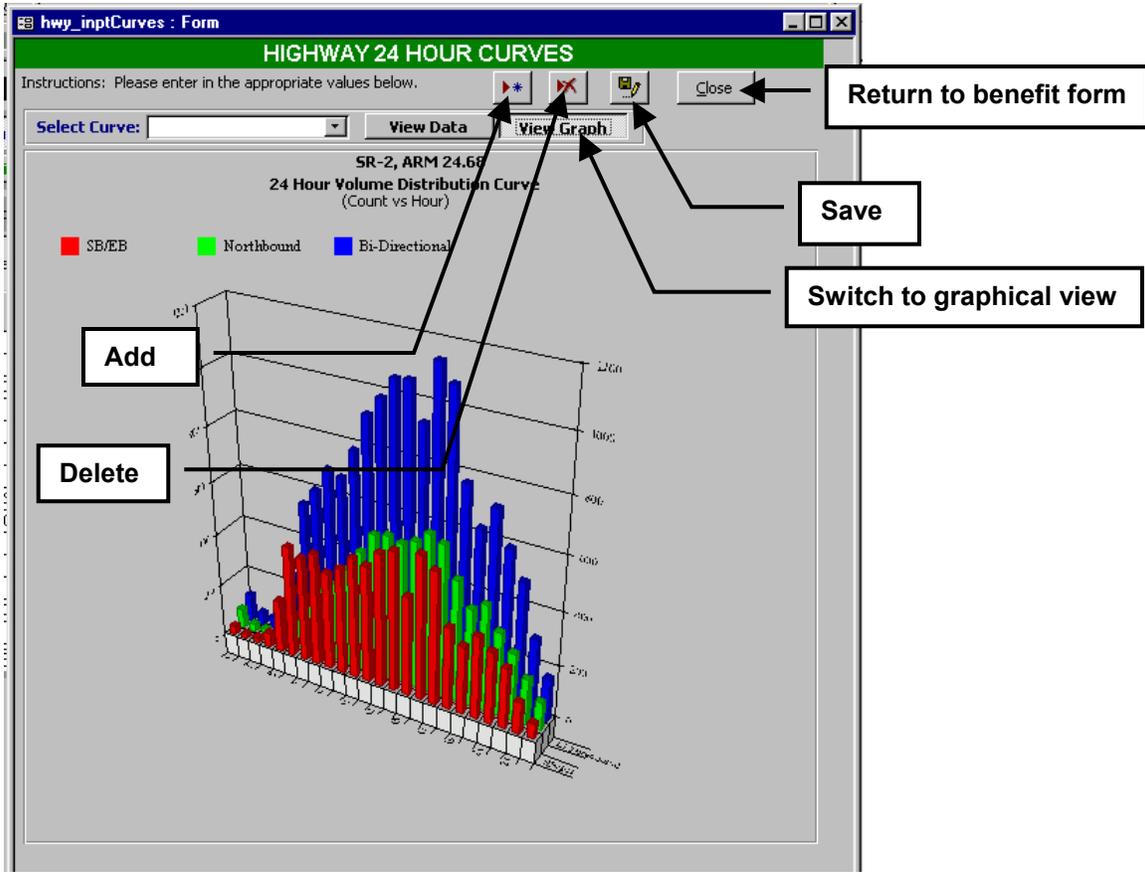
Figure 5-4: Graphical form for 24-hour ADT Volume Distribution Curve

Accident Reduction Calculation

All seven highway improvement project types utilize the same procedure for the safety benefit calculation, which is the procedure already utilized for Highway Mobility Improvements. The method uses historical accident data for the facility under analysis. The average number of accidents over three years is determined for each of three accident types – fatality, injury, and property damage only (PDO). These averages are assumed to be the typical number of accidents that will occur during each year of the project's life. Table 5-1 shows 64 possible types of highway improvements and the corresponding reduction factors for the three accident types (Washington Traffic Safety Commission 1978). To estimate the annual accident reduction that will result from a proposed improvement, the average number of accidents in the fatality, injury and PDO categories are multiplied by the respective reduction factors.

If a project includes more than one improvement, a weighted composite reduction factor is calculated for each accident type. The user may select up to five safety improvements for one project. Once the annual accident reduction is estimated, the safety benefit is derived by multiplying that reduction by the societal costs of accidents, consistent with all other MICA project analyses.

Table 5-1: Accident Reduction Factors for Highway Improvement Projects

	Reduction Factors (percent)	
Type of Improvement	**Fatality & Injury**	**PDO**
Intersection		
Add Stop Sign on Minor Leg, Rural, 2 lanes	80	65
Add Stop Sign on Minor Leg, Urban, 2 lanes	70	50
Add Stop Sign on Minor Leg, Urban, Multi Lane	20	40
Add Stop Sign on All Legs, Urban, 2 lanes	65	70
Add Right Turn Lane, Rural, Multi Lane	40	10
Add Right Turn Lane, Urban, Multi Lane	40	10
Add Left Turn Lane, Rural, 2 Lane	80	20
Add Left Turn Lane, Urban, 2 Lane	80	20
Add Left Turn Lane, Urban, Multi Lane	55	5
Add Left Turn Lane (T intersection), Urban, Multi Lane	60	50
Add Left Turn Lane (T intersection), Urban, 2 Lane	80	80
Add Left Turn Lane (Y intersection), Rural, 2 Lane	5	35
Increase Radii at intersection, Rural or Urban, All Lane	25	25
Add Traffic Signal, Rural or Urban, All Lane	50	30
Add Left Turn Signal (no left turn lane), Urban, Multi Lane	55	40
Modify Traffic Signal, Rural or Urban, All Lane	30	30
Interconnect Traffic Signals, Rural or Urban, All Lane	30	30
Add Pedestrian Signal, Urban, All Lane	55	15
Add Pedestrian Signal, Urban, 2 Lane	40	5
Ramp Metering, Rural, Multi Lane	45	45
Ramp Metering, Urban, Multi Lane	45	45
Install Flashing Warning Signals, Urban, Multi Lane	30	50
Install Flashing Warning Signals, Rural, 2 Lane	30	50
Install Flashing Warning Signals, Rural, Multi Lane	15	20
Add Flashing Beacons at RR Crossing, Rural, Multi Lane	20	80
Add Flashing Beacons at RR Crossing, Urban, Multi Lane	20	80
Illuminate Intersection or RR Crossing, Urban, All Lane	15	20

Type of Improvement	Reduction Factors (percent)	
	Fatality & Injury	PDO
Median		
Painted or Raised Median, Urban, Multi Lane	10	10
Concrete Median Barrier, Urban, Multi Lane	60	60
Signing		
Install Advance Warning Signs, Rural, 2 Lane	30	35
Install Advance Warning Signs, Rural, Multi Lane	5	20
Install Advance Warning Signs, Urban, 2 Lane	15	15
Install Advance Warning Signs, Urban, Multi Lane	20	20
Install Stop Ahead Sign, Rural, 2 Lane	80	45
Install Yield Sign, Urban, 2 Lane	80	60
Delineation		
Double Yellow Line, Urban, Multi Lane	5	5
Reflectorized Raised Pavement Marking, Rural, Multi Lane	5	5
Reflectorized Raised Pavement Marking, Urban, Multi Lane	5	5
Edge Marking, Rural, 2 Lane	15	15
Guide Post on Curve, Rural or Urban, All Lane	25	25
Roadway		
Widen Traveled Way, Rural, 2 Lane	30	40
Widen Shoulder, Rural, 2 Lane	5	0
Lengthen Acceleration Lane, Rural, Multi Lane	5	30
Lengthen Acceleration Lane, Urban, Multi Lane	60	60
Extend Drop Lane (Beyond Exit), Rural, Multi Lane	50	50
Extend Drop Lane (Beyond Exit), Urban, Multi Lane	50	50
Roadside	60	60
Guard Rail at Embankments, Rural or Urban, All Lane	35	35
Guard Rail at Bridge Ends, Abutments, Piers, Steel Sign Posts, Rural or Urban, All Lane	80	80
Flatten Slopes, Rural, 2 Lane	30	30
Flatten Slopes, Urban, 2 Lane	30	30
Energy Absorption Devices, Rural or Urban, All Lane	15	25
Breakaway Sign Posts and Illumination Poles, Rural or Urban, All Lane	15	25
Reflectorized Raised Pavement Marking, Urban, Multi Lane	25	25
Edge Marking, Rural, 2 Lane	50	50
Guide Post on Curve, Rural or Urban, All Lane	50	50
Roadway	40	40
Widen Traveled Way, Rural, 2 Lane	40	40
Widen Shoulder, Rural, 2 Lane		
Eliminate Parking (Signing Necessary), Urban, Multi Lane	20	20
Construct Grade Separation, Rural or Urban, All Lane	50	35
Add Two Way Left Turn Lane, Rural, All Lane	20	20
Add Two Way Left Turn Lane, Urban, All Lane	20	20
Widen Bridge (Minimum Six Feet), Rural or Urban, All Lane	50	20
Reconstruct Road and Shoulders, Rural or Urban, All Lane	50	0

Climbing Lane

The benefit input form for Climbing Lane highway projects is shown in Figure 5-5. The user inputs data under four categories:

- General Data

- Traffic Data
- Capacity Data
- Safety Benefit Data

Figure 5-5: Benefit Input Screen for Climbing Lane Projects

The Benefit Input component for Climbing Lane projects calls for the following information:

General Data

Posted Speed: Posted speed limit on facility (mph)

- Base case and Project case, initial year

NB / WB Lanes: Number of GP lanes in NB or WB direction

SB / EB Lanes: Number of GP lanes in SB or EB direction

Length: Length of project (miles)

Traffic Data

ADT: Average Daily Traffic (ADT) – Initial year

Peak Hour Volume: Peak Hour Volume (PHV) – Initial year

K factor: K Factor – Initial year

Percent Trucks: Average percentage of trucks in traffic

Grade: Roadway Grade (decimal value)

Traffic Growth Rate: Average rate of growth per year over analysis period

Curve ID: Select highway volume curve that is to be used in analysis

AVO: Average Vehicle Occupancy (AVO) for automobiles

Capacity Data

Facility Type: Selects facility type from pull down menu

- Base case and Project Case

Roadway Capacity: Capacity per one lane of the roadway (vplph)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Safety Benefit Data

Safety Improvements: Select up to five improvements from pull down lists

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

General Purpose Lane

The benefit input form for General Purpose Lane highway projects is shown in Figure 5-6. The user inputs data under four categories:
- General Data
- Traffic Data

- Capacity Data
- Safety Benefit Data

Figure 5-6: Benefit Input Screen for General Purpose Lane Projects

The Benefit Input component for General Purpose Lane projects calls for the following information:

General Data

Posted Speed: Posted speed limit on facility (mph)

- Base case and Project case, initial year

NB / WB Lanes: Number of GP lanes in NB or WB direction

SB / EB Lanes: Number of GP lanes in SB or EB direction

Length: Length of project (miles)

Traffic Data

ADT: Average Daily Traffic (ADT) – Initial year

Peak Hour Volume: Peak Hour Volume (PHV) – Initial year

K factor: K Factor – Initial year

Percent Trucks: Average percentage of trucks in traffic

Grade: Roadway Grade (decimal value)

Traffic Growth Rate: Average rate of growth per year over analysis period

Curve ID: Select highway volume curve that is to be used in analysis

AVO: Average Vehicle Occupancy (AVO) for automobiles

Capacity Data

Facility Type: Selects facility type from pull down menu

- Base case and Project Case

Roadway Capacity: Capacity per one lane of the roadway (vplph)

- Base case and Project case, initial year

- Base case and Project case, forecast year

Safety Benefit Data

Safety Improvements: Select up to five improvements from pull down lists

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

High Occupancy Vehicle Lane

The benefit input form for High Occupancy Vehicle Lane highway projects is shown in Figure 5-7. The user inputs data under four categories:
- Segment Information
- Traffic Volumes
- Traffic Composition

- Safety Benefit Data

Figure 5-7: Benefit Input Screen for HOV Projects

The Benefit Input component for HOV Lane projects calls for the following information:

Segment Information

Length: Length of project (miles)

GP Lanes: Number of GP lanes

- In NB/WB direction, and in SB/EB direction
- Base case and Project Case

HOV Lanes: Number of HOV lanes

- In NB/WB direction, and in SB/EB direction
- Project Case Only

Posted Speed: Posted speed limit on facility (mph)

- Base case and Project case, initial year

Roadway Capacity: Capacity per one lane of the roadway (vplph)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Facility Type: Selects facility type from pull down menu

- Base case and Project Case

Traffic Volumes

ADT: Average Daily Traffic (ADT) – Initial year

Peak Hour Volume: Peak Hour Volume (PHV) – Initial year

- In NB/WB direction, and in SB/EB direction
- Initial year

HOV Growth Rate: Average rate of HOV volume growth per year over analysis period

GP Growth Rate: Average rate of GP volume growth per year over analysis period

Curve ID: Select highway volume curve that is to be used in analysis

Percent Trucks: Average percentage of trucks in traffic

- Initial year and Forecast year

Traffic Composition

Peak Hour Percent: Enter percent of traffic composition for each mode

(Must sum to 100 percent):

- SOV / GP Eligible
- HOV Eligible
  - 2 - person automobile
  - 3 - person automobile

- o   4+ - person automobile

- o   Vanpool

- o   Transit

- o   Other Bus

- o   Motorcycle

Peak Hour AVO: Enter average vehicle occupancy for each mode

- • Initial year and Forecast year

  - o   4+ - person automobile

  - o   Vanpool

  - o   Transit

  - o   Other Bus

Safety Benefit Data

Safety Improvements: Select up to five improvements from pull down lists

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

Interchange

The components of the benefit input form for Interchange highway projects is shown in Figure 5-8 through Figure 5-10. The user inputs data under four categories:

- • Traffic Profile
- • Ramp Volumes
- • Safety Benefit Data
- • Facility Data

Figure 5-8: Benefit Input Screen for Interchanges – Traffic Profile, Volumes and Safety

Figure 5-9: Benefit Input Screen for Interchange Projects – Facility Data (1)
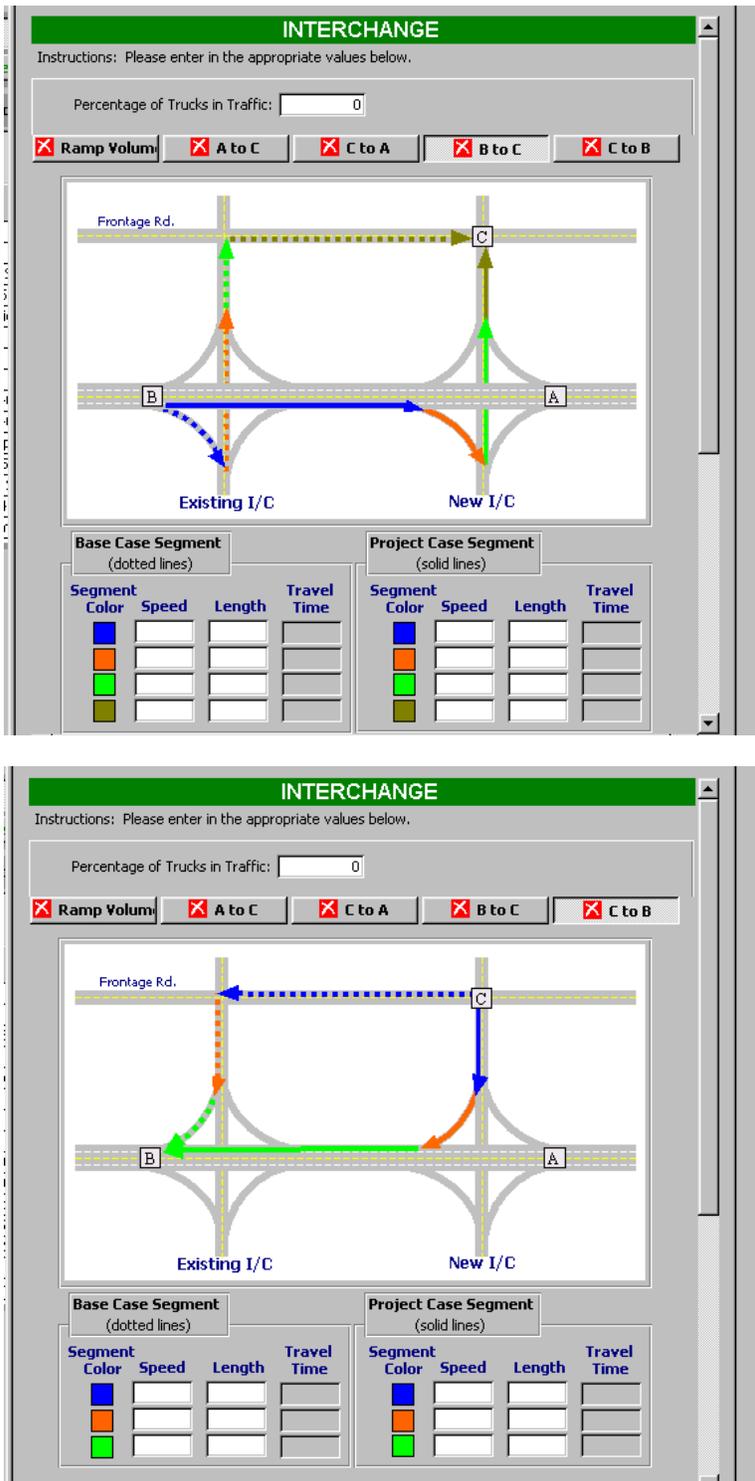
Figure 5-10: Benefit Input Screen for Interchange Projects – Facility Data (2)

The Benefit Input component for Interchange projects calls for the following information:

Ramp Volumes

K factor: Main line K factor

Peak Hour Volumes: Working peak hour volumes

- For four directions of ramp movement
- Initial year and Forecast year

Safety Benefit Data

Safety Improvements: Select up to five improvements from pull down lists

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

Facility Data

Speed: Posted speed limit on ramp (mph)

- Base case and Project Cast
- For ramp movements, connecting roadways, and adjacent frontage roads

Length: Length of roadway segment (miles)

- Base case and Project Cast
- For ramp movements, connecting roadways, and adjacent frontage roads

Intersection

The benefit input form for Intersection highway projects is shown in Figure 5-11. The user inputs data under three categories:
- Traffic Data
- Hourly Volumes
- Safety Benefit Data

Figure 5-11: Benefit Input Screen for Intersection Improvement Projects

The Benefit Input component for Intersection projects calls for the following information:

Traffic Data

Traffic Growth Rate: Average rate of growth per year over analysis period

Percent Trucks: Average percentage of trucks in traffic

Initial Year: Initial year of analysis

Total Approach Volume: Total volume for all intersection approaches – initial year

- Base case and Project case

Number of Lanes: Total number of lanes for all intersection approaches – initial year

- Base case and Project case

Average Delay: Peak hour average delay for intersection – initial year

- Base case and Project case

Intersection V/C: Peak hour volume to capacity ratio for intersection – initial year

- Base case and Project case

% Reduction by Approach: Percent reduction from base volume – Project Case

- For each approach of intersection

Hourly Volume Data

Year of Volume Data: Year that hourly volume data was recorded

Hourly Volumes:
- For each hour of the 24-hour day
- For each approach

Safety Benefit Data

Safety Improvements: Select up to five improvements from pull down lists

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

Park and Ride Lot

The benefit input form for Park and Ride Lot highway projects is shown in Figure 5-12. The user inputs data under three categories:

- General Data
- Destination Data
- Safety Benefit Data

Figure 5-12: Benefit Input Form for Park and Ride Lot Projects

The Benefit Input component for Park and Ride Lot projects calls for the following information:

General Data

# of Parking Spaces:　Total number of parking spaces in lot

Capacity Year:　Year in which demand on the lot is expected to reach capacity

# of Walk/Bike Users:　Number of people expected to walk or bike to lot per day

- Forecast year only

% of Lot Capacity Used:　Average percent of spaces in lot filled per day

- Initial year and Forecast year

Peak hour average delay for intersection – initial year

Destination Data

Enter the following data for each of up to five destinations from the park and ride lot:

Destination Name:　Name of destination city / area

Destination Percent:　Percent of lot users to this destination

Destination Distance:　Distance of destination from park and ride

HOV Miles:　Miles of HOV lanes to destination

HOV Speed:　Average speed of HOV lanes to destination

GP Speed:　Average speed of GP lanes to destination

Express Transit Headway:　Average headway for express transit to destination

Local Transit Travel Time:　Average travel time of local transit to destination

Express Transit Pass Cost:　Average cost of monthly express transit pass

Local Transit Pass Cost:　Average cost of monthly local transit pass

Carpool Size:　Average carpool size

Carpool Wait Time:　Average wait time for carpools from lot to this destination

Destination Parking Cost:　Average monthly cost of parking at destination

User Distribution:　Distribution of park and ride lot users to this destination

- Distribution between new transit riders, existing transit riders, new carpoolers, and existing carpoolers

AVO to Lot:　Average vehicle occupancy to lot

Safety Benefit Data

Safety Improvements:　Select up to five improvements from pull down lists

Fatality:　Total number of fatality accidents in 3-year data period

Disabling Injury:　Total number of disabling injury accidents in 3-year data period

Evident Injury:　Total number of evident injury accidents in 3-year data period

Possible Injury:　Total number of possible injury accidents in 3-year data period

Property Damage Only:　Total number of property damage accidents in 3-year data period

Two-Way-Left-Turn Lane
The benefit input form for Two-Way-Left-Turn Lane highway projects is shown in Figure 5-13.

Figure 5-13: Project Benefit Input Form for Two-Way-Left-Turn Lanes

The user inputs data under four categories:
- Facility Data
- Daily Traffic Data
- Hourly Traffic Data
- Safety Benefit Data

The Benefit Input component for Two-Way-Left-Turn Lane projects calls for the following information:

Facility Data

Length: Length of project in miles

Peak Lanes: Number of lanes in peak direction

Base case and Project case

Nonpeak Lanes: Number of lanes in nonpeak direction

Base case and Project case

Median Type: Median type – undivided, TWLTL, or raised median

Base case and Project case

Access Spacing: Average access spacing (in feet)

- Base case and Project case

Access Control Class: Access control class – Class I, Class II, or Class III

- Base case and Project case

Daily Traffic Data

Curve ID: Select highway volume curve that is to be used in analysis

Percent Trucks: Average percentage of trucks in traffic

Peak AVO: Average vehicle occupancy for autos during peak periods

Non-peak AVO: Average vehicle occupancy for autos during off-peak time

Initial ADT: Average daily traffic - initial year

Forecast ADT: Average daily traffic - forecast year

AM peak start: First hour of AM peak period - initial year

- Initial year and Forecast year

AM peak end: Last hour of AM peak period - initial year

- Initial year and Forecast year

PM peak start: First hour of PM peak period - initial year

- Initial year and Forecast year

PM peak end: Last hour of PM peak period - initial year

- Initial year and Forecast year

Hourly Traffic Data

Through Volumes: Avg. through volume in peak direction (veh/hr)

- Base case and Project case

- Initial year and Forecast year

- Peak direction and Non-peak direction

Right Turns per Access: Avg. volume of right turns / access in peak direction (veh/acc/hr)

- Base case and Project case

- Initial year and Forecast year

- Peak direction and Non-peak direction

Left Turns per Access: Avg. volume of left turns / access in peak direction (veh/acc/hr)

- Base case and Project case

- Initial year and Forecast year

- Peak direction and Non-peak direction

Safety Benefit Data

Safety Improvements: User may select up to five improvements from pull down list

Fatality: Total number of fatality accidents in 3-year data period

Disabling Injury: Total number of disabling injury accidents in 3-year data period

Evident Injury: Total number of evident injury accidents in 3-year data period

Possible Injury: Total number of possible injury accidents in 3-year data period

Property Damage Only: Total number of property damage accidents in 3-year data period

Outcome Objectives

The third page contains the Outcome Objectives inputs, which consist of the standard questions described in Chapter 3 of this report. While all of the input questions remain the same regardless of mode or project type, some calculations do vary with project type.

Cost Information

The final page of the input form contains the cost data. Cost inputs and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In cases where the improvement will lower the annual cost of operation and maintenance, a negative cost value will result.

Benefit-Cost Calculations

The benefits calculations for Highway Improvement Projects are primarily based upon travel time savings. The procedure for calculating travel time savings is unique for each of the seven project types. Once the travel time savings is calculated, however, the procedure for calculating benefits is the same for all project types.

User Benefits

Travel Time Savings

Climbing Lane and General Purpose Lane: The travel time savings estimation procedure is identical for these two project types. The user inputs lane and capacity information for the base case and project case, ADT for the initial analysis year, expected annual traffic growth rate, and identifies the appropriate 24-hour traffic distribution curve for the project. Forecast year volumes are estimated by straight-line extrapolation of the traffic growth rate from the initial year ADT to the forecast year. Average hourly volumes for the initial year and forecast year are determined by applying the hourly proportions from the distribution curve to the ADT. If hourly demand exceeds 1.2 times the defined capacity of the facility, a peak spreading procedure redistributes excess volumes to the adjacent hours. Volume to capacity (V/C) ratios are calculated for each hour of the 24-hour day (and due to the peak spreading procedure will never exceed 1.2). The mean operating speed for each hour is a function of the V/C ratio, and is determined from a look-up speed-flow table.

Travel time is estimated by dividing the length of the facility by the mean operating speed. Travel time savings are calculated by subtracting the project case travel times from the base case travel times and multiplying by the volumes, for the initial and final years of the analysis period. Travel time savings are assumed to change at a uniform rate from the initial year to the final year of the analysis period.

High Occupancy Vehicle Lane: Unlike the other Highway Improvement project types, the HOV benefit procedure is currently different in MICA than that used in MPPP. In the current MICA procedure, the user inputs facility and usage data, the distribution of non-SOV travelers, ADT for the initial analysis year, expected annual traffic growth rate, and identifies the appropriate 24-hour traffic distribution curve for the project. Forecast year volumes are estimated by straight-line extrapolation of the traffic growth rate from the initial year ADT to the forecast year. Average hourly volumes for the initial year and forecast year are determined by applying the hourly proportions from the distribution curve to the ADT. If hourly demand exceeds 1.2 times the defined capacity of the facility, a peak spreading procedure redistributes excess volumes to the adjacent hours (similar to the MPPP procedure for GP lanes). Volume to capacity (V/C) ratios are calculated for each hour of the 24-hour day (and due to the peak spreading procedure will never exceed 1.2). The mean operating speed for each hour is a function of the V/C ratio, and is determined from a look-up speed-flow table.

Similar to the MPPP procedure, the base case assumes no existing HOV lane, while the project case includes one or more HOV lanes. All HOV-eligible users are assumed to use HOV. Benefits are calculated by determining the difference in delay between the base case (all travelers share GP lanes) and the project case (HOV users utilize the HOV lane, and SOV users share the GP lanes).

It is intended that MICA ultimately utilize the MPPP procedure for HOV projects. The procedure uses the Federal Highway Administration "QuickHOV" Program (Dowling et al. 1996). Before converting the extensive code into MICA program code, it should first be determined that it is not more efficient just to import the "QuickHOV" Program output into MICA, similar to the methods that are used for transit and ITS.

However, since "QuickHOV" will be integrated in one of these two ways, a description of its procedures is provided as follows. The user inputs lane and capacity information for the base case and project case, ADT for the initial analysis year, expected annual traffic growth rates, traffic composition, and identifies the appropriate 24-hour traffic distribution curve for the project. Average hourly volumes are determined by applying the hourly proportions from the distribution curve to the ADT. The hour with the highest percent of ADT is identified as having the working peak hour volume. The first year eligible HOV 2+ and 3+ volumes are estimated using the Federal Highway Administration "QuickHOV" Program (Dowling et al. 1996):

$$HOV_{After} = HOV_{Before} + HOV_{Before}\left[0.13 + 2.11\left(\frac{HOVTIME_{Before} - HOVTIME_{After}}{HOVTIME_{Before}}\right)\right]$$

Where, HOV_{After} =   Estimated number of vehicles eligible to use the HOV 2+ or 3+ lanes at the end of the first year

            HOV_{Before} =   Estimated number of vehicles eligible to use the HOV 2+ or 3+ lanes before the lane is built (at year "zero"). This is estimated from the ADT and traffic composition input by the user.

     $HOVTIME_{Before}$ =   Mixed flow mean travel time before HOV lane is built.

     $HOVTIME_{After}$ =   HOV lane mean travel time on the day the new HOV lane is opened.

The first year non-HOV volumes are calculated by the following formula:

$$nonHOV_{After} = nonHOV_{Before} + nonHOV_{Before}\left[0.48\left(\frac{nonHOVTIME_{Before} - nonHOVTIME_{After}}{nonHOVTIME_{Before}}\right)\right]$$

Where, $nonHOV_{After}$ =   Estimated number of vehicles that use the general purpose lanes at the end of the first year

         $nonHOV_{Before}$ =   Estimated number of vehicles not eligible to use the HOV 2+ or 3+ lanes before the lane is built (at year "zero"). This is estimated from the ADT and traffic composition input by the user.

   $nonHOVTIME_{Before}$ =   Mixed flow mean travel time before HOV lane is built.

   $nonHOVTIME_{After}$ =   Mixed flow mean travel time on the day the new HOV lane is opened.

The difference between the HOV_{Before} volumes and HOV_{After} volumes, and the difference between the $nonHOV_{Before}$ volumes and $nonHOV_{After}$ volumes, are considered new users. All eligible users are assumed to use the HOV lane until the HOV demand capacity. The procedure assumes that

once the HOV demand exceeds capacity, the lane will be converted to 3+ at the end of that year. This is considered the Conversion Year.

The hourly volumes are estimated for the initial year, final year, and conversion year, based upon the 24-hour distribution curve. If hourly demand exceeds 1.2 times the defined capacity of the facility, a peak spreading procedure redistributes excess volumes to the adjacent hours. Volume to capacity (V/C) ratios are calculated for each hour of the 24-hour day (and due to the peak spreading procedure will never exceed 1.2). The mean operating speed for each hour is a function of the V/C ratio, and is determined from a look-up speed-flow table.

Travel time is estimated by dividing the length of the facility by the mean operating speed, and multiplying by the volume. Travel time savings are calculated by subtracting the project case travel times from the base case travel times, for the initial and final years of the analysis period. Travel time savings are calculated for new HOVs and existing HOVs.

Interchange: The user inputs ramp volumes, the mainline K-factor, and the segment speed and distances. Travel times are estimated for the individual segments by dividing their lengths be their travel speeds, for the initial year and final year base case and project case conditions. Travel time savings are computed by subtracting the project case travel times from the base case travel times and multiplying by the volumes. Travel time savings are assumed to change at a uniform rate from the initial year to the final year of the analysis period.

Intersection: For the base case and project case the user inputs lane configuration, year 1 peak hour total approach volume, average delay, and peak hour intersection V/C ratio, as well as the project case volume reduction by approach and annual traffic growth rate. The maximum hourly capacities are calculated for the base case and the project case by dividing the total intersection peak hour approach volume by the peak hour V/C ratio.

Forecast year volumes are estimated by straight-line extrapolation of the traffic growth rate from the initial year ADT to the forecast year. Hourly demand volumes for the project case are computed by multiplying the base case volumes by the reduction factors input by the user. If hourly demands exceed the intersection capacity, the excess is redistributed to the previous hour. An "uncorrected" V/C ratio is calculated for each hour by the following equation (Dowling and Associates et al. 2000):

$$V/C_U = 0.00185 * \left(TV_{Adj}/L\right) - 0.542 * \left(MSV_{Adj}/TV_{Adj}\right) + 0.918 * \left(V/C_{Int}\right) - 0.00147 * \left(TV/L\right)$$

Where, V/C_U =   Uncorrected hourly volume-to-capacity ratio

TV_{Adj} =   Adjusted hourly total approach volume

L =   Total number of lanes on all approaches

MSV_{Adj} =   Adjusted hourly maximum sum of approach volumes (approach 1+2 or approach 3+4)

V/C_{Int} =   Overall intersection peak period volume-to-capacity ratio, as input by the user

TV =   Total intersection peak hour approach volume, as input by the user

If the calculated V/C ratio for any over-capacity hour is less than 1.0, the V/C ratio for that hour is adjusted back to 1.0. Hourly intersection delay is estimated by the following equation (Dowling and Associates et al. 2000):

$$D_H = \frac{EXP\left[7.11 + 4.25 * V/C_C + 0.000494 * TV_{Adj}(4) - 1.319 * \left(MSV_{Adj}/TV_{Adj}\right) + 6.43E(-7) * D_{Int}/TV\right]}{3600}$$

Where, D_H =   Hourly delay (hours)

V/C_C =   Corrected hourly volume-to-capacity ration

TV_{Adj} =   Adjusted hourly total approach volume (equals intersection capacity for over- capacity conditions)

MSV_{Adj} =   Adjusted hourly maximum sum of approach volumes (approach 1+2 or approach 3+4)

TV =   Total intersection peak hour approach volume, as input by the user

D_{Int} =   Total intersection peak hour delay in hours, as input by the user

Travel time savings are estimated by subtracting the project case delay from the base case delay.

Park and Ride: The user inputs the characteristics of the lot, and of the people who use the lot. In addition, information is input for up to five major destinations from the lot, including the percent of lot users to the destination, distance from lot, speed, and HOV, transit and carpool information. Travel time savings is calculated for four categories of lot users.

For new transit riders, travel time savings is equal to the difference in HOV and general purpose lane travel times, minus the wait time at the lot for the bus. If no HOV lanes are present, a travel time loss is calculated, equal to the transit wait time. For existing transit riders, travel time savings equal to the difference between the local and express transit travel times. For new carpoolers, travel time savings is equal to the difference in HOV and general purpose lane travel times, minus the wait time at the lot for the carpool. If no HOV lanes are present, a travel time loss is calculated, equal to the carpool wait time. Existing carpoolers are those who switch to the new lot for convenience. No travel time savings is calculated for this group of users.

Two-Way-Left-Turn Lane: The user inputs the base case and project case facility description, as well as the turning volumes and through volumes in the peak and non-peak directions.

If a two or three lane roadway is being analyzed, the "Harwood / St. John" method is used for delay calculation. If a four or more lane roadway is being analyzed, the "NCHRP 395" approach for delay calculation is used.

Both approaches consist of a series of equations that are utilized the competing through and left turn volumes. The delay calculation equations include coefficients that were specifically derived for the method being used. The "Harwood / St. John" method utilizes a constant set of coefficients that do not vary by facility type. The delay savings is calculated directly by the equations.

The "NCHRP 395" method contains coefficients that very with the type of facility (undivided, TWLTL, or median) for both the base case and the project case. This method calculated the total delay for both the base case and the project case. Travel time savings is calculated by taking the difference between the two.

Travel Time Benefits

Travel time savings are divided between automobiles and trucks, based upon the truck percentage that is entered by the user for all Highway Improvement project types.

In all cases, travel time benefits are calculated by multiplying the estimated travel time savings for automobile drivers and passengers, and for truck drivers, by their respective values of time (as defined in the Global Variables). Travel time benefits are assumed to change at a uniform rate between the initial year and the final year of the forecast period. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Operating Cost Savings

For all Highway Improvement projects, operating cost savings is based upon the travel time savings. The average operating costs per mile that are predominantly used for other modes and project types are converted to operating cost per hour, based upon an assumed average travel speed of 50 mile per hour. The operating costs per mile for auto and truck are included in MICA as global variables. The actual value per hour will depend on whether "Direct Cost" or "Full Cost" is selected by the user (as described in *Chapter 2 – Project Measures*). The operating cost savings is calculated by multiplying the travel time savings by the operating cost per hour. Since reduction in travel time is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual operating cost savings to travelers. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Air Quality Calculations

No air quality impacts are currently calculated for Highway Improvement projects. There are two areas of air quality impacts that could be included in future program refinements. First, the reduction in delay that is already calculated for the project will typically result in emissions reduction, since vehicles traveling at optimal speed produce lower emissions than vehicles that experience delay. Second, any new traffic that is drawn to an improved facility will increase emissions, which would result in a negative air quality impact. Since one type of impact is positive and the other negative, it is advisable to include both impacts, or neither impact in air quality considerations. This will avoid an exaggeration of the air quality impacts on project benefits.

Safety Calculations

Accident Savings

Accident savings are based upon three-year historical accident data at the project location, and reduction factors that are defined by the user. The method for calculating accident reduction is described in detail earlier in this chapter.

Safety Benefit Calculations

The safety benefit is calculated by multiplying the estimated reduction in each type of accident by its respective societal value. The societal costs of accidents are global variables, and are described in *Chapter 2 – Project Measures*. For historical-based accident reduction, a uniform number of accidents are estimated to be prevented during each year of the analysis period. Equation 2-2 (Present Value of a Uniform Annual Series) is used to calculate the net present value of these safety benefits.

<u>**Environmental Retrofit**</u>

A Highway Improvement project may include one or more of the three categories of environmental retrofit projects currently recognized in the MICA process: Fish Barrier Removal, Storm Water Retrofit, or Noise Barrier Construction. In this case, the costs of these projects are itemized in the cost input worksheet. Benefits for these projects are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio (BCR), as described in *Chapter 2 – Project Measures*.

<u>**Total Project Benefit Calculations**</u>

Total project benefits are calculated by adding together the net present values of all user operating benefits, travel time benefits, safety benefits, and environmental benefits that have been calculated for the project.

<u>**Total Project Cost Calculations**</u>

The total project costs are calculated by adding together the net present value of the capital costs and operation and maintenance costs, and subtracting the net present value of the terminal cost, as described in *Chapter 2 – Project Measures*. Both the total project cost and the cost to WSDOT are calculated.

<u>**Benefit-Cost Calculations**</u>

The Benefit-Cost Ratio is calculated by dividing the net present value of total project benefits by the net present value of total project costs. In cases where WSDOT has partnered with another public or private agency, a WSDOT Benefit-Cost ratio is calculated by dividing the net present value of WSDOT project benefits by the net present value of total project costs. If WSDOT is paying the entire cost of the project, these two values will be equal.

Project Reports

The report for any specific project is brought up by clicking on the "Project Report" button on the input form when that project is active. Project level reports are structured similarly for all project types, with four major sections:

1. **Project Information** – summarizes all descriptive data for the project.

2. **Input Summary** – summarizes all of the inputs for benefit and cost calculation.

3. **Calculation Results** – summarizes all of the results of the benefit calculations, cost calculations, cost efficiency measures, and outcome objective scores.

4. **Global Assumptions** – summarizes all of the global variables that were used in the calculations, as well as their respective values.

All data must be completely input for the full project report to be displayed. However, if the inputs are incomplete, the inputs that have been completed will still be summarized if the project report is brought up. When it is created, the project report displays on-screen. The report can then be printed out from the on-screen display if a hard copy is desired.

References

Dowling Associates, Inc. WSDOT Mobility Project Prioritization Process: Benefit / Cost Software User's Guide. Prepared in conjunction with Kittelson and Associates, ECONorthwest, and Rao Associates for the Washington State Department of Transportation. (May 2000).

Dowling, R.G., J. Billheimer, V. Alexiadis, and A.D. May. Predicting the Demand for High Occupancy Vehicle (HOV) Lanes. Federal Highway Administration Project #42-10-4172. Washington, DC. (June 1996)

Reed, Tracy L., D.A. Niemeier, and G. Scott Rutherford. Prioritization of Capacity Improvements. Prepared for the Washington State Department of Transportation. Report No. WA-RD 295.1. Washington State Transportation Research Center. Seattle, WA (1995).

Washington State Department of Transportation (WSDOT). 2001-2003 Budget and Six-Year Plan. Adopted by the Washington State Transportation Commission (August 16, 2000).

Washington State Department of Transportation (WSDOT). Washington Transportation Plan Update. (2000).

Washington Traffic Safety Commission. Informational Guide for Highway Safety Improvements. 1978.

Chapter 6 – Highway Preservation

The highway preservation program is responsible for preserving existing highway infrastructure and is divided into three subprograms: Roadway Preservation (P1), Structure Preservation (P2), and Other Facilities (P3). The roadway preservation division is responsible for the repair, repaving, and restriping of state-owned highways. Note that pavement repair projects included in this category are major projects intended to extend the life of the pavement. Patching and spot repair projects are not included in P1 but are a part of the Highway Maintenance Program. The structure preservation funds projects that preserve, replace, and rehabilitate bridges and other highway structures. The third division of highway preservation, other facilities, contains projects that preserve the remaining facilities and highway features such as rest areas, weigh stations, and roadway slopes.

Currently MICA is programmed to analyze Roadway (P1) and Structure (P2) Preservation projects. Future program refinements may add P3 projects.

Historically, preservation projects have been kept in separate funding categories than projects that expand the existing system, referred to as Highway Improvement projects by WSDOT and the MICA program. Funding for preservation projects have typically been given a high priority and the remaining money left for improvement projects. Recently the argument has been made that preservation projects should compete with other project types directly for funding and that this lack of competition among preservation projects results in inefficient use of the public resources. In Poorman and Posca's paper on this subject the authors argue that preservation (in their words infrastructure renewal) and improvement projects (mobility improvements) can be directly compared. To do this preservation projects must be analyzed differently than current practice typically calls for. The question for each project becomes "why is this infrastructure valuable?" What benefits are derived by the public because of the existence of this infrastructure? Quantifying these benefits is what allows for the comparison.

Inventory of projects

Roadway Preservation

For the 2001 Biennium the P1 program lists 109 projects containing 1,756 lane miles of preservation work. The estimated amount for these projects is just over $78 million with an average project cost of approximately $640,000.

Structure Preservation

The P2 program lists 175 projects for the 2001 Biennium. Project types include bridge and structure repair, structure replacement, bridge painting, and bridge deck overlays. The total estimated amount for the projects is $103 million although only 28 of the projects have authorized funding amounting to $12.3 million.

Other Facilities

The P3 program lists 209 projects for the 2001 Biennium ranging from weigh station and rest area to drainage and slope stabilization projects. The total estimated amount for the 209 projects is $102 million with $12.2 million being authorized for 35 of the 209 projects.

Inventory of current analysis methods

Roadway Preservation

The highway preservation program utilizes lowest life-cycle cost analysis using the Washington State Pavement Management System (WSPMS). The WSPMS is a large database that includes roadway inventory information along with the roadway configuration, pavement type and thickness, pavement construction history, traffic data, jurisdictional information, and the current six-year construction schedule. In addition, roadway condition data such as friction, ride, and surface defects are stored.

The pavement data is analyzed by WSPMS and pavement condition ratings are calculated. Based on these condition ratings individual segments are analyzed for the optimal rehabilitation strategy using computed life-cycle costs for each strategy. Pavement research has shown that it is more cost effective to rehabilitate pavements earlier in the cycle since the rehabilitation costs escalate at the lower end of the pavement's life. Enhancements to the WSPMS in the mid-90's added models that estimate the vehicle operating costs due to pavement deterioration to the decision making process.

The WSPMS identifies particular segments for rehabilitation and site visits verify the need and timing of the project. Pavement engineers at WSDOT combine the identified segments into projects. Note that the pavement management system isn't determining *whether* the roadway should be preserved only *when* it is the most cost-effective time to perform the work. This is related to the discussion at the beginning of this chapter about the different approaches to analyzing preservation projects.

A program entitled Highway Development and Management System (HDM-4) provides analysis of highway investment choices including maintenance and preservation projects. Although not commonly used in the US at this time, it is gaining popularity and is being purchased by WSDOT for use in pavement management decisions. HDM-4 differs from the WSPMS in its perspective of asking whether the overall project is cost-effective. That is, it can ask the question about whether the roadway derives enough benefits for its users to justify its preservation. This type of analysis will be necessary for preservation projects to be compared directly with non-preservation projects such as capacity improvements. The program contains pavement performance predictions, estimates for user costs, and environmental impacts such as energy consumption and vehicle emissions.

The pavement preservation of the MICA analysis is based on the assumption that the needed data could be obtained from HDM-4 or a similar program. The validity of this assumption will become more apparent as personnel within WSDOT become more familiar with the capabilities of HDM-4.

Another analysis approach for project analysis would be to analyze highway preservation projects based on the relationship between speed and pavement rating conditions. If this relationship could be derived the highway improvement portion of MICA (adapted from the existing highway priority programming process) could be adapted to preservation projects based on the avoided *disbenefits* from the preservation project.
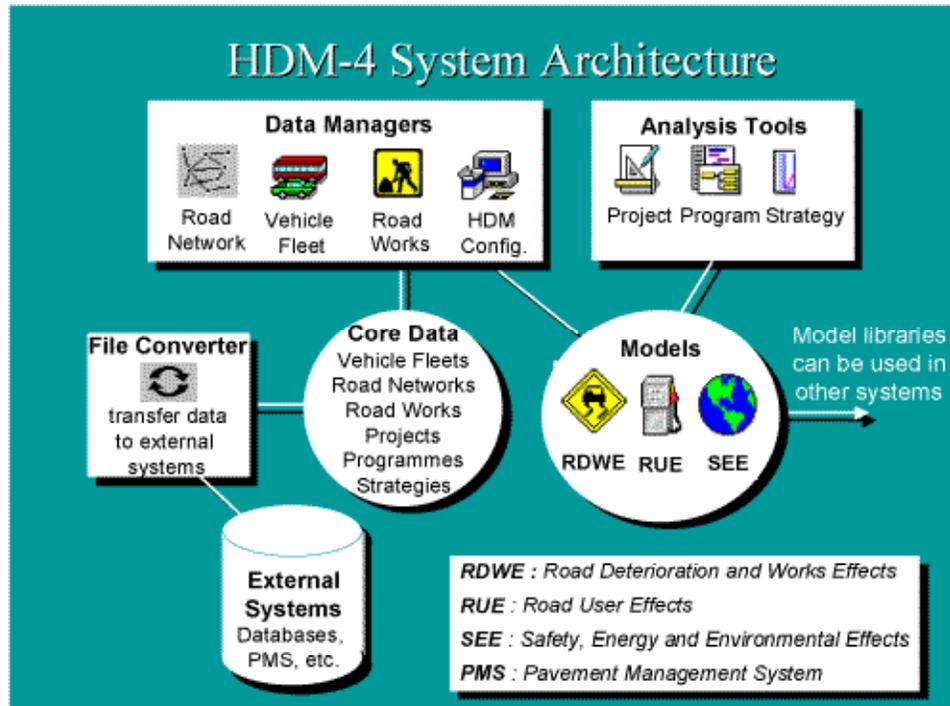
Figure 6-1: HDM-4 System Architecture

Structure Preservation

Structure preservation projects can also be analyzed using the HDM-4 program described in the roadway preservation section. In addition the MICA program allows a simplified, sketch planning approach based on the concept of avoided disbenefits. That is, the preservation project avoids potential future inconvenience to users in the case of the failure of the structure. Note that this methodology assumes that the facility would be closed by bridge inspectors prior to an actual failure of the structure.

The Bridge and Structures Office of WSDOT manages the agency's Bridge Maintenance System (BMS) using a software package called Pontis. Pontis was developed by AASHTO as part of a Federal Highway Administration sponsored project and is the most commonly used program for managing bridges in the United States. The BMS is a decision support tool that analyzes and summarizes bridge data. The BMS predicts deterioration and optimal preservation policies as well as analyzing alternative actions.

Identification of analysis gaps

Below is a list of known gaps in the analysis. The gaps are broken down into short and long-term gaps. Long-term gaps represent areas where additional data or research into developing new methodologies may be needed. These are areas recommended for further work in future phases of the project.

Short-Term Gaps

- Work with WSDOT pavement group regarding the use of HDM-4 program for P1 analysis. Refine MICA methodology based on work with the program.

- Work with WSDOT structures group to incorporate output from the Bridge Maintenance System into the MICA program.

Long-Term Gaps

- Add the safety component to the P1 analysis. This is not addressed in the HDM-4 program so methodology must be developed.
- Look at the affects of roughness on freight cargo.
- Possibly add P3 preservation projects.

Project worksheets and inputs

Chapter 3 – Operation of the MICA Program explains the general functions of the project and scenario levels of the program. The following sections focus on the input forms and calculations specific to the Highway Preservation project types.

Project Information

From the Project Level Screen for Highway Preservation the Project Information Screen shown in Figure 6-2 will be displayed when adding or editing a highway preservation project. The Highway Preservation Information Screen is identical for all project types within highway preservation. The Project Benefits screen (shown on the second tab of Figure 6-2) is the only highway preservation input screen that is specific to the project type. From any of the highway preservation project screens, the three buttons at the top of the screen can be selected to delete the current project, preview the project report, and save and exit the current project.

The following descriptions refer to the screen shown in Figure 6-2.

Project Title: Descriptive title of the project

Project Identification Number: Unique 7 digit alphanumeric number for project identification

Project Type: Select project type from pull down list. Current version only has pavement preservation but future versions will also have structure preservation and other preservation categories.

Biennium: Input the beginning year for the biennium the project is to be programmed. Leave blank if unknown or not critical

Region: WSDOT Region for the project. If multiple regions apply choose a primary region.

Legislative District: State Legislative District. If multiple districts apply choose a primary district.

Air Quality Designation: Attainment/Non-Attainment/Maintenance areas as identified by the Clean Air Act. If multiple designations apply choose primary area.

Designated WTP Corridor: Select yes or no from pull-down menu based on whether or not the project is on an identified Washington Transportation Plan corridor.

Strategic Freight Network: Select yes or no from pull-down menu based on whether or not the project is on the strategic freight network.

Figure 6-2: Highway Preservation Project Information Screen

Pavement Preservation Projects

The results from running the Highway Development and Management System (HDM-4) program are to be entered into the following worksheet. The analysis is to be performed for both an initial and forecast year. The forecast year is typically 20 to 40 years into the future. The following input descriptions refer to Figure 6-3.

Initial Analysis Year: Enter four-digit number for initial analysis year.

Forecast Analysis Year: Enter four-digit number for forecast analysis year.

Figure 6-3: Roadway Preservation Input Form

Highway Classification: Select highway classification (1-6) from pull-down list.

For the appropriate analysis year enter the following values from HDM-4.

Auto Travel Time Savings: Annual travel timesavings in hours for auto users. Note Travel Time savings represents the difference between travel time with and without the project. Positive values represent *reduced* travel times.

Freight Travel Time Savings: Annual travel timesavings in hours for freight users. Note Travel Time savings represents the difference between travel time with and without the project. Positive values represent *reduced* travel times.

User Cost Savings: Annual user costs savings excluding any travel timesavings. User cost savings includes cost of vehicle ownership and operation. Positive values represent *reduced* user costs.

Change in CO emissions: Annual change in carbon monoxide emissions calculated in tons of emissions. Note savings represent a difference between travel time with and without the project. Negative values represent *reduced* emissions.

Change in VOC emissions: Annual change in volatile carbon emissions calculated in tons of emissions. Note savings represent a difference between travel time with and without the project. Negative values represent *reduced* emissions.

Change in NOx emissions: Annual change in nitrous oxide emissions calculated in tons of emissions. Note savings represent a difference between travel time with and without the project. Negative values represent *reduced* emissions.

Change in PM10 emissions: Annual change in emissions of particulate matter 10 microns or less calculated in tons of pollutants. Note savings represent a difference between travel time with and without the project. Negative values represent *reduced* emissions.

Outcome Objectives

The Outcome Objectives inputs are the standard questions described in Chapter 3 of this report.

Project Costs

The cost input forms and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project.   In some cases this will result in a negative operation and maintenance cost if the improvement will lower the annual cost of operating the facility.

Benefit-cost calculations

The following sections describe the methodology behind the benefit-cost calculations contained in the program code. The actual calculations can be seen in the program code, which can be found in Volume II of this report.   The code can be followed using these descriptions and the annotations contained in the code itself.

Roadway Preservation Projects

Travel Time Calculations - Yearly Travel Time Benefits in Minutes

The travel time savings is calculated for the initial and forecast years and is converted to minutes of travel time saved. Note that negative numbers indicate that travel time increases with the project. Timesavings is kept separate for automobile and freight vehicles. HDM-4 allows for more refined analysis of the vehicle fleet but to maintain consistency within MICA only two types of vehicles are considered. Total travel time between the initial and forecast years is calculated assuming uniform growth and a 0% discount rate. Only monetary calculations use the global variable discount rate.

Travel Time Benefits in Dollars

Dollar values are applied to the travel time saving estimates using the global variables for Time Value for Automobile Travel and Time Value for Freight Vehicle travel.   In addition a global variable for percent of travel time travel is applied. All of these global variables are discussed in-depth in Section 2 of this report. Uniform growth between periods is assumed and the global discount rate is applied to the total travel time benefit calculation.

Operating Cost Calculations

Note that currently the calculations do not allow for adjustments to be made to the estimated operating cost savings based on full or direct user costs. All other project types within MICA allow for this cost toggle to be made. Currently the highway preservation inputs are based on full cost calculations. Future program refinements will allow for this change to be made. See Section 2 for a discussion on the differences between full and direct user automobile costs.

Air Pollution - Emissions Calculations

The change in emissions for the four pollutants included in MICA are calculated in HDM-4 and are entered into MICA by the user. Uniform growth between periods is assumed and no discount rate is applied. The total change in tons for the four pollutants is then calculated. Note that negative values represent a net reduction in emissions.

Air Pollution - Emissions Benefit Calculations

The total emissions estimates are multiplied by the global variables for cost per ton for each of the pollutant types. Emissions benefits are brought back to a present value using the global variable discount rate. Note the calculations result in a change of sign such that a negative change in emissions (reduced emissions) yields a positive emission benefit.

Safety Calculations

HDM-4 currently does not consider safety impacts so the change in accidents and the safety benefits are assumed to be zero. Future work will develop a methodology for estimating safety impacts. It is not expected that safety benefits will have a significant affect on the cost effectiveness of pavement preservation projects.

Structure Preservation Projects

Calculate the probability of structure failure

The probability of the structure failing is calculated based on the structure condition rating both with and without the proposed project. A condition rating of 1 (represents the highest condition rating) has a zero probability of failure and ratings of 2, 3, 4, and 5 (represents the lowest condition rating) have a probability of failure of 0.25, 0.50, 0.75, and 1.00 respectively. The probability of failure used for calculating project benefits is the difference between these probability rates for both the initial and forecast analysis years.

Travel Time Calculations - Yearly Travel Time Benefits in Minutes

The travel time savings is calculated for the initial and forecast years based on the number of trips, the drive-around time if the structure were closed, and the probability of structure failure. The travel time savings represents the number of avoided travel time minutes with the project. Timesavings is kept separate for automobile and freight vehicles and is based on the percentage of trips by the two vehicle types. Total travel time between the initial and forecast years is calculated assuming uniform growth and a 0% discount rate. Only monetary calculations use the global variable discount rate.

Travel Time Benefits in Dollars

Dollar values are applied to the travel time saving estimates using the global variables for Time Value for Automobile Travel and Time Value for Freight Vehicle travel. In addition a global variable for percent of travel time travel is applied. All of these global variables are discussed in-

depth in Section 2 of this report. Uniform growth between periods is assumed and the global discount rate is applied to the total travel time benefit calculation.

Operating Cost Calculations

The additional vehicle miles traveled (VMT) due to the structure closure is calculated based on the number of trips, the drive-around distance is the structure were closed, and the probability of structure failure. The additional VMT is treated as an avoided dis-benefit. The operating costs are calculated based on this VMT calculation and multiplied by the operating cost per mile for both automobile and truck vehicles. The per mile cost differs based on whether the full cost or direct cost global variable toggle is selected. See Section 2 for a discussion on the differences between full and direct user automobile costs.

Air Pollution - Emissions Calculations

The change in emissions for the four pollutants included in MICA are calculated based on the additional vehicle miles traveled due to structure closure discussed in the previous paragraph. The additional VMT is multiplied by the emission rates for the each pollutants. Uniform growth between periods is assumed and no discount rate is applied. The total change in tons for the four pollutants is then calculated.

Air Pollution - Emissions Benefit Calculations

The total emissions estimates are multiplied by the global variables for cost per ton for each of the pollutant types. Emissions benefits are brought back to a present value using the global variable discount rate.

Safety Calculations

Safety benefits are determined for the three accident types; fatality, injury, and property damage only. Accident estimates are calculated based on the additional vehicle miles traveled due to structure closure discussed previously. The additional VMT is multiplied by the accident rates for the each accident type. Uniform growth between periods is assumed and no discount rate is applied. The total change in accidents for the three accident types is then calculated.

Safety Benefit Calculations

The total accident estimates are multiplied by the global variables for cost per accident for each type. Safety benefits are brought back to a present value using the global variable discount rate.

Project reports

The highway preservation reports are structured with the first section showing the user inputs. The second section shows the results to key calculations such as travel timesavings in minutes and in dollars, benefit-cost ratios, etc. The third section shows the results to the Outcome Objective calculations. The final section shows the Global Variables that were used in the calculations and notes if values differed from the default values.

References

1. Baker, Brent and Richard Miller. "An Economic Evaluation of Bridge Seismic Retrofit Improvements". Paper Presented at the Transportation Research Board 79th Annual Meeting. Washington, D.C. January 9-13, 2000.

2. Federal Highway Administration. *Life-Cycle Cost Analysis in Pavement Design*. Pavement Division Interim Technical Bulletin. Publication No. FHWA-SA-98-079. September 1998.

3. HDM-4 Information Centre. http://hdm4.piarc.org/main/home-e.htm

4. Johnson, Bruce and Frank Nelson. "Project Selection Method Integrating BMS Data and Non-Deterioration Based Needs". Paper Presented at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January, 1999.

5. Kay, R. Keith; Mahoney, Joe P.; Jackson, Newton, C. *The WSDOT Pavement Management System – A 1993 Update*. Washington Department of Transportation Report WA-RD 271.1. September 1993.

6. Kerali, H.R. and V. Mannisto. "Prioritization Methods for Strategic Planning and Road Work Programming in a New Highway Development and Management Tool". *Transportation Research Record Number 1655*. Transportation Research Board, Washington D.C. 1999.

7. Mahoney, Joe P.; Seferian, Marc. *The WSDOT Pavement Management System – Operational Enhancements.* Washington Department of Transportation Report WA-RD 315.2. December 1995.

8. Poorman, John P. and Glenn Posca. "Comparing Infrastructure Renewal Projects to Mobility Improvement Projects". *Transportation Research Record Number 1429*. Transportation Research Board, Washington D.C. 1994.

Chapter 7 – Highway Safety Projects

The Highway Safety Program is included in the Washington State Current Law Budget as Program I-2. Safety Improvements correct deficiencies in high accident areas and make improvements at potentially hazardous locations. Activities in this subprogram include improving known high accident locations; improving locations where analyses indicate high accident potential; eliminating major at-grade intersections on high speed multilane highways; and constructing turn lanes and/or signals where they are warranted by high volumes.

Inventory of Projects

Three Highway Safety project types have been directly addressed in analysis in the current phase of MICA. These are:

1. **At-Grade Intersections**: WSDOT's goal is to eliminate at-grade intersections located on multi-lane median-divided highways with speeds of 45 mph or greater, due to their inherent accident risk.

2. **High Accident Corridors**: Locations in 1.0-mile increments in which a high number of accidents occur. The corridor may exceed 1.0 mile in length if successive increments have a high number of accidents.

3. **High Accident Locations**: Locations in 0.1-mile increments at which a high number of accidents occur. Locations may exceed the 0.1-mile length if successive increments have a high number of accidents.

Inventory of Current Analysis Methods

The analysis procedures for Highway Safety projects consist mainly of determining the number of collisions that will be prevented by a safety improvement, and calculating the societal cost savings. Secondary user benefits that may result from a project, such as travel time or operating cost savings, are not currently part of project analysis. This is appropriate within the current structure, since the sole basis for project implementation is the degree to which it makes the highways safer. Any additional benefits are certainly good, but they do not play a role in determining whether or not a project will be built. In addition to determining the monetary safety benefits of proposed projects, safety improvement locations are assigned an accident severity rating, which is used as part of the internal prioritization process.

Identification of Analysis Gaps

Additional project types that have already been defined by WSDOT are not included in this phase. These project types include:

1. Interstate Safety Matrix

2. RISK: Roadside Encroachment

3. Truck Inspection Stations

4. Signal / Channelization

5. Pedestrian Accident Locations

The signal/channelization project type currently utilizes the FHWA *Manual on Uniform Traffic Control Devices* (MUTCD) signal warrants to determine where these projects should be built. While the Pedestrian Accident Location project type is not included under the Highway Safety mode, it is included under non-motorized modes.

The Highway Safety category has much overlap with the Highway Improvements category, since these projects *are* highway improvements. Safety projects have been separated out from general highway improvements so that mitigation of high accident locations may be directly addressed as a top priority (and so that high safety benefits to travelers do not have to "compete" with fast travel times). If MICA is developed to its full potential, this separation should not be necessary. Rather, the user can define "Safety" as a top criterion and these projects should emerge high on the list of projects. In future refinements of the MICA process, the relationship between Highway Improvement and Highway Safety should be carefully examined.

The monetary benefits methods included in this phase of MICA include only accident savings, consistent with current practice. While three Highway Safety project types are explicitly listed, they utilize the same benefit procedure. Regardless of its official type, benefits for any Highway Safety project in which the number of accidents prevented by the project is known can be computed using these worksheets.

Project Worksheets and Inputs

The highway improvement mode is accessed by clicking on the "Highway" button on the starting screen of the Project Module. Additionally, the user must click on the "Safety" sub-category to access the specific Highway Safety project type. Figure 7-1 shows the opening screen for the highway safety mode. From this screen, the analyst can access existing highway safety projects in the MICA database, or add a new highway safety project (note, the general procedures for Project Level Analysis are described in *Chapter 3 – Operation of the MICA Program*).
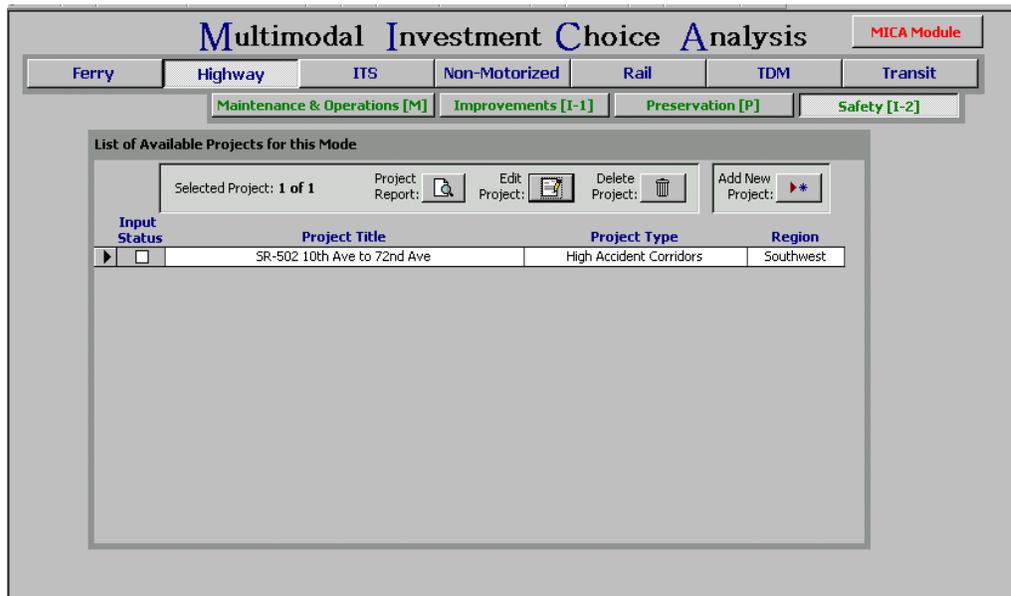
Figure 7-1: Opening Screen for Highway Safety Mode

Project Information

The Project Information input form, as shown in Figure 7-2, is the first of four screens to be displayed when a highway safety project is edited or added to the database. The user can navigate through the four screens by clicking on the tab headings. Additionally, the three buttons at the top of the screen can be selected at any time to delete the current project from the database, preview the project report, or save the current data and exit back to the opening screen for highway improvement projects.

Figure 7-2: Highway Safety Project Information Form

The Project Information component contains the following descriptive information:

Project Title:	Descriptive title of the project
Project ID Number:	Identifier that is unique to the project
State Route:	State Route Designation, if applicable.
Beginning Milepost:	Milepost number at beginning of project, if applicable.
Ending Milepost:	Milepost number at end of project, if applicable.
Project Type:	Specific type of project, selected from a pull down list. For the highway safety mode, the three project types are:

- **At-Grade Intersection**

- **High Accident Corridor**

- **High Accident Location**

Biennium:	Biennium in which the project is to be considered for funding

Region: WSDOT Region in which the project is located. A pull down menu provides eight region options:

- **Eastern**

- **North Central**

- **Northwest**

- **Olympic**

- **South Central**

- **Southwest**

- **Statewide** should be selected if the project is located in multiple regions

- **Ferry** applies only to ferry projects, and would never be selected for highway projects

Legislative District: State Legislative District in which the project is located, if the project fits completely or primarily in one district.

Air Quality: Air quality designation for the project area, as identified by the Clean Air Act. A pull down menu provides the options of:

- **Attainment Area**

- **Non-Attainment Area**

- **Maintenance Area**

- **Unclassifiable**

as described in *Chapter 2 – Project Measures*.

WTP Corridor: Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

Highway System Plan: Identifies whether or not the project is included in the Highway System Plan. Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

FGTS Classification: Identifies whether or not the project is included in the Freight and Goods Transportation System (FGTS) classification system. A pull down menu provides the options of:

- **T-1** (> 10 million tons per year)

- **T-2** (4 to 10 million tons per year)

- **T-3** (300,000 to 4 millions tons per year)

- **T-4** (100,000 to 300,000 tons per year)

- **T-5** (20,000 tons per 60 days)

- **None**

as described in *Chapter 2 – Project Measures*.

Benefit Information

The second input screen is the benefit input form, shown in Figure 7-3, which is identical for all Highway Safety project types. The user inputs data under three major categories:

- Project Features

- Analysis Period

- Accident Data

Figure 7-3: Benefit Input Screen for Highway Safety Projects

The Benefit Input component for Highway Safety projects calls for the following information:

Project Features

Description of Project:	User can input up to two lines of description of project features
Length:	Length of project (miles)
Accident Severity Rating:	Accident Severity Rating for project, determined by WSDOT

Analysis Period

Initial Year:	Initial analysis year
Forecast Year:	Forecast analysis year

Accident Data

Begin Accident Data:	Beginning year for historical accident data
End Accident Data:	Ending year for historical accident data
Fatality Accidents:	Number of fatality accidents in defined time period that would have been prevented by the project
Disabling Injury Accidents:	Number of disabling injury accidents in defined time period that would have been prevented by the project
Evident Injury Accidents:	Number of evident injury accidents in defined time period that would have been prevented by the project
Possible Injury Accidents:	Number of possible injury accidents in defined time period that would have been prevented by the project
PDO Accidents:	Number of property damage only accidents in defined time period that would have been prevented by the project

Outcome Objectives

The third page contains the Outcome Objectives inputs, which consist of the standard questions described in Chapter 3 of this report. While all of the input questions remain the same regardless of mode or project type, some calculations do vary with project type.

Cost Information

The final page of the input form contains the cost data. Cost inputs and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In cases where the improvement will lower the annual cost of operation and maintenance, a negative cost value will result.

Benefit-Cost Calculations

Benefit calculations for Highway Safety Projects are based upon the number of highway collision accidents they are expected to prevent.

Safety Benefits

Accident reduction based upon historical data

This accident reduction is based upon historical accident data at the project location. The user identifies the number of accidents that occurred over a defined period of time (Highway Safety often uses two years) for each accident type: fatality, disabling injury, evident injury, possible injury, and property damage only. The user then identifies the number of these accidents that could have been prevented by the proposed improvement. The average number of prevented accidents per year is calculated for each type, and this is assumed to be the number prevented per year, for each year of the project's analysis life.

Safety Benefit Calculations

The safety benefit is calculated by multiplying the estimated reduction in each type of accident by its respective societal value. The societal costs of accidents are global variables, and are described in *Chapter 2 – Project Measures*. For historical-based accident reduction, a uniform number of accidents are estimated to be prevented during each year of the analysis period. Equation 2-2 (Present Value of a Uniform Annual Series) is used to calculate the net present value of these safety benefits.

Environmental Retrofit

Though it is not part of the current process, MICA is set up to calculate the benefits if a Highway Safety project includes one or more of the three categories of environmental retrofit projects currently recognized in the MICA process: Fish Barrier Removal, Storm Water Retrofit, or Noise Barrier Construction. In this case, the costs of these projects are itemized in the cost input worksheet. Benefits for these projects are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio (BCR), as described in *Chapter 2 – Project Measures*.

Total Project Benefit Calculations

Total project benefits are calculated by adding together the net present values of safety benefits, and environmental retrofit benefits (if they have been specified) that have been calculated for the project.

Total Project Cost Calculations

The total project costs are calculated by adding together the net present value of the capital costs and operation and maintenance costs, and subtracting the net present value of the terminal cost, as described in *Chapter 2 – Project Measures*. Both the total project cost and the cost to WSDOT are calculated.

Benefit-Cost Calculations

The Benefit-Cost Ratio is calculated by dividing the net present value of total project benefits by the net present value of total project costs. In cases where WSDOT has partnered with another public or private agency, a WSDOT Benefit-Cost ratio is calculated by dividing the net present

value of WSDOT project benefits by the net present value of total project costs. If WSDOT is paying the entire cost of the project, these two values will be equal.

Project Reports

The report for any specific project is brought up by clicking on the "Project Report" button on the input form when that project is active. Project level reports are structured similarly for all project types, with four major sections:

1. **Project Information** – summarizes all descriptive data for the project.

2. **Input Summary** – summarizes all of the inputs for benefit and cost calculation.

3. **Calculation Results** – summarizes all of the results of the benefit calculations, cost calculations, cost efficiency measures, and outcome objective scores.

4. **Global Assumptions** – summarizes all of the global variables that were used in the calculations, as well as their respective values.

All data must be completely input for the full project report to be displayed. However, if the inputs are incomplete, the inputs that have been completed will still be summarized if the project report is brought up. When it is created, the project report displays on-screen. The report can then be printed out from the on-screen display if a hard copy is desired.

References

Washington State Department of Transportation (WSDOT). 2001-2003 Budget and Six-Year Plan. Adopted by the Washington State Transportation Commission. August 16, 2000.

Washington State Department of Transportation (WSDOT). Internal Documents: "At-Grade Benefit-Cost Analysis", "2002 Hazardous Accident Locations (HAL)", "Modifications to High Accident Corridor (HAC) Methodology", "I-2 Safety Program HSP Funding Update". (Acquired January 2002).

Chapter 8 – Intelligent Transportation Systems

Intelligent Transportation System (ITS) Projects have been traditionally handled as a separate category within WSDOT due to the innovative nature of the projects and the percentage of federal funds associated with them. As ITS projects become more mainstream they will most likely become integrated into the traditional planning and programming process. The major obstacle is the "non-traditional" nature of ITS projects. Project analysis methods for traditional highway projects focus on benefits derived from expected or recurrent congestion. ITS projects are often designed to address problems arising from operational issues and non-recurrent delay. ITS projects benefits are often from improvement to the system's reliability, benefits that are not typically captured in traditional evaluation methods.

The MICA program treats ITS projects as a separate program area because of the analysis methodology for capturing benefits from non-recurrent delay. MICA can analyze ITS projects for both highway and transit projects. In the future it may be beneficial for budgetary reasons for the program to identify which mode a particular ITS project is associated with.

Inventory of projects

As mentioned previously, ITS projects have typically been handled as a separate category with much of the funding coming from federal research dollars. The Advanced Technology Branch (ATB) within WSDOT manages the ITS program. The latest status report from ATB released in January of 2001 listed 31 projects currently underway. The projects are broken down into the following six categories: Deployment (18), Applied Projects (2), Proof of Concept (1), Research Projects (5), Planning and Policy (1), and Coordination Efforts (4). The numbers in parenthesis represent the number of projects in each category.   The projects described in the report range from traveler information numbers, to transit signal priority systems, to integrating freight data. No project costs are provided in the report.

The Northwest Region lists 24 projects for the next biennium with at least a partial ITS component (Task 9540, Intelligent Transportation System Plans) but does not separately list the ITS component's costs. As ITS moves into the mainstream it is likely that more highway projects will contain ITS elements. In MICA, the traditional highway elements and the ITS elements will be analyzed separately and the costs and benefits added to create a combined project.

Inventory of current analysis methods

There is considerable research being done on estimating the impacts of ITS projects. Most of the efforts are either still in the research or early application stages and there does not yet appear to be consensus on whether these efforts will provide suitable results for comparing ITS projects to non ITS projects. Below is a description of three methodologies for ITS project evaluation; the Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN), the ITS Deployment Analysis System (IDAS), and the Screening Analysis for ITS (SCRITS). MICA is currently programmed to use the results of the second and third methodologies. The first methodology is mentioned primarily to illustrate the direction that ITS project evaluation methods are headed.

PRUEVIIN

The Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN) was developed as part of the Impacts Assessment for the Seattle Metropolitan Model Deployment Initiative (MMDI) Case Study in 1999. PRUEVIIN is a two-level modeling system for assessing ITS impacts at the regional and corridor levels. The regional level impacts are modeled using a

traditional regionally planning model (EMME/2). Results from the regional model are then fed into a sub-area simulation model (INTEGRATION 1.5). The simulation model captures the affects of detailed traffic operation, queuing, dispersion of demand, and real-time travel responses to information. Interfaces between the two models are handled using both pre- and post-processors.
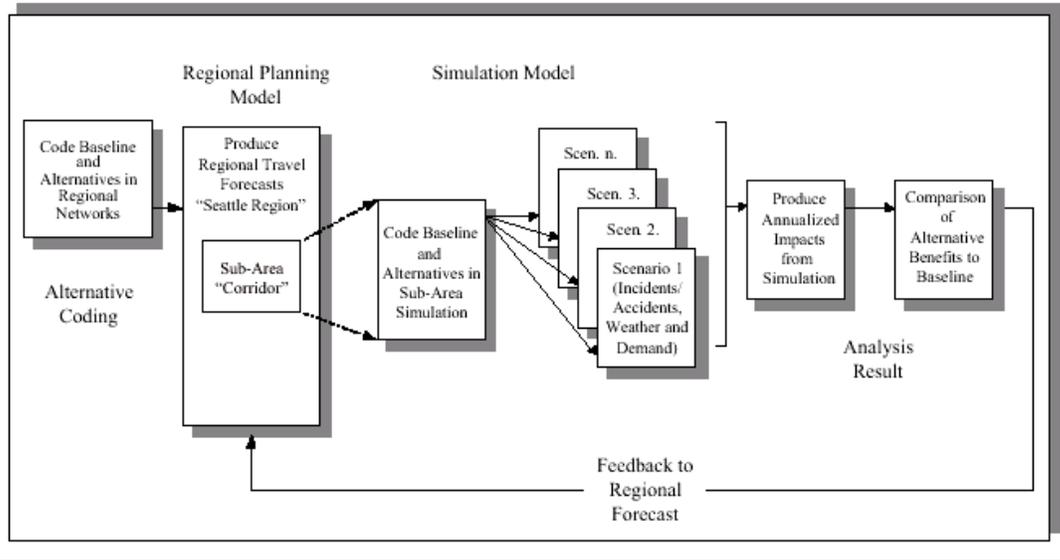
Figure 8-1: PRUEVIIN Analysis Methodology

(Source: Incorporating ITS into Corridor Planning: Seattle Case Study)

The PRUEVIIN methodology utilizes separate representative-day scenarios that were developed to reflect the variability of the conditions based on two years of travel demand, weather, and accident/incident data. In addition, the methodology incorporates several measures of effectiveness that are not used in traditional project evaluation methods:

- *Coefficient of trip time variation* is calculated from the variability of travel for similar trips across all the scenarios and is an indicator of system reliability

- *Percentage of vehicle-kilometers of travel by speed range* is created from normalized speed profiles.

- The *Number of stops per vehicle-kilometer of travel* is estimated by the simulation program.

IDAS

The ITS Deployment Analysis System (IDAS) is a sketch planning tool for the evaluation of ITS projects that was developed by Cambridge Systematics for the Federal Highway Administration. IDAS is a computer program that works as a post-processor to travel demand models based on a database of studies on the impacts of ITS projects. Impacts evaluated by IDAS include user mobility, travel time/speed, travel time reliability, fuel costs, operating costs, emissions, and noise.

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      └ ─▶│  Alternatives Comparison  │◀────│  │• Induced/foregone demand            │ │
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          │  ┌─────────────────────┐  │    │  │• IDAS ITS option assignment         │ │
          │  │  Benefit Valuation  │  │    │  │• Mode choice                        │ │
          │  └─────────────────────┘  │    │  │• Temporal choice                    │ │
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          │  │• Performance measures│ │    │  ┌──────────────────────────────⑤.3┐  │
          │  │• Cost/benefit analysis│ │    │  │      Environment                 │  │
          │  │• Sensitivity analysis │ │    │  └──────────────────────────────┘  │
          │  │• Ranking of ITS options│ │    │  ┌──────────────────────────────⑤.4┐  │
          │  │• Risk analysis        │ │    │  │        Safety                    │  │
          │  │• Plots of link volumes│ │    │  └──────────────────────────────┘  │
          │  │  and speeds           │ │    │  ┌──────────────────────────────⑤.5┐  │
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Figure 8-2: IDAS Model Structure

(Source: ITS Deployment Analysis System User's Manual)

The analysis done by IDAS looks at a peak hour period with and without the proposed improvements. Calculations within the program convert the peak hour values to daily and annual numbers. Project costs are annualized and the calculated benefit cost ratio represent the analysis year benefits over the annualized costs. On the other hand MICA looks at an initial and

forecast year and assumes linear growth of benefits between these years requiring two separate IDAS analyses (initial and forecast year) to be performed.

The IDAS program defaults to nationwide averages and many of the system settings are intended to be modified by its users to better represent the region or state being analyzed. It is not the intent of this manual to suggest IDAS settings but instead to provide a program that will allow project's analyzed within IDAS to be compared with non-ITS projects. MICA requires inputs of the "basic" numbers and does most of the monetary calculations internally to minimize differences in user assumptions.

SCRITS

The Screening Analysis for ITS (SCRITS) method is a sketch level analysis that is considerably less sophisticated then the previous two methods yet still results in user benefit estimates. It should only be used when travel demand models are not available for IDAS Analysis or for initial sketch level planning analysis. SCRITS is an Excel Spreadsheet program that was created by Science Applications International Corporation for the Federal Highway Administration and is available for free download from the FHWA's website at http://www.fhwa.dot.gov/steam/scrits.htm. The calculations found in the SCRITS program have been incorporated into MICA so that the entire analysis may be done within one program.

SCRITS calculated estimates for daily benefit so for a MICA analysis these results must be converted into annual benefits and also calculated for a base and forecast years. The spreadsheet file contains worksheets for the different ITS project types as well as a "baseline" worksheet for comparisons. The ITS projects handled by SCRITS include:

- Closed Circuit Television
- Freeway Detection (e.g. Induction Loops)
- Highway Advisory Radio
- Variable Message Signs
- Pager Based Systems
- Kiosks
- Commercial Vehicle Operation Kiosks
- Internet Traffic Information

- Automatic Vehicle Location for Transit
- Electronic Fare Collection
- Signal Priority for Transit
- Electronic Toll Collections
- Ramp Metering
- Weight In Motion
- Highway/Rail Grade Crossing Application
- Traffic Signal Strategies

The program does not directly account for strategies that involve multiple components. The user must decide whether the benefits are mutually exclusive and therefore additive. Judgments must be made in cases where the benefits are not additive but that is not handled internally within the program.

Identification of analysis gaps

Below is a list of known gaps in the analysis. These are areas recommended for further work in future phases of the project.

- Update the IDAS database to reflect regional estimates of ITS project impacts.

- Compare the analysis results of projects analyzed in IDAS to those analyzed in SCRITS and modify or adjust as necessary so that the projects are analyzed equally.

Project worksheets and inputs

Chapter 3 – Operation of the MICA Program explains the general functions of the project and scenario levels of the program. The following sections focus on the input forms and calculations specific to the ITS project types. The following sections show screen captures for the various input forms in the MICA program. In addition, a description of the required input is given.

Figure 8-3: ITS Project Information Screen

Project Information

From the Project Level Screen for ITS Projects the Project Information Screen Shown in Figure 8-3 will be displayed when adding or editing an ITS project. The ITS Project Information Screen is identical for all project types. The Project Benefit screen (shown on the second tab) is specific to the project type (IDAS or SCRITS). From any of the ITS project screens, the three buttons at the top of the screen can be selected to delete, preview the project report, and save the current project and exit.

Project Title: Descriptive title of the project

Project Identification Number: Unique 7 digit alphanumeric number for project identification

Project Type: Select project type from pull down list (either IDAS or SCRITS)

Biennium: Input the beginning year for the biennium the project is to be programmed. Leave blank if unknown or not critical

Region: WSDOT Region for the project. If multiple regions apply choose a *primary* region.

Legislative District: State Legislative District. If multiple districts apply choose a *primary* district.

Air Quality Designation: Attainment/Non-Attainment/Maintenance/Unclassifiable areas as identified by the Clean Air Act. If multiple areas apply choose a *primary* area.

Designated WTP Corridor: Select yes or no from pull-down menu based on whether or not the project is on an identified Washington Transportation Plan corridor.

FGTS Classification: Is the project on the Strategic Freight Network? If so choose one of the five Freight Goods Transportation System Classification (T-1 through T-5) from the pull-down list. Otherwise choose "None".

State Route: Enter the state route number for the highway. Leave blank if not applicable to the project.

SR Milepost   Begin: Enter the beginning state route milepost for the project, if applicable.

                End: Enter the ending state route milepost for the project, if applicable.

IDAS Results

If the ITS Deployment Analysis System (IDAS) project type was selected the screen shown in Figure 8-4 will be displayed under the Project Benefits tab. The results from running the IDAS program are to be entered into the following worksheet. Because of this the MICA program for IDAS projects can be thought of as a post-processor for the IDAS program. Future revisions to the MICA program may allow for the IDAS results to be directly downloaded to the MICA program. The analysis is to be performed for both an initial and forecast year, typically 20 to 40 years into the future.

Initial Analysis Year: Enter four-digit number for initial analysis year.

Forecast Analysis Year: Enter four-digit number for forecast analysis year.

Highway Classification: Select highway classification (1-6) from pull-down list.

For the appropriate analysis year enter the following values from the IDAS output.

Vehicle Miles of Travel: Annual Vehicle Miles Traveled for the Base and Project Cases.

Number of Trips: Annual Number of Trips for the Base and Project Cases.

Person Hours of Travel: Annual Person Hours of Travel for the Base and Project Cases.

Percent Freight Vehicles: The percent of the traffic volume that is freight vehicles. Enter in decimal format.

Figure 8-4: IDAS Project Input Screen

SCRITS Results

If the Screening Analysis for ITS (SCRITS) project type is selected the project input screen shown Figure 8-3 will be modified to include a list of 16 ITS project components as shown in Figure 8-5. The user would check each of the applicable boxes. For each box checked a project input screen for that component will be displayed as a sub-form of the Project Benefits tab. The following is a description of these 16 screens including an initial baseline screen that is necessary for all components.

Figure 8-5: Revised Project Input Screen for SCRITS Projects

The following descriptions refer to baseline input screen shown in Figure 8-6. This input screen is used in the calculations for all project components selected. Note that the components selected in the previous screen are shown as tabs. Each of these tabs represent input forms specific to the individual components.

Figure 8-6: SCRITS Baseline Input Form

Project Data

Initial Analysis Year: Enter four-digit number for initial analysis year.

Forecast Analysis Year: Enter four-digit number for forecast analysis year.

Highway Classification: Select highway classification (1-6) from pull-down list.

Baseline Information

The following is baseline information for the project area before any project improvements are made.

Centerline miles of Freeway: Enter the number of centerline freeway miles (not lane miles) for the project area.

Centerline miles of Arterial: Enter the number of centerline arterial miles (not lane miles) for the project area.

Proportion of Freeway Miles with shoulder at least one side: Enter the proportion (between 0 and 1) of Freeway miles with shoulder on at least on side of the roadway.

Average vehicle occupancy: Enter the average vehicle occupancy for the project area.

Average incident duration (Freeway): Enter the average freeway incident duration in minutes.

Percentage of secondary freeway accidents of total accidents: The percentage (between 0 and 100%) of accidents that occur on the freeway that area secondary (that is they occur because there is a previous accident on the facility).

Average bus fare: The average bus fare for the project area, if applicable.

For the appropriate analysis year enter the following values . Values specific to the project area should be used where known. Otherwise regional numbers may be used.

Area/Regional average trip length (miles): Enter the average trip length in miles for the project area (if known) or region.

Area/Regional average trip time (mins): Enter the average trip time in minutes for the project area (if known) or region.

Area/Regional average number of weekday trips: Enter the average number of weekday trips for the project area (if known) or region.

Freeway Vehicle Miles Traveled: Enter the estimated number of freeway vehicle miles traveled for the project area (if known) or region.

Arterial Vehicle Miles Traveled: Enter the estimated number of arterial vehicle miles traveled for the project area (if known) or region.

Ratio of Freeway AADT/Capacity (to nearest tenth): Enter the ratio of Freeway annual average daily trips to the Freeway Capacity. (Sometimes referred to as the ACR value)

Ratio of Arterial AADT/Capacity (to nearest tenth): Enter the ratio of Freeway annual average daily trips to the Freeway Capacity. (Sometimes referred to as the ACR value)

Ratio of AWDT/AADT (Ratio of average weekday trips to average daily trips): Enter the ratio of the average number of *weekday* trips to the average number of *daily* trips (average number that includes weekends).

Do you want to use calculated or input values for recurring VHT? Select **Calculate** or **Input** from the selection list for recurring vehicle hours traveled. Calculated values are estimated using lookup tables that relate the ACR value (Ratio of AADT to Capacity) to mean operating speed. If **Input** is selected from the previous question the program will use the entered values for subsequent calculations

Inputs for Recurring VHT on average weekday: Enter the following values for the appropriate analysis year. The term recurring refers to estimates that do not assume incident occurrences where non-recurring delay occurs.

> **Freeway:** Estimated freeway vehicle hours traveled for the project area (if known) or region.

> **Arterial:** Estimated arterial vehicle hours traveled for the project area (if known) or region.

Do you want to use calculated or input values for non-recurring VHT? Select **Calculate** or **Input** from the selection list for recurring vehicle hours traveled. Calculated values are estimated using lookup tables that relate the ACR value (Ratio of AADT to Capacity) and the presence of shoulders on the facility to the ratio of recurring to non-recurring vehicle hours traveled. If **Input** is selected from the previous question the program will use the entered values for subsequent calculations

Ratio of Recurring to Non-Recurring VHT: If Input is selected in the previous question then the ratio of recurring to non-recurring vehicle hours traveled for the project area (if known) or region must be entered.

Percentage of Secondary Freeway Accidents of Total Accidents : Secondary accidents are defined as those that occur due to situations caused by a primary accident (i.e. chain reaction accidents). Enter the percentage of secondary freeway accidents as a percentage of all freeway accidents.

<u>**CCTV (Closed Caption Television) Information**</u>
If CCTV was selected as a project component the screen shown in Figure 8-7 will be displayed. The following is a description of the required inputs.

Number of cameras to be installed: Number of CCTV cameras installed as part of the project.

Percent CCTV coverage of freeway system before improvement: Percentage of coverage of the freeway system before the proposed cameras are installed.

Percent CCTV coverage of freeway system after improvement: Percentage of coverage of the freeway system after the proposed cameras are installed.

Estimated reduction in average incident duration (min): The number of minutes the average incident duration will be reduced due to coverage by CCTV cameras. In most cases this is equal to the estimated reduction in response time due to faster incident detection.

Figure 8-7: SCRITS CCTV Input Form

Savings in VMT per weekday: The reduction in weekday vehicle miles traveled due to the cameras during the initial and forecast analysis years. In most cases this will be negligible except in cases where a reasonable detour route around the facility exists such that motorists easily change routes during incidents. In this case the change in VMT could be estimated.

CCTV Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Freeway Detection Information

If Freeway Detection was selected as a project component the screen shown in Figure 8-8 will be displayed. The following is a description of the required inputs.

Percent detection coverage before improvement: Percentage of coverage of the freeway system before the proposed detection is installed.

Percent detection coverage after improvement: Percentage of coverage of the freeway system after the proposed detection is installed.

Estimated reduction in average incident duration (min): The number of minutes the average incident duration will be reduced due to coverage freeway detection. In most cases this is equal to the estimated reduction in response time due to faster incident detection.

Savings in VMT per weekday: The reduction in weekday vehicle miles traveled due to the freeway detection during the initial and forecast analysis years. In most cases this will be negligible except in cases where a reasonable detour route around the facility exists such that motorists easily change routes during incidents. In this case the change in VMT could be estimated.

Freeway Detection Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-8: SCRITS Freeway Detection Input Form

Highway Advisory Radio Information

If Highway Advisory Radio (HAR) was selected as a project component the screen shown in Figure 8-9 will be displayed. The following is a description of the required inputs.

Number of transmitters: Number of Highway Advisory Radio transmitters installed as part of the project.

Average volume (per hour) through the HAR reception area: The average number of cars per hour passing through the highway advisory reception area during the initial and forecast analyses years.

Time (hrs) transmitter active for each incident: The number of hours the transmitter is typically turned on during an incident.

Number of times/day each transmitter activated: Average number of times an individual transmitter is activated during a typical day (value may be less then 1).

Percent of drivers tuned to broadcast: The percent of drivers within the reception area that tune to the highway advisory broadcast.

Percent of drivers hearing broadcast that save time: The percent of drivers *from the previous question* who save time due to hearing the broadcast.

Amount of time (min) saved by each vehicle saving time: The average amount of time in minutes saved by the drivers *from the previous question*.

Highway Advisory Radio Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Variable Message Sign Information

If the Variable Message Sign (VMS) component was selected as a project component the screen shown in Figure 8-10 will be displayed. The following is a description of the required inputs.

Number of signs to be installed: Number of variable message signs to be installed as part of the project.

Average volume (per hour) past sign: The average number of cars per hour passing by the variable message sign during the initial and forecast analyses years.

Number of times/day sign provides incident information: Average number of times a sign provides incident information during a typical day (value may be less then 1).

Time (hrs) sign active for each incident: The number of minutes a sign is typically active for an average incident.

Percent of passing sign that save time: The percent of drivers passing by the sign that save time due to the information provided by the sign.

Amount of time (min) saved by each vehicle passing sign: The average amount of time in minutes saved by the drivers *from the previous question*.

Highway Advisory Radio Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-9: SCRITS Highway Advisory Radio Input Form

<u>**Pager Based System Information**</u>

If the Pager Based System component was selected as a project component the screen shown in Figure 8-11 will be displayed. Pager Based Systems included both pager and FM subcarrier systems of Advanced Traveler Information Systems (ATIS). The following is a description of the required inputs.

Percent of trips where incident could impact route decision: Project area or regional estimate of the average percentage of all trips made trips where the notification of an incident could impact route decisions.

Percent of drivers that have system: Percentage of all drivers expected to have the pager based system.

Percentage of drivers that have system activated during the trip: Percentage of drivers that have the pager based system activated during the trip or immediately prior to the trip (i.e. at any point where a route decision could be made.)

Percentage of drivers with activated systems that can save time: Percentage of drivers *from the previous question* who could use the notification to make decisions that would save time (i.e. the incident information affects their route *and* they have the flexibility to change routes).

Amount of time (min) saved by each driver saving time: The average amount of time in minutes saved by the drivers *from the previous question*.

Pager Based System Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-10: SCRITS Variable Message Sign Input Form

Figure 8-11: SCRITS Pager Input Form

Kiosks Information

If the Kiosks component was selected as a project component the screen shown in Figure 8-12 will be displayed. The following is a description of the required inputs.

Number of kiosks to be installed: Number of kiosks be installed as part of the project.

Average number of weekday trips per site departing from locations where kiosks located: Average number of weekday trips only for both the initial and forecast analyses years. Note that this is the average number *per site* and not the total number of trips.

Of those, percent of persons looking at the information as they depart: Percentage of persons *from the previous question* who look at the information as they depart.

Of those looking at the information, percentage that may be able to save time: Percentage of those looking at the kiosk information (input to the previous question) that may be able to save time by using the information provided.

Amount of time (min) saved by each person saving time: The average amount of time in minutes saved by the drivers *from the previous question*.

Kiosks Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-12: SCRITS Kiosks Input Form

Commercial Vehicle Operation Kiosks Information

If the Commercial Vehicle Operation (CVO) Kiosks component was selected as a project component the screen shown in Figure 8-13 will be displayed. The CVO kiosks component is separated from the Kiosks component since users of each system would have different responses to the information provided by the system and the time saved these users would be valued differently. The following is a description of the required inputs.

Number of kiosks to be installed: Number of CVO kiosks be installed as part of the project.

Average number of weekday trips per site departing from locations where kiosks located: Average number of weekday trips only for both the initial and forecast analyses years. Note that this is the average number *per site* and not the total number of trips.

Of those, percent of persons looking at the information as they depart: Percentage of persons *from the previous question* who look at the information as they depart.

Of those looking at the information, percentage that may be able to save time: Percentage of those looking at the kiosk information (input to the previous question) that may be able to save time by using the information provided.

Amount of time (min) saved by each person saving time: The average amount of time in minutes saved by the drivers *from the previous question*.

Commercial Vehicle Operation Kiosks Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-13: SCRITS CVO Kiosks Input Form

Internet Traffic Information

If the Internet Traffic Information component was selected as a project component the screen shown in Figure 8-14 will be displayed. The following is a description of the required inputs.

Percentage of trips for which internet access is available: Percentage of trips for the project area (if known) or region for which internet access is available prior to making the trip.

Of those, percent of persons looking at the information as they depart: Percentage of persons who look at the information as they depart.

Of those looking at the information, percentage that may be able to save time: Percentage of those looking at the internet information (input to the previous question) that may be able to save time by using the information provided.

Amount of time (min) saved by each person saving time: The average amount of time in minutes saved by the drivers *from the previous question*.

Internet Traffic Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-14: SCRITS Internet Input Form

Automatic Vehicle Location for Transit Information

If the Automatic Vehicle Location (AVL) for Transit component was selected as a project component the screen shown in Figure 8-15 will be displayed. The following is a description of the required inputs.

Current average wait time per passenger (min): Average wait time in minutes per passenger for the project area (if known) or region *without* the proposed project.

Average wait time with AVL system (min): Average wait time in minutes per passenger for the project area (if known) or region *with* the proposed project.

Average number of weekday boardings: The average number of weekday transit boardings for the initial and forecast analyses years.

Average number of daily boardings, full week: The average number of daily transit boardings (including weekends) for the initial and forecast analyses years.

Percent of passenger that use the information: The percent of transit boardings that use the AVL information for the initial and forecast analyses years.

Bus Automatic Vehicle Location Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-15: SCRITS Bus AVL Input Form

Electronic Fare Collection Information

If the Electronic Fare Collection (EFC) component was selected as a project component the screen shown in Figure 8-16 will be displayed. The following is a description of the required inputs.

Current average bus speed on arterials (mph): Average bus speed on arterial roadways for the project area (if know) or region.

Average percentage of bus travel time devoted to boarding: Percentage of the total bus travel time that is devoted just to passenger boarding.

Average boarding time per passenger with conventional fare: Average boarding time in minutes for transit passenger paying with conventional fare (i.e. coins and paper money).

Average boarding time per passenger with electronic fare: Average boarding time in minutes for transit passenger paying with electronic fare.

Current percentage of passengers with electronic fare: Percentage of passengers paying with electronic fare before the proposed project.

Percentage of passengers with electronic fare after this project: Percentage of passengers paying with electronic fare after the proposed project for the initial and forecast analysis years.

Average number of daily passengers, weekday: Average number of weekday (excluding weekends) transit passengers for the project area (if known) or region for the initial and forecast analysis years.

Average number of daily passengers, full week: Average number of full week (including weekends) daily transit passengers for the project area (if known) or region for the initial and forecast analysis years.

Average passenger trip length in miles: Average transit passenger trip length in miles for the project area (if known) or region.

Elasticity of demand with respect to average bus speed: Elasticity of transit passenger demand with respect to average bus speed. (The percentage of increase in demand for every one percent increase in average bus speed.)

Bus Electronic Fare Collection Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

**Figure 8-16: SCRITS Electronic Fare Collection Input Form**

Bus Priority System Information

If the Bus Priority System (BPS) component was selected as a project component the screen shown in Figure 8-17 will be displayed. The following is a description of the required inputs.

Bus Operations:

Miles on which priority treatment is implemented: The miles of arterial roadway on which the proposed bus priority system will be implemented.

Number of buses per weekday on priority routes: The number of buses per weekday on the proposed bus priority route.

Current average bus speed on arterial (mph): The average bus speed on the arterial without the proposed bus priority system.

Percentage of bus travel time attributable to signal delay: The percentage of total bus travel time through the proposed bus priority route that is spent at traffic signals.

Estimated percent reduction in signal delay from pre-emption: The estimated percent reduction in signal delay due to signal pre-emption by the proposed bus priority system.

Number of daily passengers on affected routes: The number of daily passengers of the bus routes to be affected by the proposed bus priority route for both the initial and forecast analysis years.

Average passenger trip length (miles): Average transit passenger trip length in miles for the project area (if known) or region.

Elasticity of demand with respect to bus speed: Elasticity of transit passenger demand with respect to average bus speed. (The percentage of increase in demand for every one percent increase in average bus speed.)

Daily vehicle trips on corridor serves by bus route(s): The daily number of vehicle trips on the arterial roadway proposed for the bus priority system for both the initial and forecast analysis years.

Traffic Operations:

Weekday daily volume of cross street traffic for entire route: The weekday volume of cross-street traffic along the entire arterial route of the proposed signal priority system. (Cumulative value for all cross streets.)

Percentage of traffic that incurs pre-emption delay: Percentage of the cross-street traffic from the previous question that incurs additional delay due to the signal priority pre-emption.

Average delay time per pre-empted vehicle (sec): The average additional delay that cross-street traffic incurs due to a signal pre-emption.

Bus Priority System Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter

Figure 8-17: SCRITS Bus Priority Input Form

Electronic Toll Collection Information

If the Electronic Toll Collection (ETC) component was selected as a project component the screen shown in Figure 8-18 will be displayed. The following is a description of the required inputs.

Total average weekday volume through toll plaza: The average total (all lanes) weekday volume through the toll plaza for the initial and forecast analyses years.

Current percentage by lane type: The percentage of the average weekday volume through the toll plaza by the following three lane types *without* the project. The cumulative percentage should equal 100% (shown on the screen under the last input box.)

> **Current percent volume through the exact change lanes:** Between – and 100%.
>
> **Current percent volume through regular lanes:** Between – and 100%.
>
> **Current percent volume through other lanes:** Enter remaining percentage volume between 0 and 100%.

New percentage volume with electronic tolls: The percentage of the average weekday volume through the toll plaza by the following four lane types *with* the project. The cumulative percentage should equal 100% (shown on the screen under the last input box.)

> **Percent volume though electronic toll lanes:** Between – and 100%.
>
> **Percent volume though the exact change lanes:** Between – and 100%.
>
> **Percent volume though regular lanes:** Between – and 100%.

Percent volume though other lanes: Enter remaining percentage volume between 0 and 100%.

Average Service Times: The average service time in seconds for each of the four lane types. Service times include both the time to collect the fare and the delay due to slowing and/or stopping at the toll plaza.

Electronic toll lanes: Enter time in seconds.

Exact change lanes: Enter time in seconds.

Regular lanes: Enter time in seconds.

Other lanes: Enter time in seconds.

Electronic Toll Fare Collection Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-18: SCRITS Electronic Toll Collection Input Form

Ramp Metering Information

If the Ramp Metering component was selected as a project component the screen shown in Figure 8-19 will be displayed. The following is a description of the required inputs.

Number of unique peak period and direction combinations to be analyzed: This is the total number of combinations of peak periods and directions to be analyzed (e.g. northbound AM peak, southbound PM peak, etc.) For each unique combination the following inputs will be required:

Peak period being analyzed: Enter the peak period (AM, PM, etc) in the current combination.

Direction being analyzed: Enter the freeway direction being analyzed in the current combination.

Freeway Traffic:

Percentage of study area freeway section being metered: Percentage of the study area (freeway centerline miles entered in the baseline input form) being metered by this combination.

Percentage of volume in peak period being analyzed: Percentage of volume *from the previous question* that occurs in the peak period being analyzed by this combination.

Percentage of volume in peak direction: Percentage of volume *from the previous question* that occurs in the peak direction being analyzed by this combination.

Average speed without metering (mph): Average speed on the *freeway* without metering.

Average speed with metering (mph): Average speed on the *freeway* with metering.

Ramp Traffic:

Number of metered ramps in direction analyzed: Number of ramps in the direction specified above.

Average metered volume per ramp over peak period: Average metered volume in the peak period specified for the ramps being analyzed.

Average peak period delay per vehicle (sec): Average peak period delay for each vehicle in seconds for the peak period and direction being analyzed.

Arterial Traffic:

Percentage of volume in peak period being analyzed: Percentage of the arterial volume specified in the baseline input form that occurs in the peak period being analyzed by this combination.

Percentage of volume in peak direction: Percentage of volume *from the previous question* that occurs in the peak direction being analyzed by this combination.

Average arterial speed without metering (mph): Average speed on the *arterial* without metering.

Average arterial speed with metering (mph): Average speed on the *arterial* with metering.

Percent reduction in accidents: The estimated percent reduction in accidents with the ramp metering.

Ramp Metering Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-19: SCRITS Ramp Metering Input Form

Weigh-in-Motion Information

If the Weigh-in-Motion (WIM) component was selected as a project component the screen shown in Figure 8-20 will be displayed. The following is a description of the required inputs.

Number of weigh stations to be equipped with WIM: The total number of weigh station to be equipped with the proposed weigh-in-motion system.

Average number of vehicles though each weigh station per weekday: Average number of freight vehicles that pass though the weigh station on a weekday for both the initial and forecast analyses years.

Average delay time (min) per vehicle: The average delay in minutes for each freight vehicle passing though the weigh station without the weigh-in-motion system.

Percent of vehicles that will not have to pass through static scales: The percentage of freight vehicles that will not have to pass though the static scales with the proposed weigh-in-motion system.

Weigh-in-Motion Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Weigh-in-Motion

Number of weigh stations to be equipped with WIM:

Average number of vehicles through each weight station per weekday, Initial Analysis Year:

Average number of vehicles through each weight station per weekday, Forecast Analysis Year:

Average delay time (min) per vehicle:

Percent of vehicles that will not have to pass through static scales:

Figure 8-20: SCRITS Weight-in-Motion Input Form

Railroad Crossing Information

If the Railroad Crossing component was selected as a project component the screen shown in Figure 8-21 will be displayed. The following is a description of the required inputs.

Number of railroad crossings to be improved: The total number of railroad grade crossings to be improved with the project.

Average number of accidents at these grade crossings per year: The average number of accidents occurring at these grade crossings per year. (Average number of accidents *per* grade crossing not cumulative number.)

Percent of accident reduced by ITS improvements: Percentage of reduction in accidents estimated to occur due to proposed improvements.

Railroad Crossing Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Railroad Crossing

Number of railroad crossings to be improved:

Average number of accidents at these railroad grade crossings per year:

Percent of accidents reduced by ITS improvements:

Figure 8-21: SCRITS Railroad Crossing Input Form

Traffic Signal Systems Information

If the Traffic Signal Systems component was selected as a project component the screen shown in Figure 8-22 will be displayed. The following is a description of the required inputs.

Expected percent improvement in average arterial speed: Percent improvement estimated with the proposed project.

Current number of stops per VMT: Current number of stops along project arterial per vehicle miles traveled.

Expected percent reduction in stops: Estimated percent reduction in the number of stops with the proposed project.

Traffic Signal Systems Cost Inputs: The cost inputs for all SCRITS components are identical and are discussed in the Project Costs section of this chapter.

Figure 8-22: SCRITS Traffic Signal Systems Input Form

Outcome Objectives

The outcome objectives inputs are the standard questions described in Chapter 3 of this report. No special modifications for ITS projects have been made to the standard calculations described in that section.

Cost Information

The cost input forms and calculations for the IDAS project type are identical to those described in Chapter 3 of this report. The SCRITS project type costs have been slightly modified to remove the inputs and calculations related to environmental retrofit impacts. In addition, each component within the SCRITS project requires information on the cost, operation and maintenance, and terminal value for that particular component. This allows the individual components to be analyzed for cost efficiency. An example of the SCRITS project type cost input form is shown in Figure 8-23.

Figure 8-23: SCRITS Cost Input Form

Benefit-cost calculations

IDAS Projects

The benefit-cost calculations for the IDAS project type are based on the results of travel forecast modeling and IDAS analyses for both an initial year and a forecast year. The following descriptions explain the methodology of the calculations. The actual calculations contained in the code can be followed using these descriptions.

Yearly Travel Time Benefits in Minutes and Induced Travel

The travel time and trip number estimates with and without the project are computed directly by IDAS. MICA converts the hourly travel time estimates for both the initial and forecast years from hours into minutes. The induced number of trips is also calculated as the forecasted change in ridership due to the project. In addition, the travel time and induced trip estimates for freight users are calculated.

Travel Time Benefits in Minutes

The estimated travel timesavings in minutes for the entire analysis period is calculated assuming a uniform growth rate between the initial and forecasted years with no discount factor. Only monetary calculations used the global variable discount rate (default value 4%). Both the total travel timesaving in minutes and the freight user portion of the savings are determined.

Travel Time Benefits in Dollars

The travel timesavings are then monetized using the global variables for time value for automobile and freight vehicles. The estimated number of minutes for auto and freight vehicle travel are multiplied by the time value variable and by a global variable that represent the percent of time value attributed to each type of travel. The default global variables for values for auto travel time is 50% and for freight vehicle travel time is 100%.

Travel time benefits are calculated for both the initial and forecast years. A uniform growth rate between the two analysis years is assumed and brought back to present value using the global variable discount rate.

Operating Cost Calculations

The change in vehicle miles traveled for the initial and forecast years for both automobile and freight vehicles are calculated based on the entered results from the IDAS analysis and the percent of freight vehicle users. The estimated VMT for the entire analysis period is calculated assuming a uniform growth rate and a 0% discount rate. A positive VMT value represents a net increase in vehicle miles traveled.

User Cost Benefit Calculations

MICA is structured to consider either the full cost or the direct cost of automobile travel. The global variable Full Cost (the default is to consider full costs) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the automobile operation cost per mile is a higher value then the direct cost value and includes cost of vehicle ownership. (This is discussed more fully in the Global Variables chapter.) The user cost calculation multiplies the estimated automobile VMT by the appropriate operating cost to derive an automobile user savings for that period. In addition, freight vehicle VMT is multiplied by the freight vehicle operating cost. Note that freight vehicle operating cost always includes the cost of the vehicle regardless of the value of the Full Cost

global variable. Reduced VMT results in reduced operating costs and is therefore treated as a benefit. The estimated user cost savings are calculated for the initial and forecast years and assume a uniform growth rate in between. Benefits are brought back to a net present value using the global variable discount rate.

Air Pollution - Emissions Calculations

The change in emissions levels for the four pollutants include in MICA are calculated form the change in vehicle miles traveled for both automobile VMT and freight VMT. The emissions rates are based on global variables for the grams of emissions per mile (assuming an average running speed of 50 mph). The emission rates are based on a warm engine so an additional calculation is made to determine the emissions for cold starts. Cold start calculations are based on the percentage of trips that begin with a cold start and the emissions in grams per cold starts. These variables are based on whether the trip is being made by an automobile or a freight vehicle.

Emissions Benefit Calculations

The total emission estimates are multiplied by the global variable for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the global variable discount rate.

Accident Calculations

The number of accidents is calculated using the estimated additional vehicle miles travels and the global variables for the accident rates for the different accident types. The accident rates are based on both vehicle type (automobile or freight vehicle) and highway class. The resulting value is calculated for the initial and forecast years and the sum value is determined assuming uniform growth between and no discounting.

Safety Benefit Calculations

The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using the global discount rate.

Benefit-Cost Ratio Calculations

The benefit-cost ratio is calculated as the sum of the present value of project benefits over the sum of the present value of project costs. The WSDOT benefit-cost ratio considers al of the project benefits but only the WSDOT portion of the costs.

SCRITS Projects

The benefit-cost calculations for the SCRITS project type are based on the work done by the Federal Highway Administration for the development of the SCRITS program. The calculations contained in MICA are based on this work and have been modified so that analysis of the ITS project is done for both initial and forecast years to maintain consistency with the other MICA project types. The following descriptions explain the methodology of the calculations. The actual calculations contained in the code can be followed using these descriptions. More information on the calculations can found in the SCRITS User Manual referenced later in this chapter.

Baseline Calculations

The inputs and results from the baseline calculations are used throughout the SCRITS calculations and represent the baseline or "no build" situation. The recurring vehicle hours traveled (VHT) for freeway and arterials can either be calculated or entered directly. Calculated values use a look-up table that relates the ACR ratio (AADT/Capacity) to the mean operating speed of the facility. Currently the look-up table is based on a national average relationship but future revisions to the program will allow the user to choose from a list of tables that will more accurately model the project facility.

The incident percentage is the determined using a lookup table that relates the ACR ratio and the presence of shoulder along the facility to an estimated incident percentage rate. This rate is used in calculating the ratio recurring to non-recurring vehicle hours traveled (VHT) if the ratio is not entered in directly by the analyst. If the calculate option is selected the ratio is calculated using the incident percentage and the percentage of shoulders along the freeway facility.

The average weekday speeds with recurring VHT for the freeway and arterial facilities are calculated by dividing the vehicle miles traveled by the recurring vehicle hours traveled. The non-recurring VHT is then calculated and the average weekday speeds with both recurring and non-recurring VHT is determined. These calculations are performed for both the initial and forecast analysis periods on the arterial and freeway facilities.

Finally the net present value factor for a gradient flow of benefits is calculated using the global variable discount rate and the analysis period (forecast year minus initial year). This factor is used throughout the calculations for bringing monetary values back to a net present values.

The remaining calculations are divided by each of the 16 possible SCRITS components. These calculation are only performed is the user selected the particular component in the initial project screen.

Closed Circuit TV Calculations

Traffic and Travel Time
The percent of camera coverage is calculated and the percent reduction in incident duration due to increase coverage is calculated. This percent reduction is then related converted into yearly vehicle hours traveled savings for the initial and forecast analysis years. The increase in average freeway speed is calculated and a freeway speed with the project estimated.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the increased speed. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit estimates.

Operating Cost Calculations
The change in vehicle miles traveled for the initial and forecast years are annualized based on the daily results entered by the user for each analysis year. The total VMT savings for the analysis period is then calculated.

User Cost Benefit Calculations
MICA is structured to consider either the full cost or the direct cost of automobile travel. The global variable Full Cost (the default is to consider full costs) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the automobile operation cost per mile is a higher value then the direct cost value and includes cost of vehicle ownership. (This is discussed more fully in the Global Variables chapter.) The user cost calculation multiplies the estimated automobile VMT by the appropriate operating cost to derive an automobile user savings for that period. Reduced VMT results in reduced operating costs and is therefore treated as a benefit. The estimated user cost savings are calculated for the initial and forecast years and assume a uniform growth rate in between. Benefits are brought back to a net present value using the present value factor of the gradient. User transfers are assumed negligible for the CCTV component.

Energy and Emissions
The CCTV calculations do not differentiate between automobile and freight vehicles. Future refinements to the program may add a variable for the percent of freight vehicles on the facility. Until then the energy and emissions calculations assume only automobile emission rates.

The emission rates for the four pollutants are pulled from the global assumption lookup table based on the facility speed, the pollutant type, and the vehicle type (in this case automobile only). The rate with and without the facility for the two analysis years is determined. The change in emissions for CO and NOX are calculated from the change in pollutant rates derived from the change is mean operating speed of the facility. The change in emissions of PM-10 and VOC are from a reduction in vehicle miles traveled.

Emissions Benefit Calculations
The total emission estimates are estimated by using the global variables for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the present value factor of the gradient. The total emissions benefit is the sum of the benefits for each of the pollutant types.

Safety Calculations
The number of accidents is calculated using the estimated additional vehicle miles travels and the global variables for the accident rates for the different accident types. The accident rates are based on both vehicle type (automobile or freight vehicle) and highway class. The resulting value is calculated for the initial and forecast years and the sum value is determined assuming uniform growth between and no discounting.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Traffic Detection

Traffic and Travel
The percent of traffic detection is calculated and the percent reduction in incident duration due to increase detection is calculated. This percent reduction is then related converted into yearly vehicle hours traveled savings for the initial and forecast analysis years. The increase in average freeway speed is calculated and a freeway speed with the project estimated.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the increased speed. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit estimates.

Operating Cost Calculations
The change in vehicle miles traveled for the initial and forecast years are annualized based on the daily results entered by the user for each analysis year. The total VMT savings for the analysis period is then calculated.

User Cost Benefit Calculations
MICA is structured to consider either the full cost or the direct cost of automobile travel. The global variable Full Cost (the default is to consider full costs) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the automobile operation cost per mile is a higher value then the direct cost value and includes cost of vehicle ownership. (This is discussed more fully in the Global Variables chapter.) The user cost calculation multiplies the estimated automobile VMT by the appropriate operating cost to derive an automobile user savings for that period. Reduced VMT results in reduced operating costs and is therefore treated as a benefit. The estimated user cost savings are calculated for the initial and forecast years and assume a uniform growth rate in between. Benefits are brought back to a net present value using the present value factor of the gradient. User transfers are assumed negligible for the detection component.

Energy and Emissions
The detection calculations do not differentiate between automobile and freight vehicles. Future refinements to the program may add a variable for the percent of freight vehicles on the facility. Until then the energy and emissions calculations assume only automobile emission rates.

The emission rates for the four pollutants are pulled from the global assumption lookup table based on the facility speed, the pollutant type, and the vehicle type (in this case automobile only). The rate with and without the facility for the two analysis years is determined. The change in emissions for CO and NOX are calculated from the change in pollutant rates derived from the change is mean operating speed of the facility. The change in emissions of PM-10 and VOC are from a reduction in vehicle miles traveled.

Emissions Benefit Calculations
The total emission estimates are estimated by using the global variables for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the present value factor of the gradient. The total emissions benefit is the sum of the benefits for each of the pollutant types.

Safety Calculations
The number of accidents is calculated using the estimated additional vehicle miles travels and the global variables for the accident rates for the different accident types. The accident rates are based on both vehicle type (automobile or freight vehicle) and highway class. The resulting value is calculated for the initial and forecast years and the sum value is determined assuming uniform growth between and no discounting.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Highway Advisory Radio (HAR)

Traffic and Travel
The number of users saving time with the proposed HAR system is calculated by multiplying the volume of traffic in the in the HAR reception area by the amount of time the system is activated by the number expected to tune into the system by the number that tune in that are expected to save time. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings for those tuning into the system. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit estimates.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for HAR projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the HAR projects.

Energy and Emissions
The energy and emission impacts for HAR projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The accident savings for HAR projects is derived from a reduction in the number of secondary accidents. The accident reduction is calculated for the three accident types.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Variable Message Sign (VMS)

Traffic and Travel
The number of users saving time with the proposed variable message sign system is calculated by multiplying the volume of traffic past the sign by the amount of time the system is activated by the number that are expected to save time. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit estimates.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for VMS projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the VMS projects.

Energy and Emissions
The energy and emission impacts for VMS projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The accident savings for VMS projects is derived from a reduction in the number of secondary accidents. The accident reduction is calculated for the three accident types.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Pager Based ATIS

Traffic and Travel
The number of users saving time with the proposed pager system is calculated by multiplying the number of people with the system by the percentage of people that are expected to save time by a particular page by the number that tune in that are expected to save time by the number of minutes the page is expected to save them. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for pager projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the pager projects.

Energy and Emissions
The energy and emission impacts for pager projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The accident savings for pager projects is derived from a reduction in the number of secondary accidents. The accident reduction is calculated for the three accident types.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Traffic Information Kiosks

Traffic and Travel
The number of users saving time with the proposed kiosk system is calculated by multiplying the number of people with access to the system by the number actual viewing the information by the percentage of people that are expected to save time with the information by the number of minutes the page is expected to save them. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for kiosk projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the kiosk projects.

Energy and Emissions
The energy and emission impacts for kiosk projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The accident savings for kiosk projects is derived from a reduction in the number of secondary accidents. The accident reduction is calculated for the three accident types.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

CVO Traffic Information Kiosks

Commercial Vehicle Operations (CVO) Kiosks are calculated the same as the Kiosks Systems described in the previous section except that the freight users value of travel time is used instead of automobile travel time values.

Internet Information

Traffic and Travel
The number of users saving time with the proposed internet system is calculated by multiplying the number people and the number of trips for which there is access to the internet system by the percentage who look at the information prior to departing by the percentage estimated that would find information that would affect that particular trip by the number of minutes that would be saved by this information. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for internet projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the internet projects.

Energy and Emissions
The energy and emission impacts for pager projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The accident savings for internet projects is derived from a reduction in the number of secondary accidents. The accident reduction is calculated for the three accident types.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between

Automatic Vehicle Location (AVL) and Information

Traffic and Travel
The travel time savings with the AVL system is calculated by multiplying the wait time savings by the number of boarders by the percentage expected to use the system for the initial and forecast analysis years. These estimates are converted into a yearly vehicle hours traveled savings for the initial and forecast analysis years.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated. In addition induced ridership due to improvements in the facility is not considered.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for AVL projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the AVL projects.

Energy and Emissions
The energy and emission impacts for AVL projects are assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The safety impacts for AVL projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero.

Bus Electronic Fare Collection (EFC)

Traffic and Travel
The travel time savings for EFC systems are derived from increases in bus speeds due to reduced boarding times. The minutes saved by each electronic fare boarding are multiplied by the number of people boarding by the percentage expected to use the EFC system. This is then converted into an increase in bus speed along the route.

The program them uses the bus riders' elasticity of demand with respect to bus speed to calculate and induced bus ridership due to the increased speed. The induced ridership is assumed to come from former automobile trips so a reduced vehicle miles traveled is also calculated.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit.

Operating Cost Calculations
The change in vehicle miles traveled from the induced transit ridership is annualized over the analysis period.

User Cost Benefit Calculations
MICA is structured to consider either the full cost or the direct cost of automobile travel. The global variable Full Cost (the default is to consider full costs) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the automobile operation cost per mile is a higher value then the direct cost value and includes cost of vehicle ownership. (This is discussed more fully in the Global Variables chapter.) The user cost calculation multiplies the estimated automobile VMT by the

appropriate operating cost to derive an automobile user savings for that period. Reduced VMT results in reduced operating costs and is therefore treated as a benefit. The estimated user cost savings are calculated for the initial and forecast years and assume a uniform growth rate in between. Benefits are brought back to a net present value using the present value factor of the gradient. User transfers are assumed negligible for the detection component.

A revenue transfer occurs as new transit riders pay a bus fare. This additional cost is considered a revenue transfer and not an incurred cost.

Energy and Emissions
The EFC calculations do not differentiate between automobile and freight vehicles. Future refinements to the program may add a variable for the percent of freight vehicles on the facility. Until then the energy and emissions calculations assume only automobile emission rates.

The emission rates for the four pollutants are pulled from the global assumption lookup table based on the facility speed, the pollutant type, and the vehicle type (in this case automobile only). Emission benefits are derived from automobile trips not taken due to increased transit ridership.

Emissions Benefit Calculations
The total emission estimates are estimated by using the global variables for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the present value factor of the gradient. The total emissions benefit is the sum of the benefits for each of the pollutant types.

Safety Calculations
The safety impacts for EFC projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero. Future revisions to the program may take into account the accidents avoided due to induced transit riders shifting to the safer transit mode.

Bus Priority Systems (BPS)

Traffic and Travel
The travel time savings for BPS systems are derived from increases in bus speeds due to reduced delay at traffic signals. The number of passengers are multiplied by the number of minutes saved along the route.

The program them uses the bus riders' elasticity of demand with respect to bus speed to calculate and induced bus ridership due to the increased speed. The induced ridership is assumed to come from former automobile trips so a reduced vehicle miles traveled is also calculated.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years benefit.

Operating Cost Calculations
The change in vehicle miles traveled from the induced transit ridership is annualized over the analysis period.

User Cost Benefit Calculations
MICA is structured to consider either the full cost or the direct cost of automobile travel. The global variable Full Cost (the default is to consider full costs) is used to determine whether a full or direct cost calculation is being used for all projects in the database. If full cost is being considered then the automobile operation cost per mile is a higher value then the direct cost value and includes cost of vehicle ownership. (This is discussed more fully in the Global Variables chapter.) The user cost calculation multiplies the estimated automobile VMT by the appropriate operating cost to derive an automobile user savings for that period. Reduced VMT results in reduced operating costs and is therefore treated as a benefit. The estimated user cost savings are calculated for the initial and forecast years and assume a uniform growth rate in between. Benefits are brought back to a net present value using the present value factor of the gradient. User transfers are assumed negligible for the detection component.

A revenue transfer occurs as new transit riders pay a bus fare. This additional cost is considered a revenue transfer and not an incurred cost.

Energy and Emissions
The BPS calculations do not differentiate between automobile and freight vehicles. Future refinements to the program may add a variable for the percent of freight vehicles on the facility. Until then the energy and emissions calculations assume only automobile emission rates.

The emission rates for the four pollutants are pulled from the global assumption lookup table based on the facility speed, the pollutant type, and the vehicle type (in this case automobile only). Emission benefits are derived from automobile trips not taken due to increased transit ridership.

Emissions Benefit Calculations
The total emission estimates are estimated by using the global variables for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the present value factor of the gradient. The total emissions benefit is the sum of the benefits for each of the pollutant types.

Safety Calculations
The safety impacts for BPS projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero. Future revisions to the program may take into account the accidents avoided due to induced transit riders shifting to the safer transit mode.

Electronic Toll Collection (ETC)

Traffic and Travel
The travel time savings for ETC systems are derived from the avoidance of the transaction time at the toll both including the delay causes by slowing down the vehicle. The average time saved by each driver using the new system is multiplied by the number of drivers expected to use the system.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated savings per person calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for ETC projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the ETC projects.

Energy and Emissions
The energy and emission impacts for ETC projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero. As more research becomes available on the emissions benefits of improved toll plaza operations this component may be added.

Safety Calculations
The safety impacts for ETC projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero.

Ramp Metering

Traffic and Travel
The travel time saving due to ramp metering is the net impact of the improved freeway operations minus the added delay at the ramp meter itself and the on the adjacent arterial roadway.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated net savings calculated in the previous step. Note that the calculations do not consider freight movements separately so only a total travel time savings is calculated.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for automobile travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for Ramp metering projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the Ramp metering projects.

Energy and Emissions
The energy and emission impacts for Ramp metering projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The safety impacts for Ramp metering projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero.

Weight-in-Motion (WIM)

Traffic and Travel
The travel time savings due to weigh-in-motion systems is derived from the avoidance of freight vehicles having to stop at the weight station's static scale. The savings is calculated by multiplying the number of freight vehicles using the system by the average processing time at a static scale.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated net savings calculated in the previous step. Note that the calculations only consider freight movements separately so only a total travel time savings is equal to the total freight travel time savings.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for freight vehicle travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in freight vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for WIM projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the WIM projects.

Energy and Emissions
The energy and emission impacts for WIM projects is assumed negligible so that the emission reduction values and environmental benefits are set to zero.

Safety Calculations
The safety impacts for WIM projects are assumed negligible so that the safety reduction estimates and safety benefits are set to zero.

Railroad Crossing

Travel time, user, or environmental benefits
Only safety benefits are considered for railroad crossing improvements. Travel time, user operating costs, revenue transfer, and environmental values are all set to zero.

Safety Calculations
The number of accidents at each crossing is multiplied by the estimated percent reduction in accidents. The accidents are assumed to be severe (fatality or disabling injury) so only the highest accident category is estimated.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost fatality accident type. The benefits value is determined assuming a uniform growth rate between the initial and forecast years.

Traffic Signal Systems (TSS)

Traffic and Travel
Traffic signal systems travel time benefits are derived from reduced delay due to increases in average operating speed of the facilities with and without the improvements.

Travel Time Calculations
The yearly travel time benefits in minutes is calculated from the estimated reduced delay calculated in the previous step. Note that the calculations only consider freight movements separately so only a total travel time savings is equal to the total freight travel time savings.

Travel Time Benefits in Dollars
The travel time benefits in dollars for the initial and forecast analysis years are calculated using the global variables for time value for freight vehicle travel. The estimated number of minutes saved is multiplied by the time value variable and a global variable that represents the percent of time value attributed to in freight vehicle travel. The travel time savings in minutes is then monetized using the present value factor for a gradient and the initial and forecast years.

Operating Cost Calculations
The change in vehicle miles traveled is assumed negligible for TSS projects therefore the user benefit estimate is set to zero. User transfers are also assumed negligible for the TSS projects.

Energy and Emissions
The detection calculations do not differentiate between automobile and freight vehicles. Future refinements to the program may add a variable for the percent of freight vehicles on the facility. Until then the energy and emissions calculations assume only automobile emission rates.

The emission rates for the four pollutants are pulled from the global assumption lookup table based on the facility speed, the pollutant type, and the vehicle type (in this case automobile only). The rate with and without the facility for the two analysis years is determined. The change in emissions for CO and NOX are calculated from the change in pollutant rates derived from the change is mean operating speed of the facility. The change in emissions of PM-10 and VOC are from a reduction in vehicle miles traveled.

Emissions Benefit Calculations
The total emission estimates are estimated by using the global variables for cost per ton for the four pollutant types. The emission benefits are brought back to a present value amount using the present value factor of the gradient. The total emissions benefit is the sum of the benefits for each of the pollutant types.

Safety Calculations
The number of accidents is calculated using the estimated additional vehicle miles travels and the global variables for the accident rates for the different accident types. The accident rates are based on both vehicle type (automobile or freight vehicle) and highway class. The resulting value is calculated for the initial and forecast years and the sum value is determined assuming uniform growth between and no discounting.

Safety Benefit Calculations
The safety benefit calculation uses the global variables for the accident rate as well as the global variable for the societal cost of each accident type. The benefits value is determined assuming a uniform growth rate between periods and is brought back to present value using present value factor of the gradient.

Total Project Calculations

The impacts for all 16 project component calculations are combined for a cumulative impact estimate. There is a potential for overlap of impact estimates among components and the analyst must use sound engineering judgment to ensure that the benefits of the combined project are not overestimated. It may be necessary to adjust some of the inputs to avoid this over estimation.

Benefit-Cost Calculations

The benefit-cost ratio is calculated as the sum of the present value of project benefits over the sum of the present value of project costs. The WSDOT benefit-cost ratio considers al of the project benefits but only the WSDOT portion of the costs.

Project reports

The ITS IDAS and SCRITS reports are structured similarly with the first section showing the user inputs. The second section shows the results to key calculations such as travel timesavings in minutes and in dollars, benefit-cost ratios, etc. The third section shows the results to the Outcome Objective calculations. The final section shows the Global Variables that were used in the calculations and notes if values differed from the default values.

References

1. Cambridge Systematics, Inc. *ITS Deployment Analysis System User's Manual*. January 2000.

2. Mitretek Systems. *Incorporating ITS into Corridor Planning: Seattle Case Study Final Report*. August 1999.

3. Mitretek Systems. *ITS Impacts Assessment for Seattle MMDI Evaluation – Modeling Methodology and Results – Final Report*. September 1999.

4. Science Applications International Corporation. *Users Manual for Screening Analysis for ITS (SCRITS)*. Prepared for the Federal Highway Administration. January 1999. http://www.fhwa.dot.gov/steam/scrits.pdf

5. Washington Department of Transportation Advanced Technology Branch. *Status Report of Current Activities*. January 2001.

Chapter 9 – Non-Motorized Projects

Non-motorized projects are not considered an independent budget category in the Washington State Transportation Plan, but are included as part of the I-1 Highway Improvements Program. Non-motorized projects do not compete for funding against other modes. They are often considered as enhancements to highway projects.

Inventory of Projects

Non-motorized projects are those that promote or improve the use of bicycling and walking as a transportation mode. The non-motorized division of Highway Mobility has developed four categories of projects:

1. **Pedestrian Accident Locations**: Projects at locations where significant pedestrian-vehicle accidents have occurred

2. **Pedestrian Risk Locations**: Projects at locations where significant pedestrian-vehicle accidents have not occurred, but where a high risk for pedestrian-vehicle accidents has been identified

3. **Rural Bicycle Touring**: Projects that improve or provide connections for bicycle lanes or trails along longer distance rural touring routes

4. **Urban Bicycle**: Projects that improve or provide connections for bicycle lanes or trails within urban areas

Inventory of Current Analysis Methods

Existing analysis methods for non-motorized projects primarily consist of ranking systems that have been developed for each of the four project types. The non-motorized division developed the ranking systems, strictly for prioritizing proposed projects against others of the same project type. Only the "Pedestrian Accident Location" category calculates a monetary benefit, which consists of the societal value of accidents projected to be prevented by the proposed improvement.

Identification of Analysis Gaps

In order for non-motorized projects to be incorporated into the MICA program, analysis methods consistent with those of other modes were needed to calculate the Uniform Project Measures (as described in Chapter 2). Within the existing analysis methods, safety benefits are only calculated for the Pedestrian Accident project type. Within MICA, the capability of accident analysis was expanded to all four non-motorized categories. Accordingly, if improving a shoulder results in a safety benefit for rural bicycle touring, this can be captured as an economic benefit.

The MICA analysis procedures also recognize the benefit automobile trips that are eliminated by promoting and supporting non-motorized modes. The procedures that have been developed rely on national statistics to estimate the reduction in vehicle usage that could result from the implementation of a non-motorized project. Additionally, to fully calculate user benefits, the analyst must estimate the level of usage on the facility, and the average distance of travel. It is recognized that this type of data often is not readily available for pedestrian and bicycle usage of a facility. However, even conservative estimates that reflect a general order of magnitude (which is appropriate at the sketch planning level, and consistent with procedures of other modes) will

allow for benefits to be calculated. However, future research could be directed toward obtaining better-localized data needed for the rigorous analysis of non-motorized project benefits.

Project Worksheets and Inputs

The non-motorized mode is accessed by clicking on the "Non-Motorized" button on the starting screen of the Project Module. Figure 9-1 shows the opening screen for the Non-Motorized mode. From this screen, the analyst can access existing non-motorized projects in the MICA database, or add a new non-motorized project (note, the general procedures for Project Level Analysis are described in *Chapter 3 – Operation of the MICA Program*).
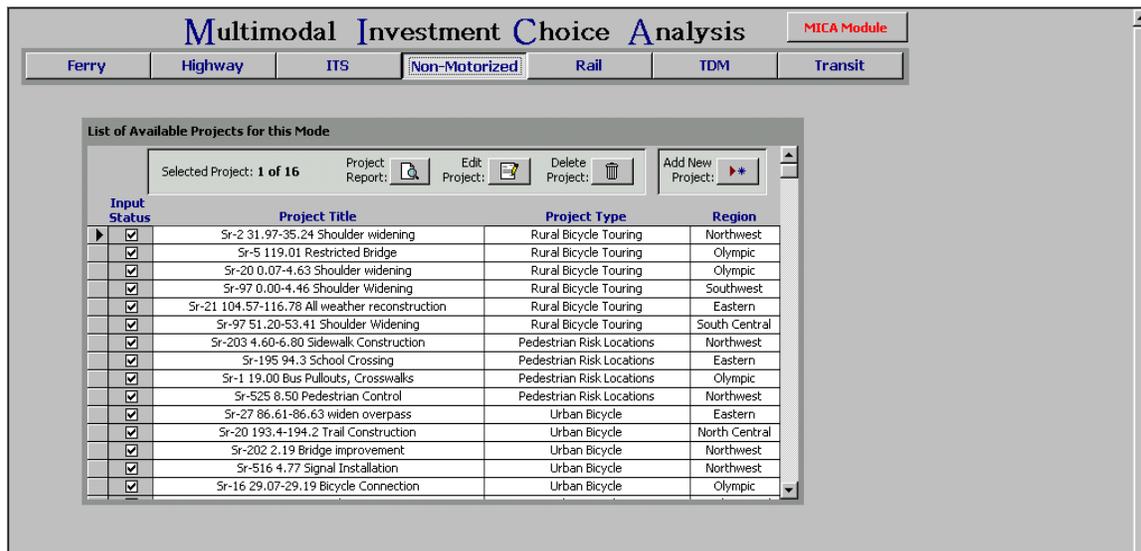
Figure 9-1: Opening Screen for Non-Motorized Projects

Project Information

The Project Information input form, as shown in Figure 9-2, is the first of five screens to be displayed when a non-motorized project is edited or added to the database. The user can navigate through the five screens by clicking on the tab headings. Additionally, the three buttons at the top of the screen can be selected at any time to delete the current project from the database, preview the project report, or save the current data and exit back to the opening screen for non-motorized projects.

Figure 9-2: Non-Motorized Project Information Form

The Project Information component contains the following descriptive information:

Project Title:	Descriptive title of the project
Project Type:	Identifier that is unique to the project
Project Type:	Specific type of project, selected from a pull down list. For the non-motorized mode, the four project types are:

- **Pedestrian Accident Locations**

- **Pedestrian Risk Locations**

- **Rural Bicycle Touring**

- **Urban Bicycle**

State Route:	State Route Designation, if applicable.
Beginning Milepost:	Milepost number at beginning of project, if applicable.
Ending Milepost:	Milepost number at end of project, if applicable.
Project Length:	Length of project (miles), if applicable.
Biennium:	Biennium in which the project is to be considered for funding
Region:	WSDOT Region in which the project is located. A pull down menu provides eight region options:

- **Eastern**

- **North Central**

- **Northwest**

- **Olympic**

- **South Central**

- **Southwest**

- **Statewide** should be selected if the project is located in multiple regions

- **Ferry** applies only to ferry projects, and would never be selected under the non-motorized mode

Legislative District:　State Legislative District in which the project is located, if the project fits completely or primarily in one district.

Air Quality:　Air quality designation, as identified by the Clean Air Act. A pull down menu provides the options of:

- **Attainment Area**

- **Non-Attainment Area**

- **Maintenance Area**

- **Unclassifiable**

as described in *Chapter 2 – Project Measures*.

WTP Corridor:　Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). Clicking on the box will check it, indicating **Yes**. If the box is not checked, **N**o is indicated.

Highway System Plan:　Identifies whether or not the project is included in the Highway System Plan. Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

Benefit Information

The second input screen is the benefit input form, shown in Figure 9-3, which is identical for all four non-motorized project types. The user inputs data under three major categories:

- Project Features

- Usage Data

- Accident Data

Figure 9-3: Benefit Input Screen for Non-Motorized Projects

The Benefit Input component for non-motorized projects calls for the following information:

Project Features

Description of Project: User can input up to four lines of description of project features.

Usage Data

Forecast Period

Initial Analysis Year: Beginning year of demand forecasts

Forecast Analysis Year: Ending year of demand forecasts

Usage

Weekday pedestrians: Average number of pedestrians per using facility per weekday

- Base case and project case, initial year
- Base case and project case, forecast year

Weekday bicycles: Average number of bicyclists per using facility per weekday

- Base case and project case, initial year
- Base case and project case, forecast year

Weekend pedestrians: Average number of pedestrians per using facility per weekend day

- Base case and project case, initial year
- Base case and project case, forecast year

Weekend bicycles: Average number of bicyclists per using facility per weekend day

- Base case and project case, initial year
- Base case and project case, forecast year

Length of trip: Average length of full trip

- For pedestrians
- For bicyclists

Accident Data

Time Span for Data

Beginning Accident Date: Beginning date of designated time period for accident data

Ending Accident Date: Ending date of designated time period for accident data

Accidents

Total No Injury: Total 'no injury' accidents that occurred within designated time period

Total Possible Injury: Total 'possible injury' accidents that occurred within designated time period

Total Evident Injury: Total 'evident injury' accidents that occurred within designated time period

Total Possible Injury: Total 'disabling injury' accidents that occurred within designated time period

Total Fatality: Total 'fatality' accidents that occurred within designated time period

Preventable No Injury: Number of 'no injury' accidents that occurred within designated time period that would be prevented by project

Preventable Possible Injury: Number of 'possible injury' accidents that occurred within designated time period that would be prevented by project

Preventable Evident   Number of 'evident injury' accidents that occurred within

Injury: designated time period that would be prevented by project

Preventable Possible Injury: Number of 'disabling injury' accidents that occurred within designated time period that would be prevented by project

Preventable Fatality: Number of 'fatality' accidents that occurred within designated time period that would be prevented by project

Outcome Objectives

The third page contains the Outcome Objectives inputs, which consist of the standard questions described in Chapter 3 of this report. While all of the input questions remain the same regardless of mode or project type, some calculations do vary with project type.

Cost Information

The fourth page of the input form contains the cost data. Cost inputs and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In cases where the improvement will lower the annual cost of operation and maintenance, a negative cost value will result.

Departmental Scoring

The final page of the input form contains the Departmental Scoring form, which is unique for each of the four project types, and is described in the following sections.

Pedestrian Accident Locations

Since projects in this category are analyzed by the safety benefits they will accrue, no departmental scoring system was developed for this category. The MICA safety benefit procedure developed for all non-motorized project types (and described later in this chapter) is based on the procedure that was developed at the WSDOT non-motorized division.

Pedestrian Risk Locations

Figure 9-4 illustrates the form that is completed for departmental scoring of the Pedestrian Risk Location project type.

Figure 9-4: Departmental Scoring Form for Pedestrian Risk Locations

Departmental scores for this project type can total to a possible 60 points, with higher points indicating a greater need for the project. The criteria and scoring for this category are as follows:

PEDESTRIAN PRESENCE INDICATORS

Current Land Use:

- Dense urban or downtown area = 6 points
- Suburban (commercial and residential) = 5 points
- Apartments = 4 points
- High use recreational = 3 points
- High density residential = 2 points
- Low density residential = 1 point

Presence of at-risk groups such as grade schools, parks, large retirement complexes, and other facilities where high-risk pedestrians are likely to be found, within one-half mile of the proposed project:

- Heavy concentration = 6 points
- Moderate concentration = 3 points
- Normal concentration = 0 points

INDICATORS OF INSUFFICIENT FACILITIES

Provide a crossing to transit, school, park or other pedestrian trip oriented destination?

- Yes = 10 points
- No = 0 points

Complete a missing link in an existing walkway system?

- Yes = 5 points
- No = 0 points

Connect to an existing walkway?

- Yes = 3 points
- No = 0 points

Replace a deficient section of a walkway?

- Yes = 1 point
- No = 0 points

Average shoulder width:

- 0 - 4 feet = 6 points
- 4.1 - 8 feet = 3 points
- >8 feet = 0 points

Signalized intersection spacing, or distance to alternate crossing:

- $\geq$ 1,320 feet = 3 points
- 660 – 1,319 feet = 2 points
- < 660 feet = 0 points

DEGREE OF HAZARD INDICATORS

Current ADT (pedestrian exposure to vehicles):

- >25,000 = 3 points
- 8,001 – 25,000 = 2 points
- ≤ 8,000 = 1 point

Posted vehicle speed

- > 45 mph = 6 points
- 35 – 45 mph = 4 points
- 25 – 34 mph = 2 points
- < 25 mph = 0 points

Prior vehicle-pedestrian crashes at location within past 3 years:

- ≥ 3 crashes = 5 points
- 1 or 2 crashes = 2 points
- no crashes = 0 points

Width of roadway:

- 4 or more lanes with TWLTL = 4 points
- 4 lanes = 2 points
- 2 or 3 lanes = 1 points

Horizontal and vertical stopping sight distance:

- Does not meet minimum SSD requirements = 2 points
- Meets minimum SSD requirements = 1.5 points

Rural Bicycle Touring

Figure 9-5 illustrates the form that is completed for departmental scoring of the Rural Bicycle Touring project type.

Figure 9-5: Departmental Scoring Form for Rural Bicycle Touring

Departmental scores for this project type can total to a possible 21 points, with higher points indicating a greater need for the project. The criteria and scoring for this category are as follows:

What is the shoulder width along the project area?

- No shoulder = 5 points

- 1 foot wide = 4 points

- 2 feet wide = 2 points

- 3 feet wide = 1 point

- >3 feet wide = 0 points

Is the roadway lane width less than 12 feet?

- Yes = 1 point

- No = 0 points

What is the distance from an incorporated urban growth boundary (under Growth Management Act)?

- 0 to 5 miles = 3 points

- 6 to 12 miles = 2 points

- 13 or greater miles = 1 point

Current Average Daily Traffic (bicyclist exposure to vehicles):

- > 3000 = 3 points

- 1001 to 3000 = 2 points

- 501 to 1000 = 1 point

- ≤ 500 = 0 points

Is truck traffic greater than 10% of total traffic?

- Yes = 1 point

- No = 0 points

Can this project be built in conjunction with another WSDOT project?

- Yes = 5 point

- No = 0 points

Does this project connect or serve a rural activity center such as a school or park?

- Yes = 1 point

- No = 0 points

Length of proposed project:

- > 2 mile = 2 points

- 1 to 2 miles = 1 point

- < 1 mile = 0 points

Urban Bicycle

Figure 9-6 illustrates the form that is completed for departmental scoring of the Urban Bicycle project type.

Figure 9-6: Departmental Scoring Form for Urban Bicycle

Departmental scores for this project type can total to a possible 72 points, with higher points indicating a greater need for the project. The criteria and scoring for this category are as follows:

Is this project included in a local (city or county) Comprehensive Transportation, Park and Recreational Plan?

- Yes = 3 points

- No = 0 points

Is this project included in a Regional or Metropolitan Transportation Plan?

- Yes = 3 points
- No = 0 points

Are other organizations or agencies expected to participate in funding this project?

- Yes, partner providing >25% = 6 points
- Yes, partner providing 10-25% = 5 points
- Yes, partner providing <10% = 4 points
- No = 0 points

<u>**LINKS TO CURRENT SYSTEM**</u>

Is there an alternative county road or city street to serve bicyclist needs?

- Yes = 0 points
- No = 10 points

Is there an alternative county road or city street to serve bicyclist needs?

Complete a missing link in an existing trail system?

- Yes = 5 points
- No = 0 points

Connect to an existing bicycle trails system?

- Yes = 3 points
- No = 0 points

Replace a deficient section of a bicycle facility?

- Yes = 1 point
- No = 0 points

<u>**NUMBER OF USERS IMPACTED**</u>

Residential density in project area

- >24 residents / acre = 4 points
- 16 – 24 residents / acre = 3 points
- 7 – 15 residents / acre = 2 points
- <7 residents / acre = 1 point

Employment density in project area

- >49 employees / acre = 4 points
- 31 – 49 employees / acre = 3 points
- 11 – 30 employees / acre = 2 points
- <11 employees / acre = 1 point

What will the level of bicycle use be after completion of facility?

- high = 3 points

- medium = 2 points

- low = 1 point

Does this project serve a college or university?

- Yes = 1 point

- No = 0 points

Does this project serve an elementary, junior or high school?

- Yes = 1 point

- No = 0 points

Does this project serve an intermodal connection?

- Yes = 1 point

- No = 0 points

Is this project located within 3 miles of an employment center?

- Yes = 1 point

- No = 0 points

Does this project provide access across or around a natural or artificial barrier?

- Yes = 1 point

- No = 0 points

SAFETY

What is the average peak hour vehicle volume (bicyclist exposure to vehicles)?

- \> 900 veh / hr = 3 points

- 700 - 900 veh / hr = 2 points

- < 700 veh / hr = 1 point

What is the posted traffic speed?

- \> 40 mph = 3 points

- 36 – 40 mph = 2 points

- 31 – 35 mph = 1 point

- < 31 mph = 0 points

What is the shy distance from edgeline to curb?

- 1 foot = 3 points

- 2 feet = 2 points

- 3 feet = 1 point

How many vehicle-bicycle crashes have occurred at the proposed site within the past three years?

- 3 or more crashes = 5 points

- 2 crashes = 3 points

- 1 crash = 1 point

- No crashes = 0 points

Describe the access / conflict point conditions for the project roadway:

- Class 5 Hwy, >26 access pts / half mile = 2 points
- Class 5 Hwy, 22 – 26 access pts / half mile = 1 point
- Class 5 Hwy, <22 access pts / half mile = 0 points
- Class 4 Hwy, >17 access pts / half mile = 2 points
- Class 4 Hwy, 12 – 16 access pts / half mile = 1 point
- Class 4 Hwy, <12 access pts / half mile = 0 points
- Class 3 Hwy, >13 access pts / half mile = 2 points
- Class 3 Hwy, 9 – 13 access pts / half mile = 1 point
- Class 3 Hwy, <9 access pts / half mile = 0 points

OTHER PLANS

Is this project on the WSDOT Bicycling Advisory Committee Priority Project List?

- Yes = 3 points
- No = 0 points

Is this project on the Interagency Committee for Outdoor Recreation State Trails Plan?

- Yes = 3 points
- No = 0 points

Benefit-Cost Calculations

Although the internal departmental scoring varies, the procedure used for benefit-cost analysis is the same for the different non-motorized project types. The benefit-cost calculations for non-motorized projects is described in the following sections.

User Benefits

New Pedestrians and Bicyclists on Facility

The new pedestrians and bicyclists expected to use the improved facility are not estimated within the program. Rather, they are input by the user based upon outside demand forecasts. New riders are calculated by taking the difference between the base case volumes and the project case volumes, as input by the user, for the initial year and the final year of the analysis period. Straight-line growth is assumed from the initial to the final year of the forecast period.

Since current and future volume forecasts are not a standard component of non-motorized facility analysis, the inputs ask only for an average usage per typical weekday and weekend day. The program extrapolates these values to calculation annual estimates. Note, if no increase in volume is input between the base case and the project case, the program will simply calculate zero user benefits, which would then be consistent with the methods that have been used in the past.

Change in Automobile VMT

The reduction in automobile VMT is a function of the number of new users that are estimated as the result of the project. The percentage of new pedestrians and bicyclists that are assumed to be diverted from automobile is based on a statistical diversion rate, as explained in *Chapter 2 – Project Measures*. The number of diverted travelers is divided by the average vehicle occupancy to estimate the number of auto trips diverted. This is converted to VMT by multiplying by the average length of trip along the project corridor.

Operating Cost Savings to Travelers

The operating cost savings to travelers is a function of the estimated reduction in automobile VMT. Average operating costs per mile are included in MICA as a global variable. The actual value per mile will depend on whether "Direct Cost" or "Full Cost" is selected by the user (as described in *Chapter 2 – Project Measures*). The operating cost savings is calculated by multiplying the reduction in auto VMT by the operating cost per mile. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual operating cost savings to travelers. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Travel Time Benefits

In its current form, the non-motorized benefit calculations do not include travel time savings. While it is possible to implement improvements that will improve travel speeds, particularly for bicycle touring facilities, most non-motorized projects will not have any significant impact on traveling speed. However, if deemed warranted, travel time benefits could be added in future refinements of the program.

Air Quality Calculations

Pollutants Removed Due to Diversion from Automobile to Non-Motorized

Once a savings in VMT is calculated, savings in air pollution can also be calculated. Reduction in emissions is calculated for Carbon Monoxide (CO), Nitrous Dioxide (NOx), and Particulate Matter – 10 microns (PM_{10}). Future work will add Volatile Carbons (VOC) rates, and may change PM_{10} to $PM_{2.5}$ to reflect new Federal regulations. The emissions reductions are calculated by multiplying the estimated reduction in VMT by the respective emission rates per mile (as described in *Chapter 2 – Project Measures*). Emissions rates for automobiles shifted to non-motorized are based upon an assumed in-city vehicle running speed of 35 miles per hour. The initial reductions are calculated in grams, and then converted into English tons.

The emissions rates are based on a warmed up vehicle engine. To capture the effects of cold-starts, the number of eliminated vehicle trips is multiplied by the cold start percentage (global variable that estimates the percentage of total trips that begin with a cold start). The number of reduced cold starts are multiplied by the average emissions (in grams) per cold start, to estimate the total reduction. Total emissions reductions are obtained by adding the change in emissions due to cold start reductions to the change in emissions due to VMT reduction.

Cold starts are not currently included in the non-motorized emissions calculations. This results in a more conservative estimation of emissions removed, which is reasoned upon the fact that the diversion rates are based upon very aggregated statistics. However, national statistics for automobile trips removed can be found in the same source as the VMT diversion statistics (FHWA 1993) so cold start estimation could be added in future refinement of the calculations.

Air Quality Benefit Calculations

The air quality benefit is calculated by multiplying the estimated tonnage of each pollutant removed (CO, NOx, PM_{10}, and in the future, VOC) by its respective societal value. The societal cost of the tons of pollutants are global variables, and are described in *Chapter 2 – Project Measures*. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual air quality benefits. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of air quality benefits over the analysis period.

Safety Calculations

Non-motorized is the one mode where two distinct types of safety benefits are calculated. If the non-motorized project directly addresses a safety hazard to pedestrians or bicyclists (i.e. a crossing signal at a location where one or more pedestrian accidents has occurred) the benefits for future accident savings are accrued (consistent with the existing methods used by the non-motorized division). Accident savings is also calculated based upon the estimated reduction in automobile VMT. Since these two sources of accidents are independent of one another, there is no risk of double counting.

Accident reduction on non-motorized facility

This accident reduction is based upon historical accident data at the project location. The user identifies the number of accidents that occurred over a defined period of time (typically three years) for each accident type: fatality, disabling injury, evident injury, possible injury, and property damage only. The user then identifies the number of these accidents that could have been prevented by the proposed improvement. The average number of prevented accidents per year is calculated for each type, and this is assumed to be the number prevented per year, for each year of the project's analysis life.

Accident reduction due to diverted autos

Once a savings in VMT is calculated, vehicle accident savings based upon that reduction can also be estimated. Reduction is calculated for fatality, injury (assumed to be in the "evident injury category), and property damage only accident types. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so are the accidents based upon VMT.

Safety Benefit Calculations

The safety benefit is calculated by multiplying the estimated reduction in each type of accident by its respective societal value. The societal cost of accidents are global variables, and are described in *Chapter 2 – Project Measures*. Since safety benefits are assumed to change at a uniform rate from the initial year to the final year of the analysis period, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of safety benefits. Note, the facility-related accident reduction is actually estimated as a uniform annual series, but when it is added to the VMT-related reduction, the result is a uniform gradient series.

Environmental Retrofit

A non-motorized project may include one or more of the three categories of environmental retrofit projects currently recognized in the MICA process: Fish Barrier Removal, Storm Water Retrofit, or Noise Barrier Construction. In this case, the costs of these projects are itemized in the cost input worksheet. Benefits for these projects are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio (BCR), as described in *Chapter 2 – Project Measures*.

Total Project Benefit Calculations

Total project benefits are calculated by adding together the net present values of all user operating benefits, travel time benefits, safety benefits, and environmental benefits that have been calculated for the project.

Total Project Cost Calculations

The total project costs are calculated by adding together the net present value of the capital costs and operation and maintenance costs, and subtracting the net present value of the terminal cost, as described in *Chapter 2 – Project Measures*. Both the total project cost and the cost to WSDOT are calculated.

Benefit-Cost Calculations

The Benefit-Cost Ratio is calculated by dividing the net present value of total project benefits by the net present value of total project costs. In cases where WSDOT has partnered with another public or private agency, a WSDOT Benefit-Cost ratio is calculated by dividing the net present value of WSDOT project benefits by the net present value of total project costs. If WSDOT is paying the entire cost of the project, these two values will be equal.

Project Reports

The report for any specific project is brought up by clicking on the "Project Report" button on the input form when that project is active. Project level reports are structured similarly for all project types, with four major sections:

1. **Project Information** – summarizes all descriptive data for the project.

2. **Input Summary** – summarizes all of the inputs for benefit and cost calculation.

3. **Calculation Results** – summarizes all of the results of the benefit calculations, cost calculations, cost efficiency measures, and outcome objective scores.

4. **Global Assumptions** – summarizes all of the global variables that were used in the calculations, as well as their respective values.

All data must be completely input for the full project report to be displayed. However, if the inputs are incomplete, the inputs that have been completed will still be summarized if the project report is brought up. When it is created, the project report displays on-screen. The report can then be printed out from the on-screen display if a hard copy is desired.

References

FHWA (Federal Highway Administration). National Bicycling and Walking Study (Case Study 15: The Environmental Benefits of Bicycling and Walking). Publication No. FHWA-PD-93-015. U.S. Department of Transportation. Washington, DC. January 1993.

Washington State Department of Transportation (WSDOT), Non-Motorized Division. Internal Documents: Project Lists and Departmental Scoring Worksheets. (March 2001).

Washington State Department of Transportation (WSDOT). *Washington State Transportation Plan*. (2000)

Chapter 10 – Rail Projects

The Rail Program is included in the Washington State Current Law Budget as Program Y. As part of its duties, the Rail program continues operation of the state sponsored passenger rail program, which includes round trip rail service between Seattle and Portland OR, Vancouver, BC, and Bellingham. Additionally, the program provides funding for track and other improvements required to support passenger rail service, freight rail service, and the rehabilitation of light density rail lines statewide.

Inventory of Projects

Based upon the projects proposed by the Rail Program in the six-year Current Law Budget, six major types of capital improvement projects were identified for rail. These are:

1. **Freight Car Purchase**: Allows a greater volume of freight to be carried by rail.

2. **Grade Separation / Crossing Improvement**: Major improvement such as grade separation, or a crossing improvement of lesser magnitude can improve safety at the crossing, and also allow trains to operate at higher speeds through the crossing.

3. **Modal Connection Improvement:** Improves loading speed of freight from barge to rail, thus increasing freight capacity at transfer points.

4. **Passenger Trainset Purchase**: Allows increase in frequency of passenger rail service.

5. **Station Improvement**: Addition or improvement of a passenger rail station can draw a greater number of travelers to rail.

6. **Track Improvement**: Improvement of a length of track can allow higher operating speeds for both freight and passenger rail.

Inventory of Current Analysis Methods

The rail division has launched numerous studies to evaluate the benefits of various types of rail improvements (Casavant et al. 1996; HDR Engineering et al. 1998 and 2000). Thus many resources are available that both qualitatively and quantitatively demonstrate the positive role that rail can play in the interstate transportation system. Benefit data is available for most elements of freight rail improvements. However, this type of detailed analysis is not specifically performed on projects as part of the budget allocation process.

Identification of Analysis Gaps

The studies that have been performed for the Rail Program served as the starting point for the methods that were developed for MICA. However, the methodologies employed in the prior studies are more detailed than the methods appropriate for the sketch level analyses employed by MICA. The benefit analyses presented here require very general inputs. In the continuing refinement of these procedures, they should be examined for areas in which slightly more detailed data would be appropriate.

Project Worksheets and Inputs

The rail mode is accessed by clicking on the "Rail" button on the starting screen of the Project Module. Figure 10-1 shows the opening screen for the Rail mode. From this screen, the analyst can access existing rail projects in the MICA database, or add a new rail project (note, the general procedures for Project Level Analysis are described in *Chapter 3 – Operation of the MICA Program*).
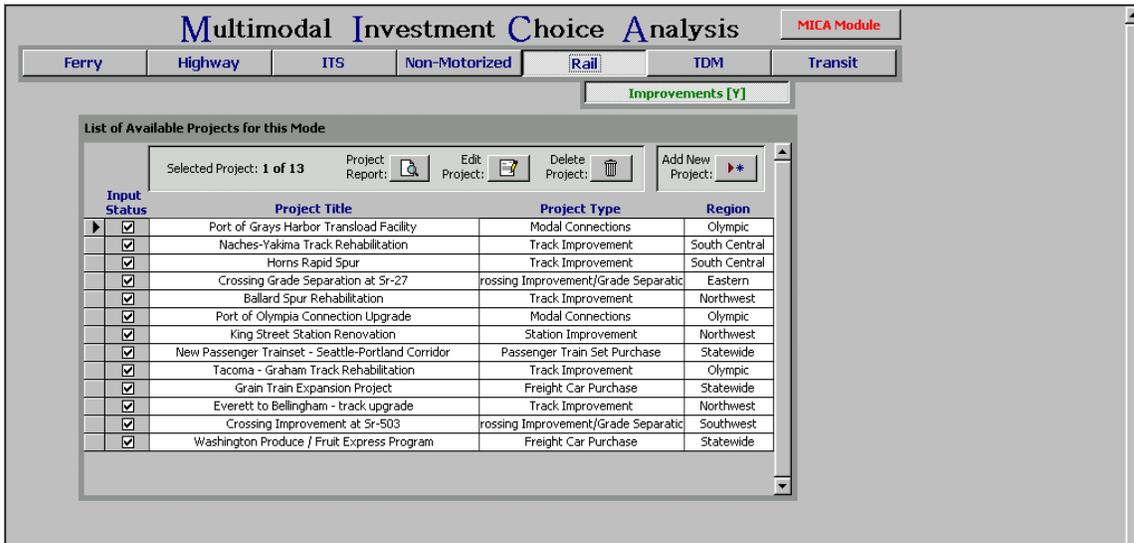
Figure 10-1: Opening Screen for Rail Projects

Project Information

The Project Information input form, as shown in Figure 10-2, is the first of four screens to be displayed when a rail project is edited or added to the database. The user can navigate through the four screens by clicking on the tab headings. Additionally, the three buttons at the top of the screen can be selected at any time to delete the current project from the database, preview the project report, or save the current data and exit back to the opening screen for rail projects.

Figure 10-2: Rail Project Information Form

The Project Information component contains the following descriptive information:

Project Title:	Descriptive title of the project
Project Type:	Identifier that is unique to the project
Project Type:	Specific type of project, selected from a pull down list. For the rail mode, the six project types are:

- **Freight Car Purchase**
- **Grade Separation / Crossing Improvement**
- **Modal Connection Improvement**
- **Passenger Trainset Purchase**
- **Station Improvement**
- **Track Improvement**

Biennium:	Biennium in which the project is to be considered for funding
Region:	WSDOT Region in which the project is located. A pull down menu provides eight region options:

- **Eastern**
- **North Central**
- **Northwest**
- **Olympic**
- **South Central**
- **Southwest**

- **Statewide** should be selected if the project is located in multiple regions

- **Ferry** applies only to ferry projects, and would never be selected for rail projects

Legislative District: State Legislative District in which the project is located, if the project fits completely or primarily in one district.

Air Quality: Air quality designation for the project area, as identified by the Clean Air Act. A pull down menu provides the options of:

- **Attainment Area**

- **Non-Attainment Area**

- **Maintenance Area**

- **Unclassifiable**

as described in *Chapter 2 – Project Measures*.

WTP Corridor: Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

FGTS Classification: Identifies whether or not the project is included in the Freight and Goods Transportation System (FGTS) classification system. A pull down menu provides the options of:

- **T-1** (> 10 million tons per year)

- **T-2** (4 to 10 million tons per year)

- **T-3** (300,000 to 4 millions tons per year)

- **T-4** (100,000 to 300,000 tons per year)

- **T-5** (20,000 tons per 60 days)

- **None**

as described in *Chapter 2 – Project Measures*.

Project Specific Benefit Worksheets

The second input screen is the benefit input form, which is unique to the each of the five types of projects analyzed within the rail mode. The following sections describe the input screens and the data required for each project type.

Freight Car Purchase

The benefit input form for Freight Car Purchase rail projects is shown in Figure 10-3. The user inputs data under four categories:

- Project Description

- Analysis Period for Project

- Freight Volume Data

- Trip Data

The Benefit Input component for Freight Car Purchase projects calls for the following information:

Figure 10-3: Freight Car Purchase Benefit Input Form

The Benefit Input component for Freight Car Purchase projects calls for the following information:

Project Features

    Description of Project: User can input up to two lines of description of project features

Analysis Period

Initial Year: Initial analysis year

Forecast Year: Forecast analysis year

Freight Volume Data

Agriculture Tons: Annual tons of agricultural/farm products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Lumber Tons: Annual tons of lumber/wood products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Mixed Tons: Annual tons of mixed shipments carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Chemical Tons: Annual tons of chemicals carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Food Tons: Annual tons of food and kindred products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Paper Tons: Annual tons of paper and pulp products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Petrol Tons: Annual tons of petroleum or coal products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Scrap Tons: Annual tons of waste or scrap material carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Stone Tons: Annual tons of stone/clay/glass products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Metal Tons: Annual tons of primary metal products carried (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Trans Equip Tons: Annual tons of transportation equipment carried (tons per year)

- Base case and Project case, initial year

- Base case and Project case, forecast year

Trip Data

Freight Trip Length: Length of average freight trip that travels along corridor

Base case and Project case

Freight Trains per Week: Weekly total number of freight trains that travel the corridor

Base case and Project case, initial year

Base case and Project case, forecast year

Grade Separation / Crossing Improvement

The benefit input form for Grade Separation and Crossing Improvement rail projects is shown in Figure 10-4. The user inputs data under six categories:

- Project Description

- Analysis Period for Project

- Passenger Data

- Freight Data

- Trip Data

- Accident Data

Figure 10-4: Grade Separation / Crossing Improvement Benefit Input Form

The Benefit Input component for Grade Separation and Crossing Improvement projects calls for the following information:

Project Features

      Description of Project: User can input up to two lines of description of project features

      Length: Length of project (miles)

Analysis Period

      Initial Year: Initial analysis year

      Forecast Year: Forecast analysis year

Passenger Data

      Annual Passengers: Annual number of passengers that will travel along the corridor

- Project case, initial year
- Project case, forecast year

Freight Data

      Freight Trains / Week: Weekly total number of freight trains that travel the corridor

- Initial year
- Forecast year

Trip Data

      Avg. Speed Passengr Trn: Average speed of passenger train through project area (mph)

- Base case and Project case

      Avg. Speed Freight Trn: Average speed of freight train through the project area (mph)

- Base case and Project case

Accident Data

      Begin Accident Data: Beginning year for historical accident data

      End Accident Data: Ending year for historical accident data

      Preventable Fatality: Fatality accidents that would have been prevented by project

      Preventable Injury: Injury accidents that would have been prevented by project

      Preventable PDO: Property damage accidents that would have been prevented by project

Modal Connection Improvement

The benefit input form for Modal Connection Improvement rail projects is shown in Figure 10-5. The user inputs data under four categories:

- Project Description

- Analysis Period for Project

- Freight Data

- Trip Data

Figure 10-5: Modal Connections Benefit Input Form

The Benefit Input component for Modal Connection Improvement projects calls for the following information:

<u>**Project Features**</u>

Description of Project: User can input up to two lines of description of project features

Analysis Period

Initial Year: Initial analysis year

Forecast Year: Forecast analysis year

Freight Data

Barge to Train: Average volume at loading point from barge to train (tons per year)

- Base case and Project case, initial year
- Base case and Project case, forecast year

Trip Data

Average Loading Speed: Average freight loading time (tons per hour)

- Base case and Project case

Freight Trains / Week: Weekly total number of freight trains that travel the corridor

- Base case and Project case, initial year
- Base case and Project case, forecast year

Freight Trip Length: Length of average freight trip that travels along corridor

- Base case and Project case

Passenger Trainset Purchase

The benefit input form for Passenger Trainset Purchase rail projects is shown in Figure 10-6. The user inputs data under four categories:

- Project Description
- Analysis Period for Project
- Passenger Data
- Trip Data

Figure 10-6: Passenger Trainset Purchase Benefit Input Form

The Benefit Input component for Passenger Trainset Purchase projects calls for the following information:

Project Features

Description of Project: User can input up to two lines of description of project features

Analysis Period

Initial Year: Initial analysis year

Forecast Year: Forecast analysis year

Passenger Data

Annual Passengers: Annual number of passengers that will travel along the corridor

- Base case and Project case, initial year

- Base case and Project case, forecast year

Auto Diversion to Rail: Percent of new rail passengers assumed to come from auto

Trip Data

Passenger Trip Length: Length of average passenger trip that travels along corridor

- Base case and Project case

Fare: Average passenger fare per trip

Passenger Trains / Week: Weekly total number of passenger trains that travel the corridor

- Base case and Project case, initial year

- Base case and Project case, forecast year

Station Improvement

The benefit input form for Station Improvement rail projects is shown in Figure 10-7. The user inputs data under four categories:

- Project Description

- Analysis Period for Project

- Passenger Data

- Trip Data

Figure 10-7: Station Improvement Benefit Input Form

The Benefit Input component for Station Improvement projects calls for the following information:

Project Features

Description of Project: User can input up to two lines of description of project features

Analysis Period

Initial Year: Initial analysis year

Forecast Year: Forecast analysis year

Passenger Data

Annual Passengers: Annual number of passengers that will travel along the corridor

- Base case and Project case, initial year
- Base case and Project case, forecast year

Auto Diversion to Rail: Percent of new rail passengers assumed to come from auto

Trip Data

Passenger Trip Length: Length of average passenger trip that travels along corridor

- Base case and Project case

Fare: Average passenger fare per trip

Track Improvement

The benefit input form for Track Improvement rail projects is shown in Figure 10-8. The user inputs data under five categories:

- Project Description

- Analysis Period for Project

- Passenger Data

- Freight Data

- Trip Data

Figure 10-8: Track Improvement Benefit Input Form

The Benefit Input component for Track Improvement projects calls for the following information:

Project Features

Description of Project: User can input up to two lines of description of project features

Length: Length of project (miles)

Analysis Period

Initial Year: Initial analysis year

Forecast Year: Forecast analysis year

Passenger Data

Annual Passengers: Annual number of passengers that will travel along the corridor

- Base case and Project case, initial year
- Base case and Project case, forecast year

Auto Diversion to Rail: Percent of new rail passengers assumed to come from auto

Freight Data

Freight Trains / Week: Weekly total number of freight trains that travel the corridor

- Initial year
- Forecast year

Trip Data

Fare: Average passenger fare per trip

Passenger Trip Length: Length of average passenger trip that travels along corridor

- Base case and Project case

Freight Trip Length: Length of average freight trip that travels along corridor

- Base case and Project case

Avg. Speed Passenger Trn: Average speed of passenger train through project area (mph)

- Base case and Project case

Avg. Speed Freight Trn: Average speed of freight train through the project area (mph)

- Base case and Project case

Outcome Objectives

The third page contains the Outcome Objectives inputs, which consist of the standard questions described in Chapter 3 of this report. While all of the input questions remain the same regardless of mode or project type, some calculations do vary with project type.

Cost Information

The final page of the input form contains the cost data. Cost inputs and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In cases where the improvement will lower the annual cost of operation and maintenance, a negative cost value will result.

Benefit-Cost Calculations

The components of benefit calculations varies among the six categories of rail projects, and are summarized as follows:

- Freight Car Purchase assumes that newly acquired freight cars will carry cargo that would otherwise be carried by trucks, resulting in a decrease in truck VMT. Benefits consist of operating cost savings, pavement savings, air quality savings, and accident savings, all due to reduced miles traveled by freight truck. Travel time savings is not considered to be a factor for this type of project.

- Grade Separation / Crossing Improvement assumes that an improvement is made at one specific crossing location. The procedure recognizes that an increase in rail travel speed might occur due to the improvement, and calculates resulting travel time benefits for both freight and passenger movement. However, the procedure currently assumes that one localized crossing project will not increase travel speeds to a degree that would induce additional freight or passenger volumes. Thus no auto or truck VMT reductions are calculated, nor are air quality benefits since they are a function of VMT. Accident benefits for this project type are based upon historical accident data.

- Modal Connection Improvement assumes that improvements are made at a loading point from barge to rail. The procedure calculates the travel time benefits that result from the faster loading times. Additionally, it allows for increased freight rail volumes due to more efficient loading and assumes that these volumes would otherwise be carried by trucks, resulting in a decrease in truck VMT. Calculated benefits that result from VMT reduction include truck operating cost savings, pavement savings, air quality savings, and accident savings.

- Passenger Train Purchase assumes that newly added passenger rail service would carry a significant number of people who would otherwise travel by automobile, resulting in a decrease in automobile VMT. Benefits consist of operating cost savings, air quality savings, and accident savings, all due to reduced miles traveled by automobiles. Travel time savings is not considered to be a factor for this type of project. However, future program refinements may include calculations for replacing a slower train with a faster train, which would include travel time savings.

- Station Improvement assumes that a passenger rail station is either newly built or significantly improved, and that an increase in rail passenger volumes will result. Procedures are based upon the additional assumption that a significant number of new passengers would otherwise travel by automobile, resulting in a decrease in automobile VMT. Benefits consist of operating cost savings, air quality savings, and accident savings, all due to reduced miles traveled by automobiles. Travel time savings is not considered to be a factor for this type of project.

- Track Improvement assumes that significant improvements will be made to the track infrastructure that will allow increased travel speeds for both freight and passenger rail. The procedure calculates the travel time benefits for freight and passenger movement that result from the faster speeds. Additionally, it allows for increased passenger and freight volumes that are estimated to be induced by the faster speeds. The increased volumes are assumed to be diverted from trucks and automobiles, resulting in a relative decrease in VMT. Calculated benefits that result from VMT reduction include truck operating cost savings, pavement savings, air quality savings, and accident savings.

Although different rail project types include different combinations of benefit elements, the calculations for each element is similar, regardless of the project type in which it is included. The various benefit and cost calculations are described in the following paragraphs.

Passenger User Benefits

New Riders Due to Passenger Rail Improvements

Three rail project types (*Passenger Train*, *Station*, and *Track Improvement*) have benefits procedures that account for new riders that result from the improvement. The new riders are not estimated within the program. Rather, they are input by the user based upon outside demand forecasts. New riders are calculated by taking the difference between the base case volumes and the project case volumes, as input by the user, for the initial year and the final year of the analysis period. Straight-line growth is assumed from the initial to the final year of the forecast period.

Change in Automobile VMT

The reduction in automobile VMT is a function of the number of new riders that are estimated as the result of the project. The percentage of new riders that are assumed to be diverted from automobile should be estimated from demand forecasts, and is input by the user. The number of diverted travelers is divided by the average vehicle occupancy to estimate the number of auto trips diverted. This is converted to VMT by multiplying by the average length of trip along the project corridor.

Operating Cost Savings to Travelers

The operating cost savings to travelers is a function of the estimated reduction in automobile VMT. Average operating costs per mile are included in MICA as a global variable. The actual value per mile will depend on whether "Direct Cost" or "Full Cost" is selected by the user (as described in *Chapter 2 – Project Measures*). The operating cost savings is calculated by multiplying the reduction in auto VMT by the operating cost per mile. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual operating cost savings to travelers. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

User Transfer – New Passenger Rail Fares

New rail passengers that are estimated to be generated from a proposed project will have to pay fares for their trips that they would not have to pay otherwise. This represents an out-of-pocket cost to the passengers. However, it also provides a benefit to the agency by generating revenue, so it is considered to be a transfer of money. User transfer based upon rail fares is calculated, but it is not counted as either a cost or a benefit.

Freight User Benefits

Increased Freight Rail Volume Due to Freight Improvements

Three rail project types (*Freight Car*, *Modal Connection*, and *Track Improvement*) have benefits procedures that account for an increase in freight volumes that result from the improvement. The volume increases are not estimated within the program. Rather, they are input by the user based upon outside demand forecasts. Freight volume increases are calculated by taking the difference between the base case volumes and the project case volumes, as input by the user, for the initial year and the final year of the analysis period. Straight-line growth is assumed from the initial to the final year of the forecast period.

The number of freight trucks that would be required to carry the load, if the project were not implemented determines the benefit of increased freight volume on rail. The equivalent number of trucks is estimated by dividing the shifted volume by the average tons carried per truck. The equivalent loads are presented in Table 2-14 of this report. In the current version, the *Freight Car Purchase* project type calls for freight volumes to be input by type of freight. The other two freight project types, Modal Connections and Track Improvements, simply call for the amount of general freight. If it were warranted, future program refinements could add the more detailed breakdown to these two project types as well.

Change in Truck VMT

The reduction in freight truck VMT is a function of the increases in rail freight volumes that estimated as the result of the project. The number of trucks that are calculated to be taken off of the highways are multiplied by the average distance that the freight is carries. The VMT savings is assumed to change at a uniform rate from the initial year to the final year of the analysis period.

Operating Cost Savings to Freight Operators

The operating cost savings to freight operators is a function of the estimated reduction in truck VMT. Average operating costs per mile are included in MICA as a global variable. The actual value per mile will depend on whether "Direct Cost" or "Full Cost" is selected by the user (as described in *Chapter 2 – Project Measures*). The operating cost savings is calculated by multiplying the reduction in truck VMT by the operating cost per mile. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual operating cost savings to travelers. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Savings in Pavement Degradation

A benefit due to savings in pavement degradation is also calculated based upon the reduced truck VMT that is expected to result from the project. Once the VMT reduction is calculated, it is multiplied by the marginal pavement cost of a freight truck per mile. The marginal cost is a global variable with a value of 12.7 cents per mile. This value is at the conservative end of a range derived in previous research for WSDOT (HDR et al. 2000). Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so does the

annual savings to pavement degradation. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Travel Time Benefits

Travel time benefits are calculated for three project types. *Grade Separation* and *Track Improvement* project types calculate travel time savings for both freight and passenger travel. Time savings is calculated based upon the estimated increase in travel speeds, and the project length. *Modal Connections* calculates travel time savings based upon the increase in loading speed from barge to rail at the connection point.

In all cases, travel time benefits are calculated by multiplying the estimated travel time savings by the value of time. Travel time benefits are assumed to change at a uniform rate between the initial year and the final year of the forecast period. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

Air Quality Calculations

Air quality benefits for rail projects are based upon the reduction in automobiles and freight trucks they bring about on the highways. If a project results in an increase in either passenger or freight rail service, the corresponding increase in pollutants is considered as a disbenefit. The total air quality impact is the net difference – the decrease in highway-related emissions minus the increase in rail-related emissions.

Pollutants Removed Due to Reduction in Automobiles and/or Freight Trucks

Air quality impacts are calculated for the five rail project types that estimate VMT reduction. Once a reduction in VMT due to rail is calculated, savings in air pollution can also be calculated. Reduction in emissions is calculated for Carbon Monoxide (CO), Nitrous Dioxide (NOx), and Particulate Matter – 10 microns (PM_{10}). Future work will add Volatile Carbons (VOC) rates, and may change PM_{10} to $PM_{2.5}$ to reflect new Federal regulations. The emissions reductions are calculated by multiplying the estimated reduction in VMT by the respective emission rates of automobiles or trucks per mile (as described in *Chapter 2 – Project Measures*). Emissions rates are based upon an assumed average intercity vehicle running speed of 50 miles per hour. The initial reductions are calculated in grams, and then converted into English tons.

Pollutants Added Due to Increased Rail Service

Three of the six types of rail projects (*Passenger Train, Station Improvement, and Track Improvement*) result in increased rail service. When this is the case, the MICA program is set up to calculate the corresponding increase in pollutants. Any increase in rail-related emissions is subtracted from the decrease in highway-related emissions to calculate the total air quality benefit.

Air Quality Benefit Calculations

The air quality benefit is calculated by multiplying the estimated tonnage of each pollutant removed (CO, NOx, PM_{10}, and in the future, VOC) by its respective societal value. The societal costs of the tons of pollutants are global variables, and are described in *Chapter 2 – Project Measures*. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual air quality benefits. Thus, Equation 2-3

(Present Value of a Uniform Gradient Series) is used to calculate the net present value of air quality benefits over the analysis period.

Safety Calculations

Accident savings is based upon the estimated reduction in automobile VMT for five of the six types of rail projects. For the sixth project type, *Grade Separation / Crossing Improvements*, the safety calculations are based upon historical accident data.

Accident reduction based upon reduced VMT

Once a savings in VMT is calculated, vehicle accident savings based upon that reduction can also be estimated. The accident rate per mile traveled for each mode is a global variable, and is described in *Chapter 2 – Project Measures*. In this case, the accident rate per mile is applied to the change in automobile or truck miles traveled. Reduction is calculated for fatality, injury (assumed to be in the "evident injury category), and property damage only accident types. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so are the accidents based upon VMT.

For the three types of rail projects (*Passenger Train, Station Improvement, and Track Improvement*) that result in increased rail VMT, MICA will calculate the corresponding increase in rail-related accidents. Any increase in rail-related accidents is subtracted from the decrease in highway-related accidents to calculate the total air quality benefit

Accident reduction based upon historical data

This accident reduction for *Grade Separation / Crossing Improvements* is based upon historical accident data at the project location. The user identifies the number of accidents that occurred over a defined period of time (typically three years) for each accident type: fatality, injury (assumed to be in the "evident injury category), and property damage only. The user then identifies the number of these accidents that could have been prevented by the proposed improvement. The average number of prevented accidents per year is calculated for each type, and this is assumed to be the number prevented per year, for each year of the project's analysis life.

Safety Benefit Calculations

The safety benefit is calculated by multiplying the estimated reduction in each type of accident by its respective societal value. The societal costs of accidents are global variables, and are described in *Chapter 2 – Project Measures*. For VMT-based accident reduction, safety benefits are assumed to change at a uniform rate from the initial year to the final year of the analysis period. Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of these safety benefits. For historical-based accident reduction, a uniform number of accidents are estimated to be prevented during each year of the analysis period. Equation 2-2 (Present Value of a Uniform Annual Series) is used to calculate the net present value of these safety benefits.

Environmental Retrofit

A rail project may include one or more of the three categories of environmental retrofit projects currently recognized in the MICA process: Fish Barrier Removal, Storm Water Retrofit, or Noise Barrier Construction. In this case, the costs of these projects are itemized in the cost input worksheet. Benefits for these projects are estimated simply by multiplying the retrofit cost by a pre-determined benefit-cost ratio (BCR), as described in *Chapter 2 – Project Measures*.

Total Project Benefit Calculations

Total project benefits are calculated by adding together the net present values of all user operating benefits, travel time benefits, safety benefits, and environmental benefits that have been calculated for the project.

Total Project Cost Calculations

The total project costs are calculated by adding together the net present value of the capital costs and operation and maintenance costs, and subtracting the net present value of the terminal cost, as described in *Chapter 2 – Project Measures*. Both the total project cost and the cost to WSDOT are calculated.

Benefit-Cost Calculations

The Benefit-Cost Ratio is calculated by dividing the net present value of total project benefits by the net present value of total project costs. In cases where WSDOT has partnered with another public or private agency, a WSDOT Benefit-Cost ratio is calculated by dividing the net present value of WSDOT project benefits by the net present value of total project costs. If WSDOT is paying the entire cost of the project, these two values will be equal.

Project Reports

The report for any specific project is brought up by clicking on the "Project Report" button on the input form when that project is active. Project level reports are structured similarly for all project types, with four major sections:

1. **Project Information** – summarizes all descriptive data for the project.

2. **Input Summary** – summarizes all of the inputs for benefit and cost calculation.

3. **Calculation Results** – summarizes all of the results of the benefit calculations, cost calculations, cost efficiency measures, and outcome objective scores.

4. **Global Assumptions** – summarizes all of the global variables that were used in the calculations, as well as their respective values.

All data must be completely input for the full project report to be displayed. However, if the inputs are incomplete, the inputs that have been completed will still be summarized if the project report is brought up. When it is created, the project report displays on-screen. The report can then be printed out from the on-screen display if a hard copy is desired.

References

Casavant, Kenneth L. and Richard Mack. An Economic Evaluation of the Performance of the Washington State Department of Transportation Grain Train Project. Prepared for the Washington State Department of Transportation. (February 1996).

HDR Engineering, Inc. and Denver Tolliver and Associates. Benefits of Rail Freight Transportation in Washington: A Multimodal Analysis. Prepared for the Washington State Department of Transportation. (December 2000).

HDR Engineering, Inc. and Denver Tolliver and Associates. Highway Benefits of Washington Grain Train Program. Prepared for the Washington State Department of Transportation. (1998).

The Resource Group, and HDR Engineering, Inc. Pacific Northwest Rail Corridor Amtrak Cascades Plan for Washington State 1998-2018 Update. Prepared for the Washington State Department of Transportation. (April 2000).

Washington State Department of Transportation (WSDOT). 2001-2003 Budget and Six-Year Plan. Adopted by the Washington State Transportation Commission. (August 16, 2000).

Washington State Department of Transportation (WSDOT) and Wilbur Smith Associates. Washington State Freight Rail Plan: 1998 Update. (November 1998).

Chapter 11 – Transit Projects

While the Washington Department of Transportation typically does not own or operate transit systems it does take consider transit of state interest and will allocate state funds toward the development or operation of transit systems run by other agencies within the state.

Inventory of projects

The Public Transportation and Intercity Rail Passenger Plan for Washington State: 1997- 2016 identifies $29.3 billion in public transportation needs (excluding intercity rail). This figure includes transit, paratransit, high-capacity transit, park and ride, and action strategies funding categories. It was estimated in the study that $17.9 billion was available in expected revenues leaving an unfunded balance of $11.4 billion. The $29.3 billion funding list includes just under 70% for system preservation and just over 30% for system improvement. Two smaller categories of education and technical support and building partnerships and planning complete the list with 0.03 and 0.04 percent respectively.

Inventory of current analysis methods

Currently transit projects are analyzed on a case-by-case basis and no standardized analysis method is utilized by WSDOT for current transit funding allocation. In order to be incorporated into the MICA program transit projects will have to be analyzed in a way where estimates of travel time savings, user cost savings, safety benefits, and environmental benefits can be made. There are two software tools available from the Federal Highway Administration that provide these types of estimates for transit systems: the Sketch Planning Analysis Spreadsheet Model (SPASM) and the Surface Transportation Efficiency Analysis Model (STEAM). Both programs can be downloaded for free from the STEAM website (http://www.fhwa.dot.gov/steam/).

SPASM and STEAM are designed for different levels of analysis. STEAM is a post-processor for the four-step modeling process while SPASM is designed for cases where running the travel demand model is not feasible either due to lack of model or lack of available personnel. Both models generate benefits and cost for a typical year based an annualized capital and operation and maintenance costs as well as annual benefits for the analysis year. In order to maintain consistency within MICA an analysis would have to be performed for both the initial year and forecast year (typically 20 year planning horizon). Benefits would be interpolated between these years assuming uniform growth.

A major limitation to SPASM is that it only addresses corridor analysis projects. This can be a problem when the transit project under consideration extends beyond a single corridor to include multiple corridors or entire transit systems. STEAM on the other hand is network based and system-wide transit improvements can be evaluated as long as the improvements can be coded into the travel demand model. Currently MICA is configured to accept inputs from either program. Later versions of the program will incorporate SPASM directly into the calculations and also will allow for direct linking between STEAM output and MICA input.

Since MICA allows for analysis of the affects of different global variables such as value of time, cost of pollutant emissions, etc. it is necessary to input numbers in their non-monetary form (i.e. minutes of savings, tons of pollutants, etc) as much as possible to allow for the sensitivity of these variables to be considered. This also ensures consistency in the analysis to the greatest extent possible.

WSDOT has been interested for several years in developing a Public Transportation Management System (PTMS). The PTMS was originally one of the six management tools

federally mandated by ISTEA in 1991 but eventually became an optional management tool. Typically PTMS tools are used for collecting, analyzing and disseminating information on the condition of the State's transit assets. Several states, most notably Florida, have put extensive efforts into the developments of the system. The management system is mentioned here since its development should be coordinated with future MICA efforts so that ultimately the PTMS would feed into the MICA program for transit project evaluation.

Identification of analysis gaps

Below is a list of known gaps in the analysis. Long-term gaps represent areas where additional data or research into developing new methodologies may be needed. These are areas recommended for further work in future phases of the project.

Short-Term Gaps

Incorporate SPASM calculations directly into MICA program.

Long-Term Gaps

Derive regional numbers for transit impacts to improve the estimation methodology.

Project worksheets and inputs

The data required for SPASM and STEAM models varies greatly. SPASM analysis requires far less data and therefore yields a more approximate estimate then a STEAM analysis. Regardless of the model used, transit agencies should have the required information available from their operating data. For smaller jurisdictions that may not have access to such data, research has been done that provides reasonable estimates for these data requirements. TCRP Report 20, "Measuring and Valuing Transit Benefits and Disbenefits" and TCRP Report 35 "Economic Impact Analysis of Transit Investments: Guidebook for Practitioners" are two good resources for this type of information.

Project Information

The following descriptions refer to the input for the Transit Project Information Input form shown in Figure 11-1.

Project Title: Descriptive title of the project

Project Identification Number: Unique 7 digit alphanumeric number for project identification

Project Type: Select project type from pull down list. (**STEAM** and **SPASM** project types available.)

Biennium: Input the beginning year for the biennium the project is to be programmed. Leave blank if unknown or not critical

Region: WSDOT Region for the project. If multiple regions apply choose a primary region.

Legislative District: State Legislative District. If multiple districts apply choose a primary district.

Air Quality Designation: Attainment, **Non-Attainment**, **Maintenance**, or **Unclassifiable** areas as identified by the Clean Air Act. If multiple designations apply choose *primary* area.

Designated WTP Corridor: Yes or **no**. Is the project an identified WTP Corridor?   If not applicable select no.

Strategic Freight Network: Is the project on the Strategic Freight Network? If so choose one of the five Freight Goods Transportation System Classifications (**T-1** through **T-5**) from the pull-down list. Otherwise select **None**.

Figure 11-1: Transit Project Information Screen

STEAM Results

The results from running the STEAM program are to be entered into the following worksheet. The analysis is to be performed for both an initial and forecast year. The forecast year is typically 20 to 40 years into the future.

The following descriptions refer to the input for the STEAM Input form shown in Figure 11-2.

Initial Analysis Year: Enter four-digit number for initial analysis year.

Forecast Analysis Year: Enter four-digit number for forecast analysis year.

For the appropriate analysis year enter the following values from STEAM output results.

In-Vehicle Travel Time: Enter the in-vehicle travel time in million person hours per year for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Out-of-Vehicle Travel Time: Enter the out-of-vehicle or excess travel time in million person hours per year for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Vehicle Miles of Travel: Enter the VMT in million miles per year for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Number of Trips: Enter the number of trips in millions of trips per year for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Revenue Transfer: Enter the total revenue transfer in $1000's per year. Combine the results for all modes.

Figure 11-2: STEAM Project Input Form

SPASM Results

The results from running the SPASM program are to be entered into the following worksheet. The analysis is to be performed for both an initial and forecast year. The forecast year is typically 20 to 40 years into the future.

The following descriptions refer to the input for the SPASM Input Form shown in Figure 11-3.

Initial Analysis Year: Enter four-digit number for initial analysis year.

Forecast Analysis Year: Enter four-digit number for forecast analysis year.

For the appropriate analysis year enter the following values from SPASM output results. Results must be entered for both the peak and non-peak periods.

In-Vehicle Travel Time: Enter the in-vehicle travel time in minutes for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Out-of-Vehicle Travel Time: Enter the out-of-vehicle or excess travel time in minutes for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Vehicle Miles of Travel: Enter the VMT in miles for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Number of Trips: Enter the number of trips for the base and project cases. Combine the results for auto and carpool and for express and local buses.

Revenue Transfer: Enter the total revenue transfer.. Combine the results for all modes.

Figure 11-3: SPASM Project Input Form

Outcome Objectives

The Outcome Objectives inputs are the standard questions described in Chapter 3 of this report. While all the input questions remain the same regardless of mode or project type the calculations are project type dependent.

Cost Information

The cost input forms and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In some cases this will result in a negative operation and maintenance cost if the improvement will lower the annual cost of operation the facility.

Benefit-cost calculations

The benefit-cost calculations for STEAM and SPASM projects are very similar. The following sections describe the methodology of the calculations. The actual calculations contained in the code (see Volume II) can be followed along using these descriptions.

STEAM Projects

In Vehicle Travel Time

The calculations first convert the entered yearly in-vehicle travel time benefits in millions of person hours into travel time minutes. This is done for each of the four modes and for both the initial and forecast years. The travel time for auto, bus, and rail are added since their travel time values are the same.

Out of Vehicle Travel Time

The calculations are then repeated using the same methodology for out-of-vehicle travel times. Once again the travel time for auto, bus, and rail area combined.

Total Travel Time

The total travel time is calculated by adding the in-vehicle and out-of-vehicle travel times for both the initial and forecast years. The present value factor is derived assuming uniform growth between periods. The total travel time for freight and non-freight travel is then calculated.

Travel Time Benefits in Dollars

The travel time benefits are calculated using the global variables for time value for vehicle travel (auto, bus, and rail) and percent of time value for in-vehicle and out-of-vehicle travel time. Travel time benefits are calculated for both the initial and forecast years. A uniform growth rate between the two analysis periods is assumed and brought back to net present value using the global variable discount rate.

Operating Cost Calculations

The change in vehicle miles travel for the initial and forecast years in converted from millions of miles to miles for the four modes and two analysis periods.   A uniform growth is assumed between periods and a net present factor calculated. The user cost calculations are based on VMT and the global variables for vehicle cost per mile and freight vehicle cost per mile. Bus and Rail operation costs are included in the project's operating and maintenance costs. Full costs or direct operating costs are used depending on the setting of the full cost global variable (yes if full costs are to be considered).

Air Pollution Emissions

The change in emissions levels for the four pollutants are calculated from the change in vehicle miles traveled. The emissions rates are based on global variables for the grams of emissions per mile (assuming a running speed of 35 miles per hour). The emission rates are based on a warm engine. Cold start effects are then considered using the global variable for number of trips starting with a cold engine.

Emissions Benefit Calculations

The total emission estimates are multiplied by the global variable for cost per ton for the four types of pollutants considered.   The emission benefits are brought back to a present value amount using the global variable discount rate.

Revenue Transfer

Fare revenues are considered a revenue transfer (neither a benefit nor a disbenefit).   The estimated change in revenue is assumed to have uniform growth between periods and is brought back to net present value using the global variable discount rate.

Safety Calculations

The number of accidents is calculating from the change in vehicle miles traveled and the global variables for accident rates for the different accident types. The resulting values are calculated for the initial and forecast years. Uniform growth between periods is assumed and no discount rate is applied.

Safety Benefit Calculations

The safety benefit calculation uses the global variables for the societal cost per accident for the different accident types. The befits value assumes a uniform growth rate and is brought back to present value using the global variable discount rate.

SPASM Projects

The calculations for the SPASM projects are identical to the STEAM calculations except that SPASM uses and peak and non-peak analysis periods so that additional calculations must be performed to convert the results into daily impacts before annual results can be obtained.

Project reports

The transit project reports are structured similarly for the two types of projects with the first section showing the user inputs. The second section shows the results to key calculations such as travel timesavings in minutes and in dollars, benefit-cost ratios, etc. The third section shows

the results to the Outcome Objective calculations. The final section shows the Global Variables that were used in the calculations and notes if values differed from the default values.

References

1. Cambridge Systematics. "*Measuring and Valuing Transit Benefits and Disbenefits.*" Transit Cooperative Research Program Report 20. 1998.
2. Cambridge Systematics. "*Economic Impact Analysis of Transit Investments: Guidebook for Practitioners.*" Transit Cooperative Research Program Report 35. 1998.
3. Washington Department of Transportation. "Public Transportation and Intercity Rail Passenger Plan for Washington State: 1997 – 2016." Olympia, WA. December 1996. http://www.wsdot.wa.gov/pubtran/pubandstudy/library/PTIRP.pdf

Chapter 12 – Transportation Demand Management

Rather than existing as a single mode, Transportation Demand Management (TDM) is a policy tool used to promote strategies aimed toward enabling more efficient use of existing roadway capacity through eliminating or combining trips, and encouraging use of high occupancy modes (such as transit or carpool) or non-motorized modes (such as bicycling or walking). In contrast to traditional capacity-oriented approaches, TDM consists of a variety of strategies that target demand on a transportation system, either through incentives for alternative mode users, or disincentives for single-occupant-vehicle (SOV) users.

TDM subprograms are included in the Public Transportation Program, Program V in the Current Law Budget. The *Statewide Commute Trip Reduction* subprogram is responsible for administering the statewide Commute Trip Reduction (CTR) programs that support the CTR law. The goals of the CTR Program are to reduce traffic congestion, air pollution and fuel consumption through employer-based programs that reduce the number of drive-alone commute trips. The Washington State Legislature passed the CTR Law in 1993, incorporating it into the Washington Clean Air Act as RCW 70.94.521-551.

The *TDM Core Program* is another subprogram of Public Transportation. The role of the TDM Core Program includes provision of funding to create trip reduction incentives for jurisdictions, employers and entrepreneurs; provision of start-up funds for trip reduction programs implemented as part of metropolitan transportation plans; support of a land use-transportation center; and trip reduction education services.

Inventory of Projects

Based upon the major TDM efforts that are happening at the State level, two major categories of TDM projects were identified:

1. **Areawide TDM Programs:** Consists of efforts to support TDM in a defined metropolitan area, often in collaboration with other public and private agencies. The WSDOT Northwest Washington Division Planning and Policy Office (PPO) has spearheaded major efforts in this category that include a TDM element for the *Translake Washington Project*, and a TDM Program for the *I-405 Corridor Study*.

2. **Commute Trip Reduction Support:** This includes programs that would fit into the first subprogram category described in the previous section.

Inventory of Current Analysis Methods

Analysis of the effectiveness TDM projects is the target of much on-going research, within and outside of the United States. The methods that were developed for MICA are based upon analysis methods that are already utilized at WSDOT, which are in turn consistent with the state of the practice in applied TDM effectiveness evaluation.

Part of the administration of the Commute Trip Reduction Program by WSDOT requires that its effectiveness be evaluated on a regular basis. To accomplish this, employees at participating worksites have been asked to complete a survey that indicates their travel habits with and without the CTR incentives in place. The results of the survey were than analyzed to estimate the reduction in the number of trips and VMT that has resulted from the requirements of CTR.

For Areawide TDM Programs, the PPO utilizes ranges of reduction factors that have been derived from a variety of TDM effectiveness studies. The reduction factors are applied to

projected vehicle-miles-traveled (VMT) for the project area to estimate the reduction in VMT that will result from the implementation of specific types of strategies.

Identification of Analysis Gaps

The CTR effectiveness evaluation is based upon a survey of actual travel behavior, which is by far the most reliable approach. The main issue that must be addressed is how to ask the questions so that the effectiveness of CTR can be isolated from other factors that can affect commute behavior. Undoubtedly, each new survey will be refined based upon lessons learned in the previous surveys. The approach developed for MICA utilizes past effectiveness data to estimate future effectiveness. Thus, the most recent and reliable estimates of past effectiveness are best utilized in these procedures.

For Areawide TDM, the current analysis procedures do not have gaps so much as they lack detailed information. This is simply a function of the general lack of detail in available TDM effectiveness data. However, information in this area will continue to improve, and the continuing efforts should be made to update analysis methods as it does. Ideally, rather applying general effectiveness estimates based upon a strategy definition (i.e. vanpool equals a 1 percent reduction in VMT), effectiveness should be sensitive to the level of improvement in time, cost, comfort, and convenience factors that are affected through the implementation of TDM.

Project Worksheets and Inputs

The TDM mode is accessed by clicking on the "TDM" button on the starting screen of the Project Module. Figure 12-1 shows the opening screen for the TDM mode. From this screen, the analyst can access existing TDM projects in the MICA database, or add a new TDM project (note, the general procedures for Project Level Analysis are described in *Chapter 3 – Operation of the MICA Program*).
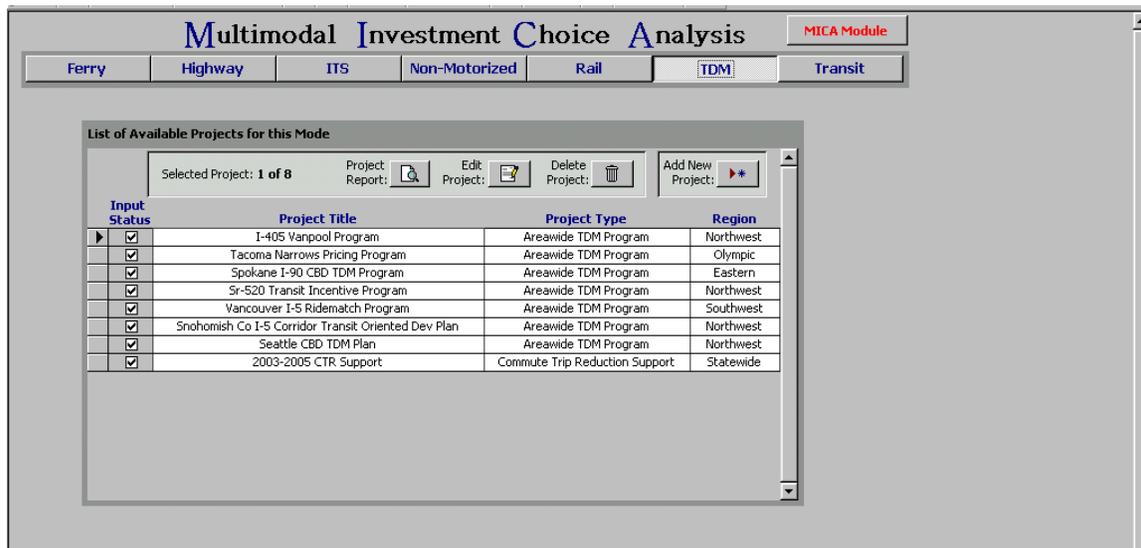
Figure 12-1: Opening Screen for TDM Projects

Project Information

The Project Information input form, as shown in Figure 12-2, is the first of four screens to be displayed when a TDM project is edited or added to the database. The user can navigate through the four screens by clicking on the tab headings. Additionally, the three buttons at the top of the screen can be selected at any time to delete the current project from the database, preview the project report, or save the current data and exit back to the opening screen for TDM projects.

Figure 12-2: Transportation Demand Management Project Information Form

The Project Information component contains the following descriptive information:

Project Title: Descriptive title of the project

Project Type: Identifier that is unique to the project

Project Type: Specific type of project, selected from a pull down list. For the TDM mode, the two project types are:

- **Areawide TDM**

- **Commute Trip Reduction Support**

Biennium: Biennium in which the project is to be considered for funding

Region: WSDOT Region in which the project is located. A pull down menu provides eight region options:

- **Eastern**

- **North Central**

- **Northwest**

- **Olympic**

- **South Central**

- **Southwest**

- **Statewide** should be selected if the project is located in multiple regions

- **Ferry** applies only to ferry projects, and is unlikely to be selected for TDM projects

Legislative District: State Legislative District in which the project is located, if the project fits completely or primarily in one district.

Air Quality: Air quality designation for the project area, as identified by the Clean Air Act. A pull down menu provides the options of:

- **Attainment Area**

- **Non-Attainment Area**

- **Maintenance Area**

- **Unclassifiable**

as described in *Chapter 2 – Project Measures*.

WTP Corridor: Identifies whether or not the project is located within an identified WTP Corridor (as described in the Project Measures chapter of this report). Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

Highway System Plan: Identifies whether or not the project is included in the Highway System Plan. Clicking on the box will check it, indicating **Yes**. If the box is not checked, **No** is indicated.

Project Specific Benefit Worksheets

The second input screen is the benefit input form, which is unique to the each of the two types of projects analyzed within the TDM mode. The following sections describe the input screens and the data required for each project type.

Areawide TDM

The benefit input form for Areawide TDM projects is shown in Figure 12-3. The user inputs data under five categories:

- Area description

- Project Description

- Analysis Period for Project

- Forecast Data

- Effectiveness Data

Figure 12-3: Benefit Input Screen for Areawide TDM Projects

The Benefit Input component for Areawide TDM projects calls for the following information:

Area Description

      Description of Area: User can input up to twp lines of description of the area in which the project is located.

Project Description

      Description of Project: User can input up to four lines of description of project features.

Analysis Period

      Initial Analysis Year: Beginning year of analysis

      Forecast Analysis Year: Ending year of analysis period

Forecast Data

Average workday VMT: Commute-related daily VMT without TDM in place

- Initial year and forecast year, base case

Effectiveness Data

TDM Strategy   *Reduction Factor***

Vanpooling:
- No = 0
- Yes = .01

Public Information:
- No = 0
- Yes = 0.005

Employer Based:
- No = 0
- Yes = 0.0075

Land Use as TDM:
- No = 0
- Yes = 0.0175

TDM Facilities / Services:
- No = 0
- Yes = 0.004

Other:
- None = 0
- Low level = 0.005
- Medium level = 0.0075
- High level = 0.01

Specify "Other":   Specify what "other" TDM element is

Pricing:
- None = 0
- Low level = 0.06
- Medium level = 0.08
- High level = 0.10

**Source of Reduction Factors (OUM 2001)

Generated Revenue: Annual revenue generated from pricing-initial yr

- Initial year and Forecast Year

Commute Trip Reduction Support

The benefit input form for Commute Trip Reduction Support projects is shown in Figure 12-4. The user inputs data under four categories:

- Project Description

- Analysis Period

- Forecast Data

- Effectiveness Data

Figure 12-4: Benefit Input Screen for Commute Trip Reduction Support Projects

The Benefit Input component for Commute Trip Reduction Support projects calls for the following information:

Project Description

Description of Project: User can input up to four lines of description of project features.

Analysis Period

Initial Analysis Year: Beginning year of analysis

Forecast Analysis Year: Ending year of analysis period

Forecast Data

Avg workday VMT: Commute-related daily VMT

- Initial year and forecast year, base case

Avg workday Veh Trips: Commute-related daily Vehicle Trips

- Initial year and forecast year, base case

Transit fare: Average daily fare for transit users

Effectiveness Data

Time Period for Effectiveness Data

Initial Evaluation Year: Beginning year of evaluation period

Final Evaluation Year: Ending year of evaluation period

Baseline Commute Trip Data

Baseline VMT: Baseline commute VMT for entire evaluation period (without CTR)

Baseline Person Trips: Baseline number of commute person trips (all modes) for entire evaluation period (without CTR)

Baseline Vehicle Trips: Baseline number of commute vehicle trips (all modes) for entire evaluation period (without CTR)

Changes in Commute Behavior, Due to CTR

Change in Daily VMT: Change in daily VMT (due to CTR, from CTR evaluation)

- drive-alone
- bicycles
- transit
- carpool
- vanpool

Change in Person Trips: Change total person trips (due to CTR, from CTR evaluation)

- drive-alone
- bicycles
- transit

- carpool

- telework

- vanpool

- pedestrian

Change in Vehicle Trips: Change total vehicle trips (due to CTR, from CTR evaluation)

- drive-alone

- bicycles

- transit

- carpool

- vanpool

Outcome Objectives

The third page contains the Outcome Objectives inputs, which consist of the standard questions described in Chapter 3 of this report. While all of the input questions remain the same regardless of mode or project type, some calculations do vary with project type.

Cost Information

The final page of the input form contains the cost data. Cost inputs and calculations are identical for all project types and are described in Chapter 3 of this report. The capital project costs entered should reflect the total project cost including engineering and project management. Costs should not be adjusted for inflation since the calculations assume a current dollar approach.

Operation and maintenance costs are relative to the "no build" case and should reflect the difference in operation and maintenance costs with and without the project. In cases where the improvement will lower the annual cost of operation and maintenance, a negative cost value will result.

Benefit-Cost Calculations

The two types of TDM project calculations have different approaches to estimating reduction in automobile VMT. However, once the VMT reduction is estimated, the calculation of project benefits is the same for both project types.

User Benefits

Reduction in Automobile VMT

Areawide TDM: The reduction in automobile VMT is based on reduction factors that are associated with specific TDM strategies. The user must input the estimated demand that will be targeted by the TDM program. The user identifies the strategies that are included in the program. Each strategy has an associated reduction factor based upon prior WSDOT research (OUM 2001). The reduction in VMT is calculated by multiplying the reduction factor by the total targeted VMT. If multiple strategies are selected, a composite reduction factor is calculated by adding the individual reductions. The additive approach assumes independence between the effects of the

different strategies. Independence is an optimistic assumption. However, in this context it is reasonable since the estimated reductions are conservative and very small in magnitude.

CTR Support: The reduction in automobile VMT is based upon previous effectiveness data. The user is asked to input data that indicates the effectiveness of CTR for a previous but clearly defined period of time. The demand targeted by the next period of CTR is also input. The reduction in VMT is estimated based upon the assumption that the effectiveness of the previous efforts will be proportionate to the effectiveness of the proposed efforts.

Operating Cost Savings to Travelers

The operating cost savings to travelers is a function of the estimated reduction in automobile VMT. Average operating costs per mile are included in MICA as a global variable. The actual value per mile will depend on whether "Direct Cost" or "Full Cost" is selected by the user (as described in *Chapter 2 – Project Measures*). The operating cost savings is calculated by multiplying the reduction in auto VMT by the operating cost per mile. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual operating cost savings to travelers. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of operating cost benefits over the analysis period.

User Transfer – New Transit Fares

New transit passengers that are estimated to generate from a TDM project will have to pay fares for their trips that they would not have paid otherwise. This represents an out-of-pocket cost to the passengers. However, it also provides a benefit to the agency by generating revenue, so it is considered to be a transfer of money. User transfer based upon transit fares is calculated, but it is not counted as either a cost or a benefit.

Travel Time Benefits

In its current form, the TDM benefit calculations do not include travel time savings. Theoretically, removal of vehicle trips by TDM should provide some relief on congestion, which in turn can mean improved travel times. However, since shifts occur throughout a network, and make up a very small proportion of total trips, impact of TDM on travel times is assumed to be negligible.

Air Quality Calculations

Pollutants Removed Due to Diversion from SOV to HOV and Non-Motorized

Once a reduction in VMT due to TDM is calculated, savings in air pollution can also be calculated. Reduction in emissions is calculated for Carbon Monoxide (CO), Nitrous Dioxide (NOx), and Particulate Matter – 10 microns (PM_{10}). Future work will add Volatile Carbons (VOC) rates, and may change PM_{10} to $PM_{2.5}$ to reflect new Federal regulations. The emissions reductions are calculated by multiplying the estimated reduction in VMT by the respective emission rates of automobiles per mile (as described in *Chapter 2 – Project Measures*). Emissions rates for automobiles shifted to non-motorized are based upon an assumed in-city vehicle running speed of 35 miles per hour. The initial reductions are calculated in grams, and then converted into English tons.

The emissions rates are based on a warmed up vehicle engine. To capture the effects of cold-starts, the number of eliminated vehicle trips is multiplied by the cold start percentage (global variable that estimates the percentage of total trips that begin with a cold start). The numbers of reduced cold starts are multiplied by the average emissions (in grams) per cold start, to estimate

the total reduction. Total emissions reductions are obtained by adding the change in emissions due to cold start reductions to the change in emissions due to VMT reduction.

Cold starts are considered for "CTR Support", since calculations for this project type include an estimated reduction in automobile trips. "Areawide TDM" does not

Air Quality Benefit Calculations

The air quality benefit is calculated by multiplying the estimated tonnage of each pollutant removed (CO, NOx, PM_{10}, and in the future, VOC) by its respective societal value. The societal costs of the tons of pollutants are global variables, and are described in *Chapter 2 – Project Measures*. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so do the annual air quality benefits. Thus, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of air quality benefits over the analysis period.

Safety Calculations

Accident savings for both types of TDM projects is based upon the estimated reduction in automobile VMT.

Accident Reduction Calculations

Once a savings in VMT is calculated, vehicle accident savings based upon that reduction can also be estimated. The accident rate per mile traveled for each mode is a global variable, and is described in *Chapter 2 – Project Measures*. In this case, the accident rate per mile is applied to the change in miles traveled. Reduction is calculated for fatality, injury (assumed to be in the "evident injury category), and property damage only accident types. Since reduction in VMT is assumed to change at a uniform rate from the initial year to the final year of the forecast period, so are the accidents based upon VMT.

A successful TDM project will result in a decrease in automobile travel, and an increase in alternative modes such as transit. If transit VMT were to increase, a corresponding increase in transit accidents should be calculated. However, these procedures assume that any increase in the number of transit trips is accommodated on existing transit capacity. In other words, it fills up buses that are already running, so no additional transit VMT results. This is a logical assumption for the scale of most TDM projects. If TDM were to bring about a significant increase in transit service, the project should be analyzed under the "Transit" mode category of MICA.

Safety Benefit Calculations

The safety benefit is calculated by multiplying the estimated reduction in each type of accident by its respective societal value. The societal cost of accidents are global variables, and are described in *Chapter 2 – Project Measures*. Since safety benefits are assumed to change at a uniform rate from the initial year to the final year of the analysis period, Equation 2-3 (Present Value of a Uniform Gradient Series) is used to calculate the net present value of safety benefits.

Total Project Benefit Calculations

Total project benefits are calculated by adding together the net present values of all user operating benefits, travel time benefits, safety benefits, and environmental benefits that have been calculated for the project.

Total Project Cost Calculations

The total project costs are calculated by adding together the net present value of the capital costs and operation and maintenance costs, and subtracting the net present value of the terminal cost, as described in *Chapter 2 – Project Measures*. Both the total project cost and the cost to WSDOT are calculated.

Benefit-Cost Calculations

The Benefit-Cost Ratio is calculated by dividing the net present value of total project benefits by the net present value of total project costs. In cases where WSDOT has partnered with another public or private agency, a WSDOT Benefit-Cost ratio is calculated by dividing the net present value of WSDOT project benefits by the net present value of total project costs. If WSDOT is paying the entire cost of the project, these two values will be equal.

Project Reports

The report for any specific project is brought up by clicking on the "Project Report" button on the input form when that project is active. Project level reports are structured similarly for all project types, with four major sections:

1. **Project Information** – summarizes all descriptive data for the project.

2. **Input Summary** – summarizes all of the inputs for benefit and cost calculation.

3. **Calculation Results** – summarizes all of the results of the benefit calculations, cost calculations, cost efficiency measures, and outcome objective scores.

4. **Global Assumptions** – summarizes all of the global variables that were used in the calculations, as well as their respective values.

All data must be completely input for the full project report to be displayed. However, if the inputs are incomplete, the inputs that have been completed will still be summarized if the project report is brought up. When it is created, the project report displays on-screen. The report can then be printed out from the on-screen display if a hard copy is desired.

References

Lovrich, Nicholas, David Nice, and Edward Weber. Benefits and Costs Associated with the WSDOT CTR Program. Prepared for the Washington State Department of Transportation. Report No. WA-RD 468.1. Washington State Transportation Research Center. Seattle, WA (June 1999).

Office of Urban Mobility (OUM), Washington State Department of Transportation. I-405 Corridor Program Benefit-Cost Study: Final Working Paper. (June 2001).

Office of Urban Mobility (OUM), Washington State Department of Transportation. I-405 Transportation Demand Management (TDM) Program: Working Paper. (March 2001).

Washington State Department of Transportation (WSDOT) and Sound Transit. Draft TDM Element of Trans-Lake Multimodal Alternatives. Slide Presentation. (April 2001).

Washington State Department of Transportation (WSDOT). 2001-2003 Budget and Six-Year Plan. Adopted by the Washington State Transportation Commission. (August 16, 2000).

Washington State Department of Transportation (WSDOT). Commute Trip Reduction Home Page. http://www.wsdot.wa.gov/pubtran/tripreduction/ (accessed April 2001).

Chapter 13 – Project Selection Optimization

Optimization Introduction

In an effort to be as fair as possible to all parties and to ensure that budgets are utilized responsibly and efficiently, most agencies utilize some method of assessing potential transportation projects. Many different methods for project assessment and prioritization are in use today and the complexity of these methods vary greatly from purely judgment-based or political decisions to highly involved mathematical decision modeling. There is no universally accepted method for selecting the "best" projects and the literature on this subject is extensive. However, as the question of government accountability becomes more of an issue, agencies are finding that it is desirable to have a formalized method for project selection. By clearly documenting the decision-making process, the methods become more transparent to the public and a higher level of confidence in the decisions may be possible.

An added dimension to this complex issue is one of making decisions across transportation modes. Much of the earlier work in project prioritization methods has focused on selecting projects from a within a single transportation mode such as highway or transit. Analyzing across modal divisions is more complicated because of consistency issues with impact analysis methods for the different modes. Inherently, a highway project has different attributes than a transit project. In addition to analytical obstacles, there are also considerable institutional barriers. Many transportation agencies are structured around modal divisions. These divisions are historically given individual budgets allocations so that competition rarely exists across modal boundaries. Considerable institutional changes both structurally and mentally may be necessary for these modal barriers to be removed. In addition, legal barriers may also exist. For example tax revenue, such as money collected from gas taxes, may have legal requirements that restrict its allocation to a particular mode such as highways.

This optimization research effort is just a portion of the larger MICA research project. The goal of this work is to better understand the goal programming aspect of MICA to properly formulate the optimization process such that the priorities of the decision-maker are best modeled. The following tasks will be performed to achieve this goal:

- Perform a state of practice review to determine what methods are being utilized by other agencies and to learn from previous research efforts,

- Review the issues with goal programming formulations and modify the MICA formulation to address these issues,

- Perform a sensitivity and uncertainty analysis of the resulting formulation to determine if programming result are stable, and

- Modify the formulation to provide additional functionality so that the goal programming process can be more responsive to the types of questions the decision-makers are asking.

This chapter provides the background and proposed methodology for investigating the possibility of utilizing a computer-based tool, MICA, to aid decision makers in selecting transportation projects. To link the planning and programming processes, MICA is being designed with the ability to look at timeframes ranging from 2 to 20 years.

Goal Programming

Multi Criteria Decision Making

Multi Criteria Decision Making (MCDM) is a subset of the field of MS/OR – Management Science (MS) and Operations Research (OR). MCDM problems are a set of problems where the decision maker (DM) has the following: a set of criteria (project attributes), a set of decision variables (fund or not fund), and a process for comparing alternatives (scenario development). (Hwang 1979) MCDM problems can be further classified as Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). Multiple Attribute Decision Making problems have a predetermined number of alternatives with each alternative having an associated achievement level and the decisions are made by comparing attributes for each alternative. On the other hand, in Multiple Objective Decision Making, the number of alternatives is not predetermined and the object of the model is to determine the 'best' alternative. In the case of MICA the number of potential alternatives is not predetermined and the object of the optimization method is to select the 'best' set of projects that meet the user's priorities. Therefore the optimization technique to be utilized should come from the MODM set of methods.

The next step in selecting a MODM method, as defined by Hwang and Masud's classification system, is the "stage at which preference information is needed". The four categories are: (1) no articulation of preference information, (2) a priori articulation of preference information, (3) progressive articulation of preference information, and (4) a posteriori articulation of preference information. For the MICA case, the user defines the preference information through the selection of priority categories and their associated weights prior to the selection of projects so the MODM method falls under the second category.

For "a priori articulation" the major classes of methods include utility functions, bounded objective method, lexicographic method, goal programming, and goal attainment. Of these methods the last three are very similar and can be viewed as modifications of the same method. As discussed in the literature review section, linear and goal programming are thought to be methods well suited for project selection problems.

Goal Programming vs. Linear Programming

The main difference between goal programming and linear programming is that goal programming allows for multiple objectives to be considered simultaneously while linear programming focuses on one objective. (Ignizio 1985) For example a common linear programming objective function would be to minimize cost subject to constraints particular to the system such as production limitations and product demand. Goal programs on the other hand can be formulated to consider multiple objectives such as to minimize cost *and* maximize employment.

Another important difference between goal and linear programming is the concept of soft and rigid constraints. In a linear program the constraints are treated as rigid. That is, if production must be greater than a given value then even a small negative deviation from that value is not allowed. Goal programming allows for both rigid and soft constraints. Soft constraints utilize deviation variables (typically both positive and negative deviation variables) that measure the difference between the desired value (or goal) and the predicted model value.

Romero's (1991) textbook contains a discussion on the equivalence of GP and LP formulations. Romero states that this will only occur if the GP model has been poorly formulated where one goal has been set too optimistically (outside the feasible region) while all other goals have been set too pessimistically (well within the feasible region). The solution to this goal program could be equivalent to a linear program that optimizes the optimistically set goal area. Romero also states that equivalency between GP and LP has lead to some researchers believing that GP is not a useful tool when in fact its flexibility of utilizing multiple objectives makes it highly useful. The fact

that in certain cases the two may be equivalent is not a detriment to the field of goal programming.

Problem Statement

Each project in the database has impact estimation including project Benefit-Cost Ratio, WSDOT Benefit-Cost Ratio, Travel Time Savings, User Cost Savings, Environmental Savings, Safety Savings, and 17 Outcome Objective Scores.

All projects that have been completely entered into the database can be considered for funding. The user can screen the potential project list by selecting projects by mode(s) and/or by region(s). Additional screening can occur by setting minimum threshold values of the project level impacts. The remaining projects in the list are passed to the goal programming module of the program.

In addition to project lists, constraints are passed to the goal programming module. This includes both rigid and flexible constraints as discussed earlier. The rigid constraint is the budget level, which can be further constrained by regional and modal restrictions. A future feature of the program may include the ability to consider combined projects (a composite of two or more individual projects). Additional rigid constraints would then be necessary to prevent a project from being funded multiple times. The flexible constraints include the 23 goal priority areas and their associated weights as defined by the user.

An added complexity to the goal programming problem is the ability to program projects for multiple bienniums. The original MICA formulation handles only single biennium time-frames but modified formulations include the capability of looking at multiple time-periods. .

Model Formulation

The are three commonly used types of goal programming formulations. (Romero 1991) The following is a brief definition of these three types:

1. Weighted Goal Programming (WGP) –All goals are considered at the same time in a composite objective function. Goals are weighted according to the relative importance to the DM. WGP is sometimes referred to as archimedean or minsum GP.

2. Lexicographic goal programming (LGP) – Uses pre-emptive priorities, where the higher priorities are satisfied before lower priorities are even considered. LGP is also referred to as non-archimedean or preemptive GP.

3. MINMAX Goal Programming (MINMAX) – Maximum of the goal deviations is minimized. Computationally a linear programming problem. MINMAX is also referred to as Chebyshev GP.

Another categorization of goal programming formulations concerns the variables within the model. Using this taxonomy goal programs are typically linear, integer, and non-linear. The algorithms for solving these three types of goal programming problems are different and are summarized below (Schniederjans 1995):

- Linear GP - Solved typically using Simplex based algorithm. Most common type of GP problem. (Note that some researchers refer to linear goal programming as LGP, not to confused with lexicographic goal programming which also used the acronym LGP.)

- Integer – Problems where the decision variables are limited to integer values. Integer problems are typically solved using a Branch-and-Bound solution

method. A subset of integer problems is Zero-One problems where the decision variables are further limited to the integers zero and one. Zero-One solution methodology usually based on an enumeration or Branch and Bound methods.

- Nonlinear Problems where the decision variables are non-linear. There are four major methods for solving nonlinear goal programming problems: simplex based nonlinear GP (also called approximation programming), direct search based nonlinear GP, gradient search based nonlinear GP, and interactive approaches to nonlinear GP.

These goal programming types can be viewed on a continuum with linear goal programming being the most computationally straightforward and nonlinear problems being the most computationally intensive.

This section contains the formulation of the problem statement from the previous section. The MICA problem type fits a class of optimization problems known as capital budgeting problems, program selection or multidimensional knapsack problems. (Ignizio 1972) These types of problems involve the decision-maker choosing a subset of projects from a larger, finite set while maximizing the objectives and meeting the budget constraints.

Typical model formulations for capital budgeting problems include a zero-one integer model and a continuous linear model. The integer model does not allow for partial funding of projects, while the continuous model does. Allowing for the partial funding of projects ensures that the entire budget amount is utilized since the final project selected will be funded until the budget constraint is meet. The attributes associated with the partially funded project are multiplied by the percentage of the project funded. In addition to fully utilizing the budget, the continuous formulation has the added advantage of notably faster computing times due to the reduced complexity of the a solution algorithm. This becomes more important as the number of projects being considered increases.

Prior to showing the model formulation it is useful to define the formulation terminology. The terminology varies greatly in the literature so any other common names will be listed in parentheses after each item along with the mathematical term used in formulas. The terminology definition will also refer to the MICA problem statement in the previous section.

- Decision Variables – (X_i, Unknowns, Solution Variables, Structural Variables) A set of unknowns the problem is determining. For MICA this is the FUND variable. These are the variables that the solution algorithm has control to change.

- Technical Coefficients – (b_{ij}, Project Attributes) Values that describe the contribution of each project with respect to the particular goal area. For MICA these are the values of the project measures for the 23 areas.

- Goal Levels – (B_j, Right-Hand Side Values, Target Value, Aspiration Level) Values that the decision-maker seeks to achieve. For MICA these are the target levels for the 23 project measure areas.

- Deviation Variables – (d_{Bj}) Values that allow for negative and positive differences from the achieved and aspired goal levels. Deviation variables are the crucial difference between linear and goal programming.

As the model formulation in Equation 13-1 shows, only the negative deviations are considered in the objective function. This is not always the case in goal programming but is so when positive

deviations are considered desirable and should not be penalized. The goal levels are calculated as the highest possible score in the 23 categories by adding up the project attributes for each project being considered and setting the goal level as this sum.

Equation 13-1: Goal Programming Formulation

$$\text{Min Z} = \sum_{j=1}^{m} W_{Bj} d_{Bj}^{-}$$ Minimize Weighted Negative Deviations

Subject to:

$$\sum_{i=1}^{n} b_{ij} X_i + d_{Bj}^{-} - d_{Bj}^{+} = B_j \quad \text{Soft Contraints for } j \text{ Goal Areas, for } j = 1,...,m$$

$$\sum_{i=1}^{n} c_i X_i \leq C \qquad\qquad \text{Rigid Budget Constraint}$$

$$d_{Bj}^{-}, d_{Bj}^{+} \geq 0 \qquad\qquad \text{Non-negativity Constraint, for } j = 1,...,m$$

$$0 \leq X_i \leq 1 \qquad\qquad \text{Bounding of Decision Variable, for } i = 1,...,n$$

Where:

W_{Bj} = Weighting Factor for outcome area j

d_{Bj}^{-} = Negative deviation variable for outcome area j

d_{Bj}^{+} = Positive deviation variable for outcome area j

b_{ij} = Outcome area score for project i and criteria j

X_i = Decision variable. X_i = 1 is project *i* is accepted, 0 otherwise

B_j = Goal level for outcome area j

n = Number of projects being considered

m =Number of goal areas being considered

c_i = Cost of project i

C = Budget level

Schniederjans (1984) discusses in his linear programming textbook the underlying assumptions and limitations to linear GP models. These limitations include:

- Additivity and Linearity

- Divisibility

- Finiteness

- Data Certainty and static time period.

Additivity assumes that the technical coefficients on the right hand side of the goal constraints proportional to the to achieved goal level. For the capital budgeting program this means that regardless of the overall goal level reached, the contribution by the particular project will not change.

Divisibility is an issue with continuous models where projects may be partially funded.   The divisibility assumption says that the proportion of a partially funded project to the goal achievement level is equal to the proportion that project is funded. For example, a project that was funded 50% would contribute half of its project attribute values towards the overall goal level in the problem solution.

The finiteness limitation says that the decision and deviation variables must be finite in nature and that the formulation must ensure this.   The last assumption states that the technical coefficients, goal levels, and weights are known with certainty and are static over time.

Model Formulation Issues

As discussed in the literature review section there are several issues relating to the use of weighting methods and goal level scaling factors. Schniederjans (1995) outlines possible model formulation problems in his goal programming textbook. These problems include:

- Dominance

- Inferiority

- Efficiency

- Naïve Relative Weighting

- Incommensurability

- Naïve Prioritization

- Redundancy

- Setting goal levels

Each of these issues will be discussed in greater detail in the following sections along with possible formulation remedies to these issues. The next chapter looks at the application of these remedies using the MICA model and sample projects.

Dominance, Inferiority, and Efficiency

The issues of dominance, inferiority, and efficiency are all closely related and will be discussed together. A dominated solution exists when an alternate, feasible solution exists that will not worsen the objective function of one goal but will improve the objective function of another goal. If no alternate solution exists that will not improve one goal without worsening another then the existing solution is considered nondominated. Inferiority is another term referring to the same situation. A dominated solution is sometimes referred to as an inferior solution and a non-dominated solution as noninferior. These terms are often used interchangeably.

Dominance and inferiority are directly related to the term efficiency.   By efficiency, goal programming literature is referring to Pareto efficiency referenced frequently in economic literature. The idea of Pareto efficiency was developed by an Italian economist Vilfredo Pareto and exists where the situation (or utility) of one person cannot be improved without the worsening of another person's situation. A GP solution is said to be Pareto efficient when no other feasible

solution can achieve the same or better for one goal without worsening other goals. Relating back to the terms of dominance and inferiority, an efficient solution is one that is nondominated and noninferior.

The possibility for GP solutions that are nonefficient is a major criticism of goal programming. Originally goal programming was developed to find solutions that satisfy criteria and was not formulated to guarantee efficiency. An example of an nonefficient solution in GP is illustrated in Figure 13-1. The case shown is a simple goal program with two goal areas with the target goal levels set at b_1 and b_2. The constraints for the problem set the feasible region as the area defined by OABCD. If the goal program's intent is to minimize the deviations from the target levels then the solution would be Z. If positive deviation from the is not considered (and in the case of MICA desired) then the solution would be nonefficient since any point within the ZBC triangle would dominate point Z.
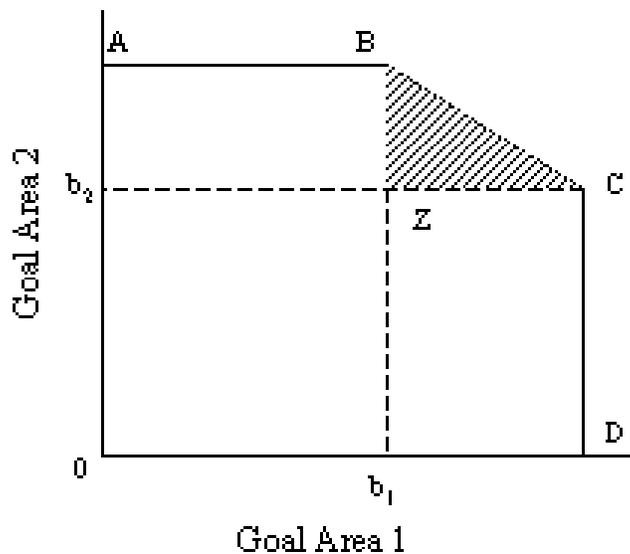
Figure 13-1: Nonefficient GP Solutions

Considerable debate exists in GP literature on the topic of efficiency and researchers have found that GP can be easily adapted to generate efficient solutions. Two methods for doing this are sequential GP solutions and the setting of unachievable goal levels. Romero (1991) outlines a general process for solving GP models that will avoid inferior solutions using the sequential method. The process described in his textbook is reproduced in Figure 13-2 and described below.

The first step for sequential GP solutions is to solve the original GP problem (e.g. minimize negative deviations from the goal levels). If no alternative feasible solutions exist then the solution is efficient. If alternative feasible solutions exist then the analyst must decide whether one efficient solution is all that is needed or whether the entire set of efficient solutions should be found. If only one efficient solution is required, that is that the DM has no preference among different efficient solutions, then a second goal programming model is solved where the opposite deviation variables are maximized.
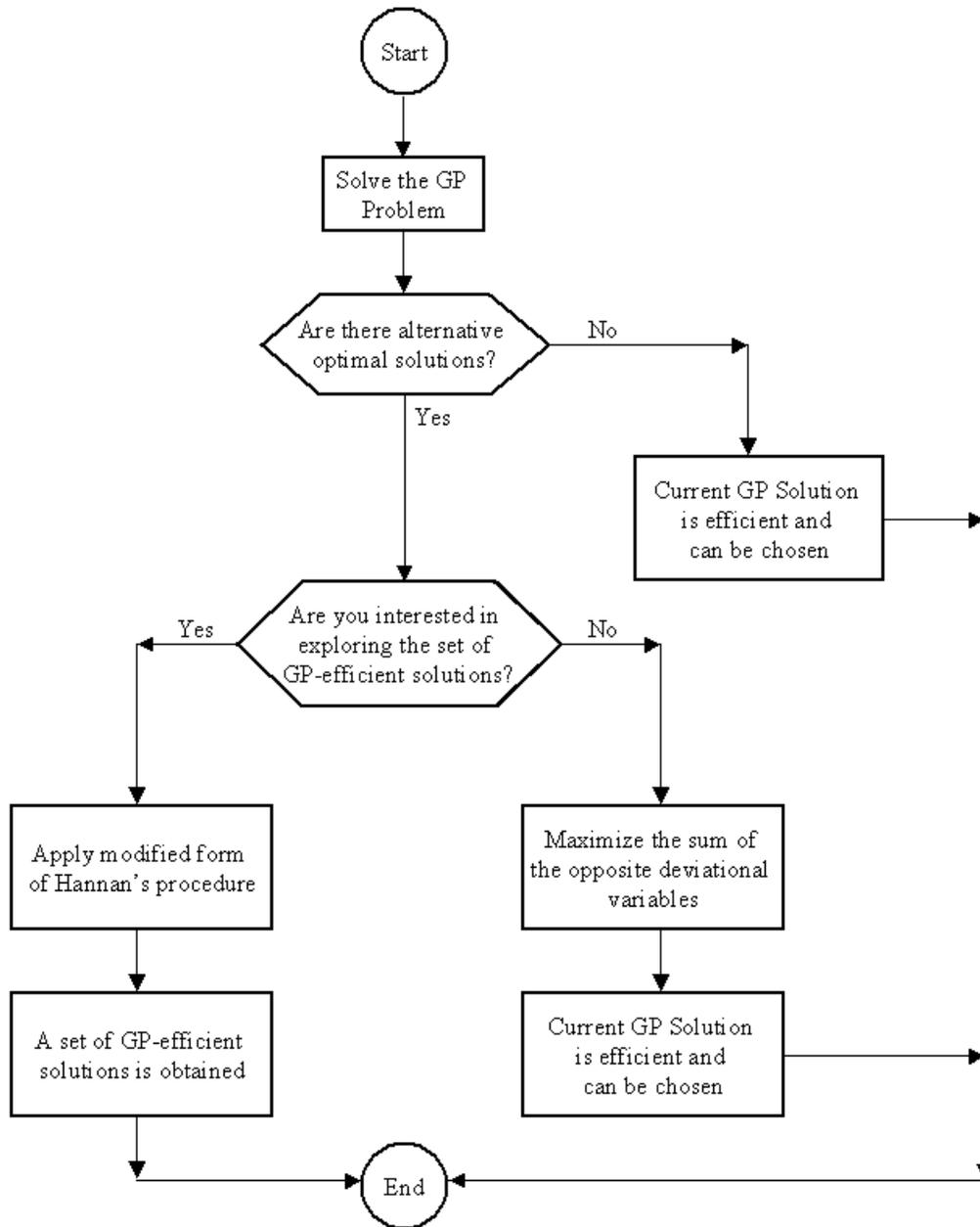
Source: Handbook of Critical Issues in Goal Programming (Romero 1991)

Figure 13-2: Procedure for Efficient GP Solutions

Using the MICA problem formulation as an example, the first step would be to minimize the negative goal deviations followed by a formulation that held the negative deviation objective function and then maximize the positive goal deviations. This is directly related to the concept of Pareto efficiency, the goal levels in the initial solution are not allowed to worsen while the algorithm searches for solutions that will increase the goal levels in other areas. The solution obtained by the second problem is an efficient solution. Referring to Figure 13-1, the first solution minimizing the negative deviations could result in the solution shown at point Z. Maximizing positive deviations would then result in the solution shown at point C.

If the DM is interested in all efficient solutions (note in many cases there may only be one) then the problem must be converted into multiple objective problem (MOP) where the objectives are sequentially set to each of the goal areas.

Multiobjective programming looks for a set of efficient (or Pareto optimal) solutions as opposed to goal programming which finds only one solution. Since the simultaneous optimization of all the objectives is impossible multiobjective programming looks for a feasible solution such that no other feasible solution could yield improvement in one objective area without sacrificing the level of another objective. Therefore it can be said that the purpose of multiobjective programming is to find efficient solutions.

Equation 13-2: Multiobjective Programming Equation

$$Eff\ f\left(x\right)=[f_1\left(x\right),f_2(x),...,f_q\left(x\right)]$$
$$subject\ to:x\in F$$

Where *Eff* is the search for the efficient solutions. There are several ways to find or approximate the efficient set. The most common are the weighting method, the constraint method, and the multicriterion simplex method. The weighting method combines all the objectives into a single objective. The constraint method involves one of the objectives and then placing the others as constraints. The efficient set is then generated through the parameterization of the right-hand side of the coefficients representing the objectives. The Multicriterion simplex finds all the extreme efficient points by moving from one extreme efficient point to an adjacent efficient point.

Another method of ensuring an efficient solution is to set the goal targets to impossible (optimistic) levels. If the goal levels are unachievable then the goal programming algorithm looks for the solution that comes the closest. By never reaching the satisfying goal levels the solution is guaranteed to be efficient since it will be on the outer bounds of feasibility and only infeasible solutions would allow the objective function to increase further. Referring again to Figure 13-1 this would mean setting the goal levels of b_1 and b_2 outside the area defined by ABCD.

The MICA program sets the goal levels as the weighted sum of all the projects attributes for each project in the database. For example, using the 91 sample projects the benefit-cost ratio goal level would be the sum of the BCR values for those 91 projects multiplied by the BCR weighting value assigned for each scenario. This results high goal targets under most reasonable budget scenarios where there are more projects under consideration then money to fund them. Even with unlimited available budget the goal levels are unsurpassable, ensuring an efficient solution. In terms of the sequential optimization discussed earlier it would not be necessary to do the second step of maximizing positive deviations from the goal level since it is unrealistic for the goal level to be surpassed. This guarantees that MICA will find an efficient solution.

The issue of multiple efficient solutions is still of concern even with large goal targets. It is possible for several projects to have similar project attribute/cost ratios that would result in the program's indifference between one project and another for satisfying the goal objectives. In the sequential GP formulation shown in Figure 13-2, this is the step where the DM is asked whether any efficient solution will suffice or whether the set of solutions is necessary. When selecting transportation projects for funding it would be useful information to the DM to know whether particular projects were "interchangeable" in the funding list. While it is unlikely for projects to be completely interchangeable the DM would most likely want to know which projects are "close" to efficiency, particularly since the timing of projects, environmental conditions, political climate, regional equity, etc. may speed up, slow down, or completely remove projects from the funding picture at any point in the process. This issue will be addressed in Chapter 9 on project scoring.

Naïve Relative Weighting

Naïve relative weighting refers to the situation where the weights used in the formulation do not accurately reflect the decision maker's preferences or do not accurately model the decision-making environment. There is considerable research into this area and has resulted in weighting methods such as the analytic hierarchy process (AHP), conjoint analysis, and Delphi Method techniques.

The analytic hierarchy process is a method for dividing the elements of a decision-making problem or process into the hierarchies that comprise it (Saaty 1988). This in turn allows the DM to prioritize potential alternative solutions. The typical product of the AHP is a decision tree. AHP uses both qualitative and quantitative data and breaks the complex decision down into a series of one to one comparisons. These comparisons are then synthesized into results. While this process could conceivably be used for the entire transportation project selection process the number of pair wise comparisons for each project in each goal area would make the process infeasible to apply. On the other hand AHP may be a useful technique for providing decision makers with the relative weights among goal areas, particularly for different funding scenarios.

Conjoint analysis is a methodology used extensively in product marketing that analyzes the consumer's preferences in products or services, usually based on rank ordering of the products attributes, to determine the part-wise utilities of these attributes. (Louviere 1988) Conjoint analysis techniques often use factorial design methods to quantify these part-wise utilities.

The Delphi method is a technique where a group of informed decision makers make a group decision based on several rounds of group discussions and anonymous responses, typically two to three rounds are used. The decision makers are encouraged to modify their responses after each round according to the influences of the previous discussions. At the end of all rounds averaging the final rounds responses sets the relative weights. The Delphi method was used in September of 1993 to determine the criteria weights used by WSDOT for the highway mobility prioritization process, the predecessor of MICA. (Reed 1997)

For the MICA program, WSDOT could utilize the same process using either the full list of 23 criteria or a shorter list that was created from the priorities set by the visioning process for the particular biennium where the decision-makers set the broad transportation goals for the next two years. If the full list of 23 criteria were to be considered one of the other methods such as the Analytic Hierarchy Process or conjoint analysis might be more appropriate since it would be difficult for decision-makers to assign points to all areas at one time.

Incommensurability

When modeling different goal areas the issue of incommensurability becomes important to avoid problems with "apples and oranges" comparisons. Differences not only in measurement units but also in scales of magnitude between areas result in unseen biases in problems solutions. Relative weighting can be used to offset magnitude differences. More common is the use of scaling methods that normalize the goal constraints. This type of normalizing equates the magnitude of the goal constraints without violating the proportionality of the model.

One final method is to keep the priorities within the model separate. This is related to the lexicographic goal programming (LGP) model discussed in the previous chapter. In a LGP the priorities are handled sequentially so that no comparisons are made across goal areas, removing the "apples and oranges" comparisons. A LGP formulation is only applicable when strict priorities between goal areas can be made. LGP is also commonly referred to as preemptive goal programming.

Naïve Prioritization and Redundancy

Naïve prioritization is a well-documented problem with lexicographic goal programming (LGP) models and is related to the issue of redundancy. When LGP models have too many priority levels often times the lower levels do not play a role in the decision making process if a higher priority constrains the result to only one optimal solution. This is called naïve prioritization since the decision maker believes that the decision reflects all levels of priorities when in fact it may only be reflecting the upper levels. (Romero 1991) Redundancy refers to these unused priority levels in LGP. In the case of weighted goal programming, redundancy refers to goal constraints that are not considered in a given solution for the model. (Schniederjans 1995)

Some researchers argue that to avoid this problem a maximum of 5 to 6 priority areas should be used (Ignizio 1985) while others say that redundancy is only an issue of computational efficiency and that as long as the priorities are reflecting the decision-making environment they should be included and that redundancy does not necessary reflect poor modeling practice. (Schniederjans 1995)

Goal Levels and Weighting

Some researchers view the setting of goal levels as arbitrary. (Schniederjans 1995) In order to ensure that this is not the case a sensitivity analysis of the goal level should be performed. Another method to address this issue is to set impossibly high target values. This also forces nondominated solutions as discussed in a previous section.

When the goal areas within the GP model are not measured in the same units, the resulting aggregated deviation variables are meaningless. That is, a unit of negative deviation in the benefit-cost ratio goal area is not equivalent to a unit of negative deviation in the Preservation outcome objective area. An additional issue in goal program formulations is where the targets associated with each goal areas have different values. This can lead to model bias towards the goal areas with higher target areas. In effect, these higher goal levels are inadvertently given additional weighting. To avoid these problems, a normalizing or scale method should be applied to the goals within the model formulation. (Romero 1991)

The simplest method for normalizing the GP goals is to convert them from absolute values into percentages. This is done by multiplying each goal constraint by 100 and then dividing the equation by the right hand side coefficient (goal target value). This results in each of the goal target being set to 100. Each project attribute becomes the percentage of that project to the overall goal target level. Equation 13-3 shows how each goal area equation is transformed using percentile goal normalizing.

Equation 13-3: Percentile Goal Normalizing

$$\sum_{i=1}^{n} b_{ij} X_i + d_{Bj}^- - d_{Bj}^+ = B_j$$

Becomes:

$$\sum_{i=1}^{n} (\frac{b_{ij}}{B_j} \times 100) X_i + d_{Bj}^{'-} - d_{Bj}^{'+} = 100$$

Where:

$$d_{Bj}^{'+} = \frac{d_{Bj}^+}{B_j} \times 100$$

$$d_{Bj}^{'-} = \frac{d_{Bj}^-}{B_j} \times 100$$

One benefit of this system is that the resulting modified model becomes more intuitive than the previous model by utilizing non-dimensional percentages. In addition, the biasness towards goals with high target levels is removed.

Another issue with respect to goal levels found in the literature is that the numeric value of the deviation variables does not correspond to the actual geometric distance causing a possible bias in the problem solution. Hannan (1985) states "to make the scales between goals equal then the deviations of equal geometric distances must yield equal numerical values." This issue is not achieved by the percentile goal normalizing method. In order to obtain a true correspondence between the numeric values and the geometric differences the goals must be adjusted using the Euclidean norms.

The technical coefficients (i.e. project attributes) and each goal area are divided by the Euclidean norms. The resulting relationship between the goal equations is shown in Equation 13-4. It should be noted that the Euclidean normalization procedure described here is related to the vector normalization process utilized by the TOPSIS algorithm that is currently used by the Mobility Priority Programming Process (the highway mode predecessor to the MICA project). The TOPSIS algorithm uses the same normalization formula shown in Equation 13-4 but goes on to derive a priority index score for each project that is related to the distance of the project do an ideal best and an ideal worst project.

Equation 13-4: Euclidean Goal Normalizing

$$\sum_{i=1}^{n} b_{ij} X_i + d_{Bj}^{-} - d_{Bj}^{+} = B_j$$

Becomes:

$$\sum_{i=1}^{n} \left(\frac{b_{ij}}{\left(\sum_{j=1}^{n} b_{ij}^2 \right)^{1/2}} \right) X_i + d_{Bj}^{"-} - d_{Bj}^{"+} = \frac{B_j}{\left(\sum_{j=1}^{n} b_{ij}^2 \right)^{1/2}}$$

Where:

$$d_{Bj}^{"+} = \frac{d_{Bj}^{+}}{\left(\sum_{j=1}^{n} b_{ij}^2 \right)^{1/2}}$$

$$d_{Bj}^{"-} = \frac{d_{Bj}^{-}}{\left(\sum_{j=1}^{n} b_{ij}^2 \right)^{1/2}}$$

Euclidean goal normalizing lessens the biasness towards the achievement of goals with large target values. Two potential problems with Euclidean normalizing are that the objective function loses its intuitiveness and secondly that Euclidean normalizing doesn't consider the target value. This second problem is more of an issue when the difference between the target value and the technical coefficients is high. In this situation the issue of biasness again arises.

The next section looks at these normalizing systems and applies them to the MICA sample projects in order to determine the best method for the MICA program to use.

Goal Programming Analysis

The following chapter tests different goal programming formulations to address the issues described in the previous chapter. 91sample projects and five test scenarios were used to test these formulations.

Setting of Weights

A discussion on setting of weights is included in this chapter because it is an important element of the goal programming but due to the structure of the MICA program the weighting factors cannot be controlled by the model formulation. Instead of discussing what the most appropriate weighting factors would be this section will describe the three weighting methods that are used by the program.

The MICA program allows the user to choose one of three methods for selecting optimization criteria; single criterion, multi criteria, and weighted multi criteria. The single criterion option allows the user to select one of the 23 project attribute areas from a pull down list. The program then sets the weighting factor of this criterion to 1 and all other weights to zero. For multi criteria the user selects as many criteria from the list as desired. The program then sets the weights of the selected criteria according to Equation 13-5 where each area is given equal weighting. The third option is weighted multi criteria where the user enters a value from 0 to 1 for each criteria to be considered. The program then checks to ensure that the sum of all weights equals 1. If this check is satisfied the program then sets the weights of the criteria to the values entered by the user.

Equation 13-5: Equal Weighting Equation

$$\sum_{j=1}^{m} W_{Bj} = 1$$

Where:

W_{Bj} = 1/m

m = the number of attribute areas considered in the calculation (1 to 23)

Equation 13-6: User-Input Weighting

For User-Input Weighting

$$\sum_{j=1}^{m} W_{Bj} = 1$$

Where:

W_{Bj} = user-input value (decimal value from 0 to 1)

m = the number of attribute area considered in the calculation (1 to 23)

Goal Normalization

The attributes for the sample projects were normalized using both the percentile goal normalizing (Equation 13-3) and the Euclidean goal normalizing (Equation 13-4) procedures discussed in the

previous section. The percentile normalization the project attribute for each criterion is converted into a percentile contribution of each project towards the overall goal level. Since the goal level is set as the sum of all project attributes, it follows that the sum of the percentile normalized attributes would be one hundred, representing 100%. In goal programming it is not always the case that the goal is set at the maximum possible level. For instance, it is possible to set the goal level at 50% of the possible target value, resulting in a sum of the percentile normalized attributes would be two hundred (200%).

It was found that the two normalization processes are returning slightly different results. This would be expected given that the scaling differences between the two procedures would be more exaggerated in these scenarios due to the magnitude of the included monetary attributes. Looking at the attribute values for the sample projects it appears that the percentile normalization has biasness for the larger scaled monetary attributes.

Setting Goal Levels

The current goal programming formulation sets the goal levels for each *j*th goal area as the sum of the project attributes over *n* projects for that goal criteria as shown in Equation 13-7. For this case the scaling factor is set to 1.

Equation 13-7: Goal Levels

$$B_j = S_j \times \sum_{i=1}^{n} b_{ij}$$

Where:

$B_j = $ Goal Target for the *j*th goal area

$S_j = $ Goal Scaling Factor for the *j*th goal area

$b_{ij} = $ Project Attribute for the *i*th project

As discussed in the previous section, there are advantages to using a scale factor of 1 in ensuring that the solution found is nondominated, noninferior, and efficient.

There are situations where the decision maker may be more interested in meeting minimum achievement levels in particular goal areas instead of maximizing these areas. An example of this would be if the decision maker were more interested in having a diverse selection of projects than maximizing a few particular areas. A way to achieve this diverse project mix would be to set the goal targets lower and at the same time have more criteria included in the optimization. The goal levels become increasingly feasible to reach as the scaling factor is reduced. Note that as the goal targets enter the feasible regions efficient solutions become a concern and sequential optimization becomes necessary (see discussion on efficiency in previous chapter). Also note that the goal achievement levels for the sample projects appear to be quite high even given a budget level of 25% of the sum of all projects. This suggests that efficiency issues should be addressed for any scaling factor less then one.

The use of goal scaling factors is not the only method for obtaining a diverse project mix. Another more straightforward way would be to adjust the criteria weighting, most likely setting the weights more equally across more categories, to achieve this balance. This method might be more transparent to the decision-maker then the use of goal scaling factors.

Resulting Model

Based on the issues discussed in previous sections and analyzed in this chapter the MICA goal programming model was modified to include:

- Euclidean normalizing of goals and project attributes

- Setting of goal levels outside of the feasible region

- No use of goal scaling factors

In addition, it is recommended that WSDOT utilize some formal method of setting the criteria weights such as the Delphi method.

Sensitivity and Uncertainty Analysis

A full sensitivity analysis and parametric programming of the weighting factors and scaling factors and problem constraints needs to be analyzed to ensure that the final optimization formulation is creating the project sets that best reflect the priorities set by the decision maker. In general there are the following types of changes to consider in a sensitivity analysis:

1. Changes to the weighting factors
2. Changes in the goal level
3. Changes in the technical coefficients
4. Changes in constraints
5. Addition of a new project
6. Addition of a new constraint (either rigid or soft)

Sensitivity analysis in goal programming is linked to the concept of what is termed the dual problem. Note that duality in goal programming is a direct extension of applications in linear programming and that basic linear programming theory holds for goal programming. (Dauer 1997) When solving the original (termed the primal) problem, linear and linear goal programming solutions also solve a secondary related problem called the dual problem. The relationship between the primal and dual problems is shown in Equation 13-8. For every primal constraint there is one dual decision variable and for every primal decision variable there is one dual constraint.

The solution of the dual problem results provides information on the sensitivity of the primal problem. The Y_{ij} vector in the dual problem represents the shadow prices for the decision variable vector X_i. The shadow price value is also referred to as the dual value.

Equation 13-8: Relationship between Primal and Dual Problems

Primal Problem

$$\text{Minimize:} \ = \sum_{j=1}^{m} W_{Bj} d_{Bj}^{-}$$

Subject To:

$$\sum_{i=1}^{n} b_{ij} X_i + d_{Bj}^{-} - d_{Bj}^{+} = B_j \quad \text{Soft Constraints for j Goal Areas}$$

$$\sum_{i=1}^{n} c_i X_i \leq C \quad \text{Rigid Budget Constraint}$$

Non-negativity Constraint

$$d_{Bj}^{-}, d_{Bj}^{+} \geq 0$$

$$0 \leq X_i \leq 1 \quad \text{Bounding of Decision Variable}$$

Dual Problem

$$\text{Maximize:} = \sum_{j=1}^{m} B_j Y_j + (C \times Y_C)$$

Subject To:

$$\sum_{j=1}^{m} b_{ij} Y_j + c_i Y_C \leq 0 \qquad \text{Constraint for } i \text{ projects}$$

$$Y_j \leq W_{Bj} \qquad\qquad \text{Constraint for } j \text{ Goal Areas}$$

Sensitivity of capital budgeting problems is a unique subset of programming in which relatively little literature exists. Traditional sensitivity analysis offers some insight into the problems but is not entirely helpful. The sensitivity of these types of problems differs from traditional problems in the discrete nature of the project selection problem. The question is not how much of a given resource to use but whether a particular project should be part of the optimal funded project list or not. This is further complicated by the fact that the answer is dependent upon the particular project list.   Many of these complications are mitigated by the introduction of project scoring criteria, which will be discussed in-depth in the next chapter. Regardless, the following sections will look at the sensitivity of the sample project list to illustrate the types of sensitivity questions that can be analyzed. The following sections ask the question, how much can a variable change such that the optimal project list remains the same.

The project attribute values are based on benefit-cost methodology unique to each project type as well as the responses to qualitative questions for the outcome objective scores.   Because there is a level of uncertainty or variability associated with these values an uncertainty analysis becomes a useful tool to see how sensitive the project rankings are to random error.

Uncertainty Analysis Methodology

An uncertainty simulation was performed by adding different levels of random error to every project's attribute values. The random error levels tested were 2.5%, 5%, 10%, 15%, 20%, and 25%. A multiplicative error structure was used by centering a normal distribution at one with the standard deviation (σ) equal to the percent error. This allowed for random error to both increase and decrease the original attribute value. A random error value was multiplied by each attribute value for every project.

The project scores were recalculated using these new values and the projects optimized by ranking the project score to cost ratio. Ten trials were performed at each error level so that the resulting solution set contained 10 project ranking lists in addition to the original ranking for each error level.

Difference Measure

To measure the differences in the simulated project rankings the mean absolute difference (MAD) value was determined for each error level simulation. The MAD value is determined by finding the absolute difference between the project ranking in each trial and the original ranking and then averaging that value over all trials. This is done for each project and then the average over all projects is calculated to determine the overall average or MAD value.

Equation 13-9: Mean Absolute Difference

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

Where:

x = rank of project

$i = \{1...N\}$ N number of projects

$j = \{1...M\}$ M number of trials

k = Base Rank

The calculated mean absolute differences for each error level are shown in Table 13-1. As expected the absolute difference increases as the applied percent random error increases. The values shown represent the average change in project rank for that error level. For example, at a 10% error level project rankings changed an average of 0.90 or slightly less then one change in rank.

Table 13-1: Mean Absolute Difference Results

Percent Random Error	Mean Absolute Difference
2.5%	0.24
5%	0.50
10%	0.90
15%	1.44
20%	1.76
25%	2.29

Another useful way to analyze the results of the uncertainty analysis is to look at a histogram of the frequency of average rank change. Histograms for the uncertainty analysis on Scenario B are shown in Figure 13-3 and Figure 13-4. Figure 13-3 shows a histogram of all six random error levels. Figure 13-4 shows only the lowest (2.5%), mid-range (10%), and highest (25%) error levels to better illustrate the trends. The Average Rank Change along the x-axis is the average change for each project averaged over the 10 trials. The y-axis is the number of projects out of the 91 total projects with an average rank change in that range.

Similar to the MAD calculations the histograms also illustrate that the rank changes become more pronounced as the error level increases. An interesting point illustrated by the histograms though is the magnitude of the average change. For the 2.5% error level no projects had an average rank change greater then 1.5. In fact if you look at the results you will see that no individual trial had a rank change greater then 2.

At the upper random error levels more rank change is more apparent yet, as the histograms show, the rank change is typically less then 4. Very little change in the funded versus unfunded project lists would be expected with this amount of rank change. This leads to the conclusion that the results are reasonably stable over expected error ranges.

Frequency of Average Rank Change
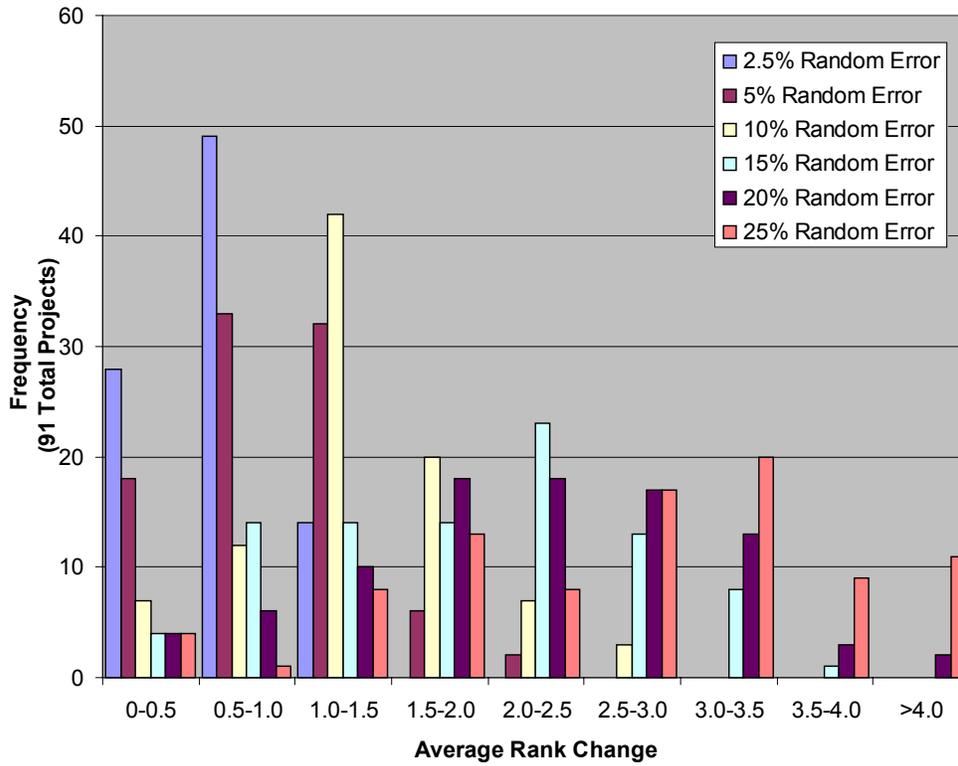
Figure 13-3: Frequency of Average Rank Change (All Random Error Levels)

Frequency of Average Rank Change
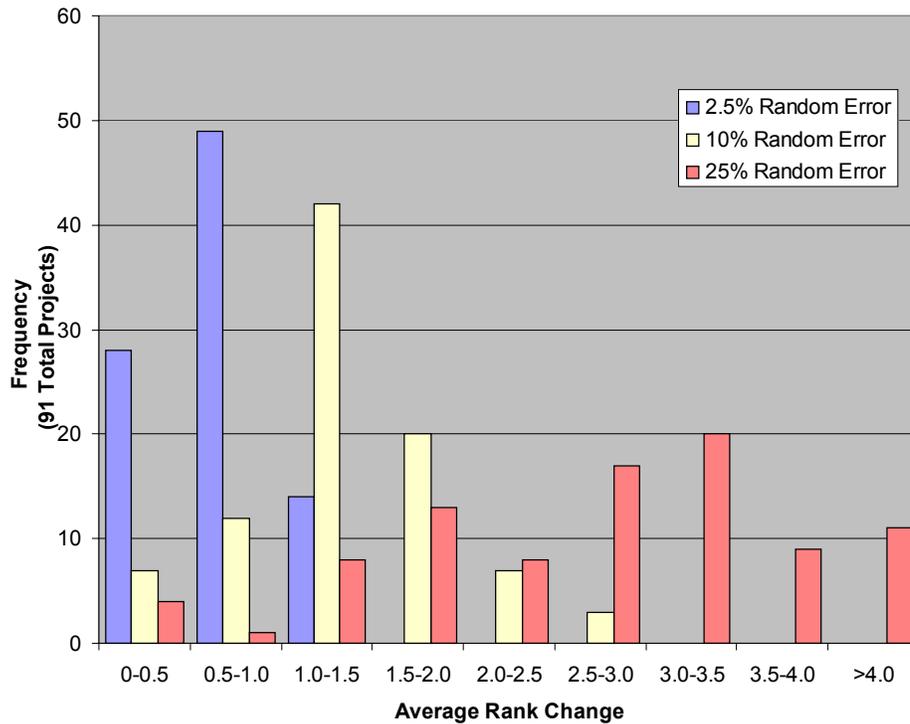
Figure 13-4:Frequency of Average Rank Change (2.5%, 10%, and 25% Error Levels)

Project Scoring

Project Scores

The optimization process does not create a rank order or priority listing of the projects it selects for funding. Projects are either funded, unfunded, or partially funded with no identification being made of how the close unfunded projects are to being selected. Since analysts may be familiar with this feature in other project selection methodologies it may be helpful to add a scoring feature to the MICA optimization process. The downfall to adding a scoring feature may be that this value may be overused by the decision-maker resulting in non-optimal solutions being utilized.

The complexity to assigning project scores within the MICA program comes from the flexibility of the program's weighting system. Any scoring index would have to account for criteria weighting but since this can change with each scenario the scoring index itself would change. A compromise to this is a scoring system that allows for the relative "worth" of projects to be judged in a rank ordered project list that is specific to the criteria and weighting system selected. That is, the scoring system could not be universal and still allow for decision-maker flexibility in scenario planning.

The scoring system must utilize normalized attribute values since the same scaling and magnitude problems discussed in an earlier chapter would be a concern for a scoring system as it was for model formulation. As shown earlier, the Euclidean normalized system removed more of the potential scaling bias and therefore should be used in the scoring system. Also, it is logical that using the goal programming calculations in the scoring system also would be desirable and computationally efficient.

The existing mobility project programming process used by WSDOT utilizes a ranking procedure called TOPSIS-8, which is a modification of a methodology developed by Hwang and Yoon. (Hwang 1995) As mentioned in a previous section, this process is closely related to the Euclidean normalizing of project attributes. TOPSIS takes the Euclidean normalizing process a step further by comparing the Euclidean distances to an ideal positive solution. This generates a priority index for each project. While TOPSIS allows for rank ordering of projects it does not optimize based on tradeoffs between ranking and project costs. (Niemeier 1995)

The discussion on project scoring will be continued in a later section but first it is useful to look at the relationship between optimization and project ranking.

Optimization vs. Ranking

Zabinsky and Niemeier (1998) discuss a relationship between rank ordering and formal optimization of projects that is applicable to the MICA program. The paper finds the theorem shown in Equation 13-10 to be true.

Equation 13-10: Optimization by Rank Ordering

$$\text{Maximize } Z = \sum_{j=1}^{n} m_j x_j$$

Subject to:

$$\sum_{j=1}^{n} c_j x_j \leq b$$

$$0 \leq x_j \leq 1 \quad \text{for } j = 1, \ldots, n$$

with $c_j > 0$ for all j, can be found by rank ordering on m_j/c_j and funding in that order until the budget is completely allocated. Formally, the optimal solution x^* is:

$$x_i^* = \begin{cases} 1 & \text{if } i = 1,...,k \\[2ex] \dfrac{b - \sum\limits_{i=1}^{k} c_i}{c_{k+1}} & \text{if } i = k+1 \\[2ex] 0 & \text{if } i = k+2,...,n \end{cases}$$

where the subscript $i = 1,…,n$ represents the rank order, so that

$$\frac{m_1}{c_1} \geq \frac{m_2}{c_2} \geq ... \geq \frac{m_n}{c_n}$$

and k is the largest integer such that

$$\sum_{i=1}^{k} c_i \leq b$$

To apply this theorem to the MICA problem we must first generate a project score (m_j) for each project for maximizing (this is equivalent to minimizing the deviations from the maximum possible score). The score is the weighted, normalized attributes for each project. For example, a project in Scenario B would have a score equal to one-half the normalized benefit-cost ratio plus one-half the normalized safety benefit value. Using the theorem above, the optimization of these projects could be obtained by rank ordering the projects by this score over the project cost ratio.

If we fund the projects in rank order until the budget constraint is reached we achieve the same funded project list as formally optimizing Scenario B. It is not proposed that this rank ordering method be utilized for optimization within MICA since it becomes cumbersome when additional constraints are added (this is discussed further in a later chapter on adding functionality). This index would allow the decision-maker to see which projects are close in value to optimal projects providing more information to the decision-making process. In addition, since transportation projects are often delayed for political and environmental reasons it allows for informed substitutions to be made to the project list if a funded project should be removed from funding consideration for outside reasons. As mentioned earlier the project index values are entirely dependent on the criteria used and the weights assigned by the analyst. These values are only valid within the scenario that generated them.

More on Project Scoring

Revisiting the idea of project scoring it appears that the project to score ratios would be a useful scoring index since it allows for the rank ordering of projects without losing the efficiency of formal optimization. This scoring system does not solve the issue of transferability of scores across different scenarios but does allow for the decision maker to make decisions about the relative "worth" of one project compared to another.

Since the scaling of the project index scores may not be desirable, a useful transformation would be to convert the scores to a percentile ratio with the highest scoring project being assigned a

score of 100 and all other project scores being based on the ratio of their score to the highest score.

Adding Functionality

To increase the MICA program's usefulness as a tool for decision makers additional functionality can be added to the optimization formulation that would expand the types of analysis the program could perform. The following functions in particular would be useful to the process:

- Analysis of Multiple Time Periods

- Minimum Budget Levels by Region and/or by Mode

Multiple Time Periods

A critical function for the program is the ability to analyze projects over multiple time periods, in particular for the 6, 10, and 20-year time periods. The original formulation only analyzes an individual biennium. To perform this function the user will input budget forecasts for the time periods to be analyzed and the program will create project lists for each 2-year period within this time frame. The usefulness of this formulation is the ability for projects to be constrained by a "fund no later then" or a "fund no sooner then" dates. This ability to constrain projects by time limitations is where the revised formulation differs from the original.

The optimization of projects over a longer time period brings up an earlier issue of the stability of the project attributes over time. This was discussed in the chapter on the original formulation as being one of the key assumptions to goal programming. The reason this assumption remains valid is that the MICA program utilizes a "constant dollar" approach to monetary calculations and the discount rate that is applied to all monetary calculations reflects this approach. A constant dollar approach expresses costs and benefits in terms of price levels found at a particular date – typically the first biennium that is being considered for funding. The constant dollar approach removes inflation from the monetary calculations, which allows for the assumption that prices remain static over time to remain valid.

Equation 13-11: Formulation for Multiple Time Periods

$$\text{Min Z} = \sum_{j=1}^{m} W_{Bj} d_{Bjt}^{-} \quad \text{Minimize the Weighted Negative Deviations for Time period } t$$

Subject to:

$$\sum_{i=1}^{n} b_{ij} P_{it} X_i + d_{Bjt}^{-} - d_{Bjt}^{+} = B_j \quad \text{Soft Constraints for } j \text{ Goal Areas and } t \text{ Time Periods, for } j=1,..,m \text{ and } t=1,...,T$$

$$\sum_{i=1}^{n} c_i X_{it} \leq C_t \qquad \text{Rigid Budget Constraint for Time Period } t, \text{ for } t=1,...,T$$

$$d_{Bjt}^{-}, d_{Bjt}^{+} \geq 0 \qquad \text{Non-negativity Constraint, for } j=1,..,m \text{ and } t=1,...,T$$

$$0 \leq X_{it} \leq 1 \qquad \text{Bounding of Decision Variable, for } i=1,...,n$$

Where:

W_{Bj} = Weighting Factor for outcome area j

d^-_{Bjt} = Negative deviation variable for outcome area j and time period t

d^+_{Bjt} = Positive deviation variable for outcome area j and time period t

b_{ijt} = Outcome area score for project i and criteria j and time period t

X_{it} = Decision variable for project i and time period t. X_{it} = 1 is project i is accepted, 0 otherwise

B_j = Goal level for outcome area j (constant over all t)

n = Number of projects being considered

m = Number of goal areas

T = Number of 2-year time periods

c_i = Cost of project I (constant over all t)

C_t = Budget level for time period t

Equation 13-11 is a reformulation of Equation 13-1 with the addition of multiple time periods t. The key to Equation 13-11 is to loop the optimization process for T time periods. At each time period the list on feasible projects becomes those projects that have not previously been funded. In addition, a new binary variable P_{it} is introduced. The definition of P_{it} is shown in Equation 13-12. This binary variable is set within the visual basic code of the MICA program and then transferred to the optimization process.

Equation 13-12: Time Period Feasibility Variable

For Project $i \; = \; 1,...,n$ and Time Period $t = 1,...,m$

$$P_{it} = \begin{cases} 0 & \text{For t=1,..., } F^+_i - 1 \\ 1 & \text{For t=} F^+_i,...,F^-_i \\ 0 & \text{For t=} F^-_i + 1,...,m \end{cases}$$

Where:

$F^+_i \; = \;$ "Fund no sooner" Biennium for Project i

$F^-_i \; = \;$ "Fund no later" Biennium for Project i

$P_{it} \; = \;$ Time Period Feasibility Variable

(1 if Project i is feasible for funding in time period t, 0 otherwise)

Figure 13-5 illustrates the optimization process for multiple time periods. The projects selected for funding consideration are passed to the optimization process along with the number of time periods being analyzed and budget levels for each time period. The time period feasibility variables are set for each project based on Equation 13-12. The technical coefficients for each project are multiplied by the feasibility variable and the goal levels set accordingly. The funded

project list for the first budget period is then determined through the same optimization process as the original formulation.   The unfunded projects are then re-optimized using the feasibility variables, technical coefficients, budget level, etc. for the next budget period. This continues until the final budget period has been analyzed. At the end of the process, the funded project lists for each time period are reported along with the remaining unfunded list.
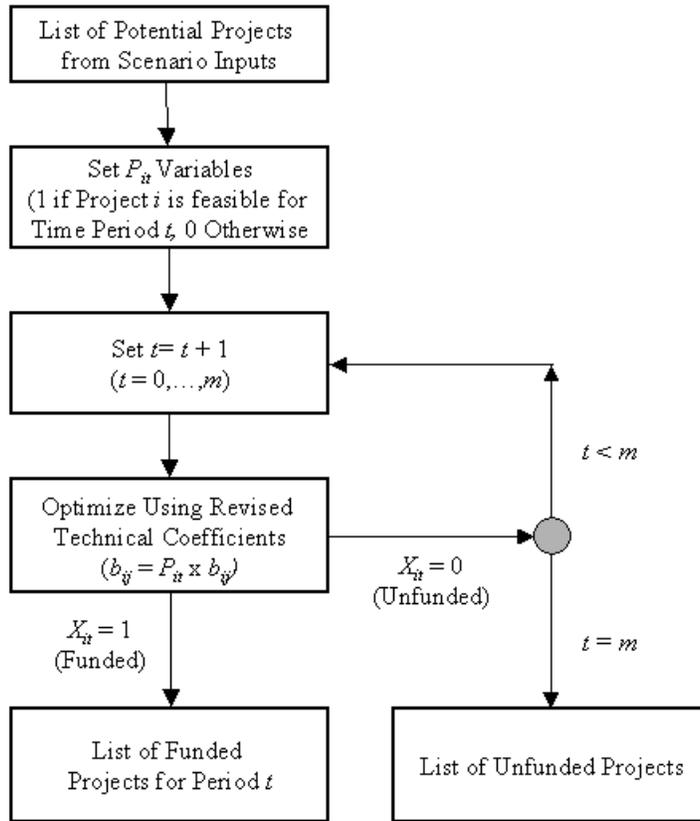
Figure 13-5: Multiple Time Period Optimization Process

The underlying assumption to this formulation is that the superior projects should be funded as soon as possible. Essentially this assumption is in itself an additional constraint. To further "loosen" the solution, the optimization could be solved simultaneously instead of sequentially by time period. To do this, each project has a decision variable and associated coefficients for each time period. One additional constraint would be needed that limits the funding variables such that the project could only be funded once. Note that instead of an objective function for each time period there is only one for the entire problem.

Equation 13-13: Revised Multiple Time Period Formulation

$$\text{Min } Z = \sum_{t=1}^{T}\sum_{j=1}^{m} W_{Bj} d_{Bjt}^{-}$$

Minimize Weighted Negative Deviations for

Time Period t

Subject to:

$$\sum_{i=1}^{n} b_{ij} P_{it} X_{it} + d_{Bjt}^{-} - d_{Bjt}^{+} = B_{j}$$

Soft Constraints for j Goal Areas and

Rigid Budget Constraint for Time Period t

$$\sum_{i=1}^{n} c_{i} X_{it} \le C_{t}$$

$$\sum_{t=1}^{l} X_{it} \le 1$$

Decision Variable Constraint

Non-negativity Constraint

$$d_{Bjt}^{-}, d_{Bjt}^{+} \ge 0$$

$$0 \le X_{it} \le 1$$

Bounding of Decision Variable

An important issue when considering multiple time periods is the stability of the project attributes over time. The calculations assume a "constant dollar" economic approach to remove inflation from the calculations. Even considering this many of the benefit calculations may not be stable over time since they rely heavily on traffic projections and congestion levels at the time of analysis. This is of particular concern when considering projects on a 20-year horizon.

A way around this would be do multiple project analysis with varying assumptions on traffic levels for the benefit calculations and then use the time period feasibility variable to limit the analysis results to the valid time period. For example a highway project could be analyzed three times, once for current levels, again for 10-year traffic projections, and finally for 20-year projections. The time period feasibility variable could be set to limit the first analysis to years 1-6, the second to years 7-16, and the third to years 17-20. Future versions of MICA will allow for combining of projects and multiple configurations of the same projects. When this function is added the user will be able to link the three projects together such that only one of the three would be allowed for Funding.

Minimum Budget Levels
Another useful function is the ability to set minimum budget levels. In the original formulation, budgets are either allocated by lump sum or by particular regions or modes. A separate optimization is run for each region where a budget amount has been allocated. The same is true for budget by mode. An additional function would be to set *minimum* budget levels by region and/or mode. This feature would allow for more efficient use of available money since all funding above the minimum amounts would "compete" across regional and modal boundaries.   The analyst has the option of choosing between a set and a minimum budget allocation by modes and/or regions. This feature is particularly useful if a portion of the budget resource had spending limitations, such as tax restrictions for highway projects.

Each project has a Region and Mode variable assigned to it. There are eight possible Regions (the six WSDOT regions plus a Ferry and a Statewide region) and seven possible modes (Ferry, Highway, ITS, Non-Motorized, Rail, TDM, and Transit). To optimize using minimum funding requirements, 15 additional budget constraints are necessary.   The budget constraints programming is formulated as shown in Equation 13-14. As this equation shows, the funded projects are tallied by mode and by region. These totals are then constrained to meet the minimum levels entered by the program user.

Equation 13-14: Minimum Budget Constraints

$$\sum_{i=1}^{n} c_i X_i \geq C_{\text{Region } l} \quad \text{for } i \in \text{ Region } l$$

$$\sum_{i=1}^{n} c_i X_i \geq C_{\text{Mode } m} \quad \text{for } i \in \text{ Region } m$$

Findings

As discussed in the literature review chapter, the structure of MICA has been tailored to address the institutional and analytical obstacles that have previously hindered advancements in this area of research. The development of the MICA program is a critical step in removing these obstacles. Hopefully, one of the primary results of this research effort is to move the discussion away from "how this type of analysis tool is not possible" to "how can this analysis tool be improved".

The application and formulation of the goal programming portion of the program has shown to be suitable and well structured to meet the analysis needs of the decision-makers.   The modifications discussed in chapters 4 through 10 have addressed the critical areas of goal programming formulation and have led to verification of the model formulation.

The following summarizes the goal programming formulation resulting from this research effort:

- Formulation incorporates Euclidean normalization of goals and project attributes to remove biasness towards criteria with large monetary values and to address the issue of incommensurability.

- Goal target levels are programmed to be outside of the feasible space to ensure that the resulting solutions are efficient, nondominated, and noninferior.

- Goal scaling factors were determined not to be a useful method for achieving a diverse project mix as they can create inefficient solutions. Decision-makers should rely on modifying criteria weighting factors to achieve the desired balance of projects.

- The formulation was modified to allow for greater flexibility in the decision-making process by incorporating multiple time periods and minimum budget constraints.

In addition, the research effort has resulted in the following modifications to the MICA program outside of the actual goal programming formulation:

- Scenario input screens will display a warning message recommending that a maximum of 6 criteria be selected for any particular scenario to address the issue of naïve prioritization and redundancy.

- Project scores based on the percentile of the maximum project score will be part of the MICA program output along with project ranking. Scenario output reports will clearly state that the scores and rankings are dependant on the scenario inputs and are not transferable across scenarios.

The sensitivity and uncertainty analyses that were performed as part of this research effort show that the results of the project selection optimization are reasonable stable and can be treated with a some confidence. Sensitivity of the coefficients and budget level were found to be reasonable.

Rank order changes are minimal at random error levels of less then 10% and are fairly stable at 25% random error levels.   The results of the uncertainty analysis showed that the project selection methods are quite robust to errors in project level analysis methods that utilize uncertain inputs such as future traffic volumes.

Further Study in Optimization Process

Further study on the optimization process within MICA will involve more sensitivity analysis with larger project lists, particularly in the area of criteria weighting. The sample project lists only contained 91 projects while in reality WSDOT could be considering thousands of projects at a time. As the number of projects increase the likelihood of projects with project scores close to each other increases. This in turn will amplify the affect of random error, as smaller error levels will have a greater affect on the project rank.

As mentioned earlier, it would be important to model the preferences of the decision makers through the use of a Delphi analysis, Analytic Hierarchy Process, or Conjoint Analysis in order to derive suitable weights for the funding scenarios under consideration. From the results of this additional analysis, the sensitivity of the program to changes in these weights would provide valuable insight.

As mentioned previously, the potential for very large data sets exists, as the number of projects under consideration for a particular biennium is much larger than the 91 projects used in the sample list. This potential is even greater when considering 20 planning horizons. As the project lists gets lengthy, computational efficiency will become more of an issue and it may be a useful exercise to study the efficiency of different formulations.   Theoretically, the final formulation achieved through this research effort and discussed in the previous section does not limit the number of projects.

Through the use of MICA by DOT officials additional functionality may be necessary to address unforeseen issues.

Computer Software for Optimizing

The linear and goal programming models in MICA are solved using commercial optimization software called LINGO developed by Lindo Systems, Inc. Code within the Microsoft Access-based MICA program call up the LINGO program using a dynamic link library (dll) files. Because of the structure of dll and a licensing agreement with Lindo Systems, Inc. the MICA user does not need to have a copy of the LINGO program on their computer.

For each scenario run, the MICA program determines the list of potential projects for funding from the entire database based on the user inputs.   MICA then determines the goal areas and weighting factors based on the user inputs for priority areas. For priority areas not selected by the user the weights are set to zero. Next MICA sets the goal levels based on the list of projects. Currently the goal levels are the sum of the weighted scores for each of the priority areas. Future research work will address whether the goal levels need to be scaled to achieve tighter solution sets (Niemeier 1995) and if so what those scaling factors should be.

The project list, weighted scores for each project, budget constraint(s), and a FUND variable, are sent to the LINGO dll. The LINGO solver then solves the optimization problem and sets FUND to be 1 if the project is selected for funding and 0 otherwise.   For continuous models one project will have a FUND value between 0 and 1, which represents the percentage of funding for that project. For integer models all FUND variables will be either 0 or 1.

The LINGO solver utilizes a revised simplex method with a product form of the inverse for linear models. For integer modes the branch and bound algorithm is utilized.

References

Alexander, Ernest R. and Edward A. Beimborn. (1987) "Sensitivity Analysis of Multiple-Choice Decision Methods for Transportation." *Transportation Research Record 1124*. Transportation Research Board, Washington D.C.

Dauer, Jerald and Ji-Hsin Lui. (1997) "Multi-Criteria and Goal Programming." *Advances in Sensitivity Analysis and Parametric Programming*. Klewer Academic Publishers, Boston, Massachusetts.

Gomez-Ibanez, J.A. and M.M. O'Keefe. (1995) *The Benefits from Improved Investment Rules: The Case Study of the Interstate Highway System*. U.S. Department of Transportation, University Research Program, Washington, D.C.

Franklin, JP, and D.A. Niemeier. (1998) *The Prioritization of Mobility Improvements Using a Multicriteria Prioritization Algorithm.* Federal Highway Administration Report FHWA-OR-RD-99-01. Federal Highway Administration, Washington D.C.

Hannan, E.L. (1985) "An Assessment of Some Criticisms of Goal Programming." *Computers and Operations Research.* Volume 12, Pages 525-541. Pergamon Press, New York.

Hwang, Ching-Lai, and Abu Syed Md. Masud. (1979) *Multiple Objective Decision Making – Methods and Applications: A State-of-the-Art Survey.* Lecture Notes in Economics and Mathematical Systems, Springer-Verlag, New York.

Ignizio, James P. (1985) *Introduction to Linear Goal Programming*. Quantitative Applications in the Social Sciences, Sage University Paper, Thousand Oaks, California.

Ignizio, James P. (1972) "An Approach to the Capital Budgeting Problem with Multiple Objectives". *Engineering Economist*. Vol. 21, No. 4, pg 259-272. Engineering Economy Committee of the American Society for Engineering Education, Ephrata, Pa.

Ignizio, James P. (1989) "On the Merits and Demerits of Integer Goal Programming". *Journal of Operational Research Society*. Vol. 40, No. 8, pg. 781-785. Hampshire, UK.

Lingo Systems Inc. (2001) *LINGO: The Modeling Language and Optimizer User's Guide*. Lindo Systems, Inc., Chicago, IL.

Louviere, Jordan J. (1988) *Analyzing Decision Making: Metric Conjoint Analysis.* Quantitative Applications in the Social Sciences, Sage University Paper, Thousand Oaks, California.

Marshall, Kneale T. and Robert M. Oliver. (1995) *Decision Making and Forecasting: with Emphasis on Model Building and Policy Analysis*. McGraw-Hill, Inc., New York, NY.

McFarland, William F. and Jeffery L. Memmott. (1987) "Ranking Highway Construction Projects: Comparison of Benefit-Cost Analysis with Other Techniques." *Transportation Research Record 1116.* pg 1-9. Transportation Research Board, Washington D.C.

Melinyshyn, Walter and Richard Crowther. (1971) "Transportation Planning Improvement Priorities: Development of a Methodology". *Highway Research Record 458*. National Research Council, Washington D.C

Muthusubramanyan, M. and Sinha, Kumares C. (1982) Optimization Approach in Highway System Analysis and Programming. *Transportation Research Record 867.* Pg 12-19. Transportation Research Board, Washington D.C.

National Cooperative Highway Research Program. (1999) *Guidebook for Transportation Corridor Studies: A Process for Effective Decision-Making.* Transportation Research Board, Washington D.C.

Niemeier, Debbie A, Zelda B. Zabinsky, Zhaohui Zeng, and G. Scott Rutherford. (1995) Optimization Models for Transportation Project Programming Process. *Journal of Transportation Engineering.* Vol. 121, No 1, pg 14-26. American Society of Civil Engineers, New York, NY.

Parsons, Brinckerhoff, Quade and Douglas. (1995) *Least-Cost Planning: Principles, Applications, and Issues.* Federal Highway Administration, Washington, D.C.

Peyrebrune, Henry. (2000) "*Multimodal Aspects of Statewide Transportation Planning*". National Cooperative Highway Research Program Synthesis of Highway Practice. Transportation Research Board, Washington, D.C.

Reed, Tracy L. (1997) *Priority Programming Under Financial Constraints: A Case Study and Sensitivity Analysis of Transportation Project Selection Methods.* Masters of Science in Civil Engineering Thesis, University of Washington, Seattle, WA.

Reed, Tracy L., D.A. Niemeier, and G. Scott Rutherford. (1995) *Prioritization of Capacity Improvements.* Report WA-RD-295.1. Washington Department of Transportation, Olympia, Washington.

Romero, Carlos. (1991) *Handbook of Critical Issues in Goal Programming.* Pergamon Press, Oxford, England.

Saaty, Thomas L. (1988) The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill International Book Co, New York.

Schniderjans, Marc J. (1995) *Goal Programming: Methodology and Applications.* Kluwer Academic Publishers, Boston, MA.

Schniderjans, Marc J. (1984) *Linear Goal Programming.* Petrocelli Books, Princeton, New Jersey.

Shaffer, Joseph L. and John D. Fricker. (1987) "Simplified Procedures for Determining county Road Project Priorities." *Transportation Research Record 1124.* Transportation research Board, Washington, D.C.

Turochy, Rod E. (2001) "Prioritizing Proposed Transportation Improvements: Methods, Evaluation, and Research Needs. *Transportation Research Record 1777.* pg 123-128. Transportation Research Board, Washington D.C.

Walters, Lawrence C., Glen Thurgood, and Donald L Adolphson. (1993) "New Approach to Integrating Engineering, Managerial, and Political Judgment: Development of the Utah Project Prioritization System. *Transportation Research Record 1400.* pg 1-9. Transportation Research Board, Washington D.C.

Wilson, Frank R. and Gonzales, Hugo. (1985) Mathematical Programming for Highway Project Analysis. *Journal of Transportation Engineering.* Vol. II, pg. 162-171.

Wilson, George R. and Jain, Hemant K. (1988) An Approach to Postoptimality and Sensitivity Analysis of Zero-One Goal Programs. *Naval Research Logistics.* Vol. 35, pg. 73-84.

Yoon, K. Paul, and Ching-Lai Hwang. (1995) *Multiple Attribute Decision Making: An Introduction*. Quantitative Applications in the Social Sciences, Sage University Paper, Thousand Oaks, California

Young, Rhonda (2002)   *Multimodal Investment Choice Analysis: Application of Goal Programming for Selection of Transportation Projects*. Doctor of Philosophy Dissertation, University of Washington, Seattle, WA.

Young, Rhonda, Jennifer Barnes, and G. Scott Rutherford. (2002) *Multimodal Investment Choice Analysis: Phase 1 Project Report.* Washington Department of Transportation, Olympia, Washington.

Zabinsky, Zelda and Debbie Niemeier. (1998) "Rank Ordering to Optimize Project Selection" Currently unpublished.

Chapter 14 – Conclusions and Future Work

Conclusions

The results of the first phase of the MICA project have culminated in a prototype program and supporting documentation. Although it is not anticipated that MICA will be utilized for budgetary decisions next biennium, it is likely that a "dry run" of MICA in conjunction with the existing traditional budgetary process could provide great insight as to its potential effectiveness as a policy tool. Considerable Phase II work remains in refining the impact methodologies to ensure that the most accurate and fair comparisons are being made across project types, modes, and programs. Regardless of the work that remains, valuable lessons have been learned in the Phase I efforts.

From the beginning, the MICA project has progressed with full realization that the obstacles and analysis gaps that arise are an inherent component of multimodal analysis research. Rather than allowing these impediments to stall the progress of the project, the philosophy behind MICA has been to clearly identify them and move on. Gaps are identified as short-term – meaning that they can be addressed with existing data or known analysis methodologies, or long-term – meaning that they are tagged for future research or data collection. In the case of long-term gaps, simplified methods or assumptions that would yield reasonable results have been employed until more detailed techniques can be developed.

The analysis methods and database program that have resulted from this approach provide a favorable framework and momentum for addressing the barriers to multimodal evaluation. To date, barriers have either been surmounted or given way to task lists that specifically identify data needs and future research topics. Additionally, presenting these needs within the larger context of the MICA evaluation framework provides a clear illustration of how additional data or methods will be applied.

In general, completion of Phase I of this project has produced many benefits, summarized as follows:

- Better understanding of the state-of-the-practice in multimodal evaluation

- Clear picture of the types of analyses that are being done within WSDOT, at both the project and program levels

- Prototype program that provides a solid foundation for continuing program development

- Identification of short-term and long-term data and analysis needs that provide clear direction for Phase II

- Development of working relationships with the different WSDOT modal/program divisions that:

- Provide a forum for establishing more uniform analysis methods across modes

- Strong indication that development of a multimodal tradeoff analysis tool is feasible

The final point listed is especially critical since at the beginning of the process there was considerable doubt about the feasibility of developing this type of analysis tool. Although challenges remain, the research team and members of the MICA steering committee believe that

the work is going well and feel that there is reason to be optimistic about the final product of this project.

Future Work

The future research work for the MICA project are broken down into three categories; improvements to the modal analysis, improvements to the optimization process, and general program improvements.

Improvements to Modal Analysis

Long and short term analysis gaps have been identified and discussed in each of the modal chapters. They have been compiled and summarized into the list below.

Ferry System

- Refine the use of WSF's travel demand results.

- Determine if ferry boat emissions and accident rates are negligible. Add to calculations if found to be significant.

- Add calculations into code to handle isolated island route calculations.

- Refine the modeling of trip-making behavior during long-term service disruptions.

- Investigate whether a non-linear relationship would be more appropriate for modeling the probability of service failure of vessels and terminals based on condition ratings.

- Incorporate available information on freight travel.

Highway Improvements

- Add induced demand calculations.

- Consider changes in pollution emissions.

Highway Preservation

- Work with WSDOT pavement group regarding the use of the HDM-4 program for P1 project analysis.

- Work with WSDOT structures group to incorporate output from Bridge Maintenance System.

- Add safety component to P1 analysis if affects found to be significant.

- Look at the affects of roughness on freight cargo and quantify freight benefit is affects found to be significant.

- Consider the addition of P3 projects.

Highway Safety

- Add five additional safety project types not currently included.

- Investigate the relationship between highway improvement and highway safety projects to determine if the separation of project types within the program is necessary.

Intelligent Transportation System

- Update the IDAS program database to reflect the regional instead of national estimates of ITS project impacts.

- Compare the analysis results of projects analyzed in IDAS and in SCRITS and modify or adjust as necessary so that analysis is consistent across project type.

Non-Motorized

- Investigate the safety impacts of shoulder improvements for rural bicycle touring.

- Obtain better localized data on the affects of improving bicycle routes on automobile travel.

Rail

- Continued refinement of all rail project analysis methodology to reflect the planning level of project analysis.

Transit

- Incorporate SPASM calculations directly into MICA.

- Derive regional numbers for transit impacts to improve estimation methodology.

Transportation Demand Management

- Refine CTR survey questions to better isolate travel behavior factors.

- Areawide TDM projects need to have more detailed information and the analysis methodology improved to utilize this additional information.

Improvements to the Optimization Process

Further study on the optimization process within MICA will involve more sensitivity analysis with larger project lists, particularly in the area of criteria weighting. As the project lists gets lengthy, computational efficiency will become more of an issue and it may be a useful exercise to study the efficiency of different formulations. Theoretically, the final formulation achieved through this research effort and discussed in the previous section does not limit the number of projects.

As mentioned earlier, it would be important to model the preferences of the decision makers through the use of a Delphi analysis, Analytic Hierarchy Process, or Conjoint Analysis in order to derive suitable weights for the funding scenarios under consideration. From the results of this additional analysis, the sensitivity of the program to changes in these weights would provide valuable insight.

Through the use of MICA by DOT officials additional functionality may be necessary to address unforeseen issues.

General Program Improvements

Also should be noted that additional efforts will be necessary to move the program from its prototype phase into a implemented, multi-user program. The prototype version of the program is designed to serve two crucial purposes. The first is to test the analysis methodologies and to ensure that the projects are being compared accurately and fairly. The second purpose is to serve as a starting point for discussions on the user-interface of the program. During the prototype phase it is important that the future users of the program determine what features work well, don't work well, or are missing from the program so that the final version of the program serves all potential users.

The prototype program's architecture within the Microsoft Access software platform does not easily lend itself to a multi-user environment. The ability for multiple users to access the program and project lists is extremely important for a program such as MICA that has been developed to bridge the program divisions of WSDOT. Users must be able to have access to the latest project lists and global variable settings to ensure that equivalent analyses are being performed. The Access platform was selected by the research team because of its widespread use and ease of programming. The majority of the research work involved the program code and methodologies behind project and scenario analyses which is directly transferable to other software platforms. Future work will involve moving the program to a web-based or network database structure such that all users have access to the same information. Most likely the user interface portion of the program will be web-based with the data being stored on central network computers.

In addition to user interface and program architecture changes there is another area where additional programming work will be necessary. This involves how the program deals with the different modal divisions. Currently the program is structured to be modally discrete, that is, that project types are associated with one particular mode. Ideally future versions of the program would allow project types to be associated with more then one mode or for composite projects to be created. An example would be Intelligent Transportation System projects. Instead of being a separate mode it might be more useful for it to be associated with multiple modes such as highway or transit projects. An example of composite projects would be a highway capacity improvement that also involved a Transportation Demand Management component.

Appendix A – Existing Analyses Matrix

Multi-Modal Investment Choice Analysis

Benefit-Cost Calculations for Highway, Rail, Transit and Ferry

	MODAL STUDIES						OTHER STUDIES	
Category	Highway - Mobility Program [I] (1)	Highway - Pavement Preservation [P] (2)	Passenger Rail [Y] (3)	Freight (grain train) Rail (4)	Transit [Y] (5)	Ferry System Preservation [X] (9)	PSRC (7)	STEAM (8)
Assumptions and Default Values								
Discount Rate	4% Constant Dollar approach based on Real Cost of Capital.	4% Real Discount Rate (Constant Dollar Approach)	4% Annual Inflation Rate	(4a) 3.59% Real Discount Rate or (4b) uses 3.1% inflation and 4.75% return on excess revenues		6%		7%
Project Life Cycle	20 year period. Use residual values to compensate for salvage value. ROW 0.55 Grading & Drainage 0.60 Structures 0.57 All other costs 1.00	40 year period. Serviceable life calculation accounts for remaining project life at end of analysis period.	20 year period.	(4a) uses 10 year and (4b) uses 23 year [based upon the remaining life of the current fleet]	20 Year	Variable - Specific Life Cycles are assigned to each vessel and terminal component. Uses a performance measure based on the percentage of system components currently operating within their projected life cycle.		Analysis year chosen by user to represent average benefits over life of improvement. Any residual salvage value is entered in the capital costs screen to account for value beyond the useful life of the project.
Base Capacities	Vehicles per hour per lane by facility type. Values based on 1985 HCM and are generally consistent with 1997 HCM.	1994 Highway Capacity Manual		Current fleet composed of 29 grain cars				*Highway Capacity Manual* and speed models developed by Cambridge Systematics. Accounts for decreased capacity when demand exceeds capacity.
Value of Time	Wage Rate $18.36 for passenger cars and $20.22 for trucks. Value of in-vehicle time as % of wage rate is 33% for cars and 100% for trucks	A recommended value and range are given for three types of vehicles: passenger $11.58 value, $10-$13 range; single unit truck $18.54 value, $17-$20 range; combination truck $22.31 value, $21-$24 range in August 1996 dollars. A more detailed method is also given when distributional data on trip purpose and type is know.	Wage Rate $13.75. A high and low estimate of the value of rail travel time were used with the low range being $4.81 for work-related time and $2.41 for leisure time. The high range is $9.63 for work and $4.81 for leisure. These values account for increased productivity from being a passenger.	Not considered in grain train analyses	$17.00 per hour for out-of-vehicle time (time spent accessing, waiting, and transferring), $8.90 per hour for in-vehicle time for transit modes, and $9.50 per hour for in-vehicle time for auto/commercial modes.	Not considered in analysis.	Regional average wage rate $15.74. Congestion costs due to loss of time valued at 50% of wage rate. Freight handled separately in this study and captured in a regional direct private freight cost number.	In-vehicle value of time: trucks $16.50/person hour, all other modes $8.90/person hour. Out-of-vehicle time: all modes $17.00/person hour.
Terminal Time	N/A	N/A	Assumed to be 18 minutes at each end of the intercity trip.	N/A		Not considered in analysis.		Obtained from forecasting model results.
User Operating Costs	Passenger cars $0.0749 per mile and trucks $0.6570 per mile. Average running speed assumed 50 mph resulting in operating costs per hour of $3.75 for cars and $32.85 for trucks.	Vehicle operating costs include a per mile cost associated with longer detour routes ($0.31/mile in Aug. 96 $) and a speed change cost that accounts for the additional operating costs for the vehicle to slow from one speed to another and then return to the original speed. The added costs are given for passenger cars, single unit trucks, and combination trucks for speeds in five mph increments. Only work zone user costs are considered. User costs associated with rough pavement is not considered at this time.	Parking fees for rail travel. Fares considered a transfer. Automobile operating costs included fuel, oil, maintenance, tires, insurance, license/registration, and capital depreciation.	Operating expenses based upon actual 1995 values, and assumed to grow each year by 3.1% inflation rate		N/A	For automobiles operating costs estimated at $0.077/mile and SUV/light trucks estimated at $0.088/mile (includes cost of gas, oil, maintenance, and tires without taxes). Additional operating costs due to congested were estimated separately using the Texas Transportation Institutes methodology and dividing the result in half to account for recent studies that show greater fuel efficiency at lower speeds then previously thought.	Fuel consumption rates in gallons per mile for auto (0.066-0.019) and trucks (0.481-0.15) based on speed. Transit vehicle fuel consumption rates based on type of vehicle (0.377 for local and 0.235 for express bus). Rail given in KWhr/mile for light and heavy rail (11.09 and 7.63 respectively). Fuel rates default to $1.21 for autos and $1.15 for trucks. Non-fuel highway costs set at $0.034/mile for auto and carpool and $0.10/mile for trucks.
Average Occupancy	1.30 for Urban and 1.10 for Rural areas for passenger cars, 1.0 for Trucks Statewide. When known actual AVO's should be used.	Typical vehicle occupancy rates for the area.	N/A.	N/A	N/A	N/A	1.4 (does not include transit)	Determined in travel demand forecasting process.
Overall User Benefit Cost Parameter	Combination of value of time and operating costs per vehicle. $10/hour for passenger cars and $50/hour for trucks. This value is then adjusted for vehicle occupancy.	N/A Travel time and user operating costs not aggregated into an hourly cost.	N/A Travel time and user operating costs not aggregated into an hourly cost.	Per car revenue (assumes revenue decreases by 1% for each year the car ages)	N/A Travel time and user operating costs not aggregated into an hourly cost.	N/A	N/A Travel time and user operating costs not aggregated into an hourly cost.	N/A Travel time and user operating costs not aggregated into an hourly cost.
Conversion to Annual Benefits	Converts 24-hour travel time savings to annual benefit number by multiplying the estimated time savings by category by the benefit cost parameter and the 260 workdays per year.	N/A Work zone user costs are calculated for each construction period over the 40 year analysis period.	Travel time estimated on a per trip basis and would be multiplied by the estimated number of trips per year.	(4a) calculates net present value of annual benefits and (4b) calculates benefits for each year of life cycle	Travel time estimated on a per trip basis and would be multiplied by the estimated number of trips per year.	N/A	N/A	250 days per year to convert from daily trips to annual trips.
Present Value Factor	Assumes annual benefits are distributed equally between Year 1 and Year 20 estimates.	N/A Lowest Life Cycle Cost Analysis.					N/A	N/A Analysis year chosen to represent average benefits over life of project.
Societal Cost of Accidents	WSDOT Recommended Societal Costs by Accident Severity: $700,000 per fatal collision, $700,000 per disabling injury, $57,000 per evident injury, $30,000 per possible injury, $5,300 per property damage.	Accident costs (Aug. 96 $) are given for three severity categories (fatality, nonfatal injury, property damage only) for four types of facilities (RR grade crossing, intersection/interchange, bridge, highway segment) for urban and rural areas. For an urban highway segment accident costs are $1.11 million for fatal accidents, $14,800 for injury, and $3,450 for PDO.	External costs of accidents calculated on a per passenger mile basis. A range of $0.001 to $0.015 per passenger mile was used. The high value range included costs associated with both onboard and trespasser accidents.	Utilizes WSDOT Recommended Societal Costs by Accident Severity: $700,000 per fatal collision, $700,000 per disabling injury, $57,000 per evident injury, $30,000 per possible injury, $5,300 per property damage. (4b)	Not considered in analysis.	Not considered in analysis.	Washington Traffic Safety Commission: $920,000 per fatal accident, $46,000 per serious injury, $14,000 per evident injury, $8,800 per possible injury, $6,600 per property damage.	Cost per accident (internal/external): Fatality $2,317,398 / $408,952; Injury $50,759 / $8,957; Property damage $2,823 / $498
Environmental Cost Valuations - Air Pollution	Environmental Costs not included in analysis.	Environmental Cost not included in analysis.	Environmental Health Impacts - Costs per Gram of Emissions: CO_2=$5.80 per metric ton (Climate Change cost); Volatile Organic Compounds=$0.002-$0.003; CO=$0.001-$0.001; NO_x=$0.006-$0.012; Particulate Matter=$0.051-$0.110; SO_x=$0.055-$0.121	(4a) calculates the following ratio of truck to rail average emissions: PM_{10}=3.036, NO_2=0.713 to 0.987, CO_2=2.050, VOC=2.581 - no values are given for emissions savings	Change in CO, NO_x, VOC, PM_{10}, and CO_2 estimated. Only the emissions estimates are reported and dollar values are not assigned to these estimates.	Not considered in analysis.	1-cent per VMT for non-commercial travel and 2-cents per VMT for commercial travel. Includes only ground level emissions impacts and not global warming costs	Emissions costs per ton: HC=$1774, CO=$3889, NOx=$3731, PM10=$11066. Global warming cost $3.56/ton CO_2 emissions.
Environmental Cost Valuations - Other (Noise, Water, Waste Disposal)	Environmental Costs not included in analysis.	Environmental Cost not included in analysis.	Highway noise costs society between $0.001-$0.006 per passenger mile. Rail noise costs society between $0.001-$0.004 per passenger mile. Water pollution costs captured in direct construction and mitigation costs. Waste disposal costs for auto estimated at $0.001 per passenger mile. Rail waste disposal costs assumed to be internalized and captured in operating costs.	Noise, water and waste analysis costs not included in analysis.	Not considered in analysis.	Not considered in analysis.	Water pollution estimated to cost $0.002 per VMT. Auto-related solid waste disposal cost estimated for the region as $4.5 million. Noise pollution estimated at $0.002 per VMT.	Noise pollution costs: automobile modes $0.001/mile, trucks $0.018-0.054/mile based on roadway classification, bus $0.015/mile, and rail modes no noise pollution costs.

Multi-Modal Investment Choice Analysis

Benefit-Cost Calculations for Highway, Rail, Transit and Ferry

	MODAL STUDIES						OTHER STUDIES	
Category	Highway - Mobility Program [I] [1]	Highway - Pavement Preservation [P] [2]	Passenger Rail [Y] [3]	Freight (grain train) Rail [4]	Transit [Y] [5]	Ferry System Preservation [X] [9]	PSRC [7]	STEAM [8]
Uncertainty	Not considered in analysis.	Probabilistic (Risk Analysis) approach used by WSDOT for major and urban area projects.	Range of values used to account for uncertainty.	(4b) analyzes 2 scenarios - one that assumes no interest expense, and one that conservatively assumes the project is financed with bonds with 4.98% interest	Not considered in analysis.	Not considered in analysis.		Risk analysis performed and a distribution of benefit-cost ratios reported.
Benefits Calculation [6]								
User Savings	Travel time savings is computed as the difference in vehicle-hours of travel time with and without the project. This estimated travel time savings is then monetized to account for both time and user operating savings using the user benefit cost parameter.	Base capacity and work zone capacity estimates are compared and the resulting estimated speeds are calculated for the different time periods and days. From these calculations user delay and operating costs are calculated and monetized.	Travel time per passenger was converted to cost per passenger mile by calculating total travel time per passenger, including terminal times, considering how speeds for each mode were anticipated to change over the 20 year period. The relative costs of business and leisure travel were weighted according to ridership share. Total time costs were then divided by the mileage associated with each type of trip.	Transportation cost savings (over trucks) to growers averaged $0.066 per bushel	Travel time savings of people using competitive modes (auto and commercial) as well as new and existing transit users.	Not considered in analysis.	Comprehensive study of regions transportation costs and not a project level analysis. All user transportation costs were accounted for based on estimated passenger miles for all modes. Did not involve future projections.	Travel time savings is computed as the difference in vehicle-hours of travel time with and without the project. This estimated travel time savings is then monetized by trip type and mode. User operating savings are estimated based on fuel consumption and speed estimates and monetized according to fuel costs. Fares for transit modes analyzed as revenue transfers.
Accident Reduction	Safety Benefits are estimated using 36-month accident data from the TRIPS program. Accidents are sorted by type and severity with only those accidents expected to be affected by the proposed improvement type left in the analysis. Appropriate accident reduction factors from the Safety Countermeasures Reference Guide are selected and the number of accidents avoided by accident severity estimated. The WSDOT recommended societal costs by accident severity are used to monetize the safety benefit number.	Accident costs are calculated based on the differential crash rates between work zones and nonwork zones, by the vehicle miles of travel during the duration of the work zone. Crash rates are given for rural and urban areas for 8 roadway functional classifications for fatal and injury accidents.	Safety Benefits (and disbenefits) would be estimated for the proposed improvement and monetized by accident severity.	Used USDOT Transportation Safety Report for rail accident statistics, used data from WSDOT Planning and Programming Service Center for trucking accident statistics	Not considered in analysis.	Not considered in analysis.	Magnetization of accidents that occurred in a given year. Did not involve future projections.	Applies per vehicle mile rates and unit costs for fatal, injury, and property damage only accidents. Program includes default rates for limited-access and non-limited-access highways as well as allowing the user to input up to six user-defined classifications and accident rates.
Environmental Valuations - Air Pollution	Not included in analysis.	Not included in analysis.	Emission Rates for Diesel Rail - Grams per Passenger Mile: CO_2=230; Volatile Organic Compounds=0.160; CO=0.600; NO_x=0.900; Particulate Matter=0.080; SO_x=0.051. [Note that this report compared environmental costs across three modes for the same corridor. For a system-wide multimodal comparison the change in environmental costs would need to be calculated based on ridership and mode shift estimates.]	Not included in analysis.	VMT for CO, NOx, VOC, and PM10 are estimated by vehicle classification using travel demand models. Emission factors applied to VMT and the differences between the build and no-build alternatives compared. Greenhouse Gas Emissions (CO_2) are estimated using BTU consumption estimated by vehicle/fuel type.	Not considered in analysis.	Comprehensive study of regions transportation costs and not a project level analysis. All user environmental costs were accounted for based on estimated passenger miles for all modes. Did not involve future projections.	Estimates emissions as the sum of mileage-based emissions on the highway system and added emissions due to cold starts. Mileage-based emission rates are calculated using emission rates as a function of speed using the average speed per trip. Program allows for user input of locally estimated emissions rates.
Cost Calculation								
Construction	All costs of construction with the exception of costs accrued in the remaining three categories. Includes environmental analysis, mitigation costs, and right-of-way expenditures.	All costs of preliminary engineering, contract administration, and construction.	All costs of construction including environmental analysis, mitigation, and right-of-way expenditures.	No construction costs figured - capital costs consist of additional rail car purchase		Average costs are assigned to each component of the vessel or terminal system.	N/A Not a project comparison analysis. Only involved the existing transportation system.	Total capital costs of the project converted into a stream of annual costs starting in the year of opening in and extending over the useful life of the project. Capital costs are viewed as incurring in the year entered as the midpoint of the construction period.
Environmental Retrofit	Costs associated with addressing pre-existing environmental conditions not up to current standards. Funds from separate accounts may be used to pay for these items and the associated costs removed from the cost calculations.	N/A	N/A	N/A	N/A	N/A		N/A
Preliminary Engineering	Costs incurred in the development of the project such as legislative and route/design studies.	Included in construction costs.	Costs incurred in the development of the project such as legislative and route/design studies.	Not considered in grain train analyses	Not considered	A 20% factor is added to component's cost to account for design engineering (6%), construction engineering (4%), and contingency (10%)		N/A
Annual Operating and Maintenance Costs	All costs required annually for the operation and maintenance of the project. Costs not included are snow and ice removal, rest area management, and public damage repair.	Future routine and preventative maintenance, resurfacing and rehabilitation costs, and administration.	Operational costs included fuel, labor, maintenance of trains and facilities, insurance, marketing and sales, and general administrative costs for operating the entire corridor. O&M costs are then offset by generated revenue.	Operational costs are given, but are not itemized	Change in operating cost per passenger mile calculated by dividing the annual system operating cost for the build and no-build scenarios by the estimated annual passenger miles for the two scenarios.	N/A Preservation model so operating and maintenance costs already in budget. Does not consider reduced expenditures due to upgrades systems.	N/A Not a project comparison analysis. Only involved the existing transportation system.	User inputs the estimated change in operation and maintenance costs per year for the project. Transit modes also considers the agency costs per mile for providing service.

(1) See "Mobility Programming Criteria and Evaluation Procedures", WA-RD 453.1 June 1998 and the forthcoming "WSDOT Mobility Project Prioritization Process: Benefit/Cost Software User Guide" prepared by Dowling Associates, Inc.

(2) Project level analysis once Pavement Management System has identified roadway section as needing rehabilitation. See "The WSDOT Pavement Management System - A 1993 Update", WA-RD 274.1 September 1993 and "The WSDOT Pavement Management System: Operational Enhancements", WA-RD 315.2 December 1995. In addition see the FHWA Technical Bulletin "Life-Cycle Cost Analysis in Pavement Design" FHWA-SA-98-079. WSDOT has not incorporated all of the procedures in the bulletin at this point but plans to in the future.

(3) See "Economic Analysis for the Intercity Passenger Rail Program for Washington State 1998-2000" prepared by Berk & Associates, September 1998. Note that this report was an economic analysis for a corridor and is not fully applicable to a benefit-cost analysis but instead represents a starting point for discussion.

(4) See [a] "Highway Benefits of Washington Grain Train Program", HDR Engineering and Denver Tolliver, 1998, and [b] "An Economic Evaluation of the Performance of the Washington State Department of Transportation Grain Train Project", Casavant and Mack, 1996.

(5) See "Technical Guidance on Section 5309 New Starts Criteria", Federal Transit Administration, September 1997. This is not a methodology for transit benefit-cost analysis but does provide useful information on valuation of travel time and air pollution emission estimates for transit systems.

(6) The benefits categories included here (user operating savings, accident, and air pollution) are meant as a starting point for discussion. The Economic Analysis for the rail corridor was very comprehensive and included noise and water pollution and waste disposal costs for each mode. The New Starts Criteria includes many non-monetary categories such as land use impacts.

(7) Transportation cost study prepared by Puget Sound Regional Council entitled "The Costs of Transportation: Expenditures on Surface Transportation in the Central Puget Sound Region for 1995" in October, 1996. Note that this study took a conservative approach and used the lower bounds of cost ranges.

(8) Federal Highway Administration and Cambridge Systematics computer program "Surface Transportation Efficiency Analysis Model (STEAM)" that estimates impacts of multi-modal transportation alternatives. Default national values are given for model parameters. Considers the following modes: auto, truck, carpool, local bus, express bus, light rail, heavy rail, and other.

(9) Talbot, Korvola & Warwick LLP "Performance Audit of the Washington State Ferry System Capital Program". Note addresses the life cycle cost model utilized by Washington State Ferries for vessel and terminal preservation projects.

Appendix B - Discount Rate Memorandum

**Washington State
Department of Transportation**

Date: December 2, 1993

From: Eric R. Meale
Phone: 705-7942

Subject: Present Value Analysis
           Discount Rates

To: Tracy Reed

A primary element in the Mobility Prioritization formula is the calculation of the net present value of project costs and benefits as outlined in the "Cost Efficiency Worksheet." The calculation of present values, in turn, requires the use of an appropriate discount rate. The discount rate for performing present value calculations on public projects should represent the opportunity cost of capital to the taxpayer. The rate at which money could be alternatively invested is generally termed the opportunity cost of capital; i.e. the estimated average market rate of interest.

The accepted practice of estimating future benefits and costs in constant dollars, however, means that using the market rate of interest to present value the future benefits and costs is inappropriate because the market rate of interest includes an allowance for expected inflation as well as a return that represents the real opportunity cost of capital. Constant dollars express costs and benefits in terms of price levels prevailing at a particular (constant) date in time, usually what the costs and benefits would be at the time the study is conducted, such as 1993. Current dollars, on the other hand, express costs and benefits in terms of price levels prevailing at the time the costs or benefits are incurred, such as in the year 2000. Valuing costs and benefits in current dollars requires the use of an average rate of inflation to account for price changes and there are good reasons to expect highly significant differences in the rate of price changes for some costs or benefits of a proposed project. The constant dollar approach to estimating future benefits and costs is preferable, in most cases, to using current dollars for economic analysis, since it avoids the need for speculation about future inflation in arriving at the projected benefits and costs of the proposed project. Since constant dollars do not include inflationary effects and the market rate of interest does include an allowance for inflation, if future benefits and costs are computed in constant dollars, they will be understated in terms of their present value if a market rate of interest is used. Therefore, when future benefits and costs are calculated in constant dollars, only the real cost of capital should be used as the discount rate. As shown in the attached table, the real cost of capital has been estimated at about 4 percent in recent years.

To summarize, if benefits and costs are expressed in constant dollars, a constant dollar discount rate should be used. The constant dollar discount rate is about 4 percent. If a current dollar discount rate is used, such as 8 or 9 percent (which includes the anticipated inflation rate), the benefits and costs of the proposed project must be inflated to current dollars also. The constant dollar approach is preferable with the use of a 4 percent discount rate to compute the present value of proposed project costs or benefits.

ERM:em
Attachment

Year	Prime Interest Rate	Inflation Rate	Estimated Real Cost of Capital
1970	7.9%	4.6%	3.1%
1971	5.7%	4.8%	0.9%
1972	5.2%	3.9%	1.3%
1973	8.0%	5.7%	2.2%
1974	10.8%	10.1%	0.7%
1975	7.9%	8.2%	-0.3%
1976	6.8%	5.9%	0.9%
1977	6.8%	7.0%	-0.2%
1978	9.1%	7.3%	1.7%
1979	12.7%	8.9%	3.5%
1980	15.3%	10.4%	4.4%
1981	18.9%	8.9%	9.2%
1982	14.9%	5.7%	8.7%
1983	10.8%	4.8%	5.7%
1984	12.0%	4.0%	7.7%
1985	9.9%	3.9%	5.8%
1986	8.3%	3.1%	5.0%
1987	8.2%	4.2%	3.9%
1988	9.3%	4.2%	4.9%
1989	10.9%	4.8%	5.7%
1990	10.0%	5.2%	4.6%
1991	8.5%	4.3%	4.0%
1992	6.3%	3.3%	2.8%
AVERAGE	9.7%	5.8%	3.7%

Source:
    DRI/McGraw-Hill, Lexington, MA.

Note:
    1/ The rate of inflation is based upon the implicit price deflator for consumer spending.