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Common Performance Measures

Economic Efficiency and Measures of Effectiveness Tools and Methodology
for Analyzing Various Modes of Passenger Transport

For Use in Corridor Planning and Project Prioritization

Common Performance Measures Practitioner's Guidebook

COLORADO DEPARTMENT OF TRANSPORTATION

In cooperation with

The University of Colorado at Denver
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16. Abstract

This guidebook presents a methodology that uses performance measures common to various transportation modes to perform simplified corridor/project analyses. Evaluation of performance across alternatives and modes is done through a series of manual worksheets by applying an approach based on five core areas including measures of mobility, agency cost, safety, user costs, and air quality. The evaluation can be limited to an analysis based on measures of effectiveness (MOE) or completed to include a measure of economic efficiency. To calculate the measures for each of the core areas, the analyst must describe the corridor or project to be analyzed, conceptualize the alternatives to be examined, collect baseline data pertinent to those alternatives and the chosen analysis framework, and aggregate the corridor into logical segments. For cases where some local data is unavailable, the guidebook includes a series of reference tables with default and average values for variables and parameter involved in the evaluation. After the MOEs under the baseline, No-build, and alternative conditions for each analysis year are summarized, the analyst can employ a multi-criteria ranking approach to select the best alternative action based on performance measures or perform an economic efficiency analysis.

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COLORADO DEPARTMENT OF TRANSPORTATION

Common Performance Measures Practitioner's Guidebook

Research Report

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About this Report

As Coloradans increase their interest in investing in non-automotive transportation solutions, decision-makers and practitioners need tools to measures the performance, and costs and benefits of various modes of transportation in terms common to all modes.

The economic efficiency and effectiveness frameworks and tools proposed in this report are for use in analyzing various modes of passenger transport in corridor applications during the early planning stages. The frameworks proposed are focused around "core" areas (i.e., *agency cost, user cost, mobility, safety, and air quality)* in terms of measures of effectiveness and economic efficiency (i.e., *net social benefit).*

The methodologies proposed can be used for additional purposes including the use of specific measures of effectiveness for analyzing a particular community goal, the source of default values and algorithms to standardize the comparison of various actions, and the prioritization of projects (including single mode projects).

The methodologies have been developed to support the regional planning process conducted by a Transportation Planning Region (TPR). The methodologies utilize user input data consistent with that available through the Colorado Department of Transportation's (CDOT) GIS tools.

The development and final product of the methodologies has been overseen by a study panel comprised of TPRs, metropolitan planning organizations (MPOs) and transit officials, as well as staff and management representatives from CDOT. The study panel strongly suggested that the TPRs and MPOs start using the methodologies as a way to begin standardizing the examination of potential results of proposed actions (i.e., in terms of *agency cost, user cost, mobility, safety, and air quality,* and *economic efficiency*). However, the use is not mandated and deviations are expected given that certain community goals must be consider in the decision-making process which are not reflected in the "core" areas.

Executive Summary

Background

The *Common Performance Measures* (CPM) research products provide a way for transportation decision-makers and practitioners to trade off the performance and costs and benefits of various modes of passenger transportation. The CPM process employs two frameworks--economic efficiency analysis (EEA) and measures of effectiveness (MOEs)--to assess and prioritize various transportation actions. The intended point of application is long range planning at the sketch planning level for corridor analysis where various modes of transportation might address a mobility problem. However, the tools and methodologies can also be used to help prioritize projects within a single mode of transportation or to compare the results of specific MOEs.

Primary Research Products

- ☐ Framework developed around five "core" categories of cost and performance (i.e., agency cost, user cost, mobility, safety, and air quality)
- ☐ Manual and spreadsheet worksheets for a practitioner to use to analyze a project or modal alternatives within a project
- ☐ Simplified methodology for determining travel demand
- ☐ Tools for examining the MOEs and Economic Efficiency elements
- ☐ Summary sheets recapping the results of the MOE and NSB analysis
- ☐ Methodologies for examining the sensitivity of the results and for prioritizing the MOEs
- ☐ Reference and Site Specific Tables which capture the major assumptions, values, or directives by subject area

The research focused its efforts on passenger transport by way of highways (SOV, HOT, and HOV), transit, rail and bicycles with the intention of being able to make consistent (i.e., apples to apples) comparisons across these modes. The EEA and MOEs frameworks are organized into five core areas (*agency cost, user cost, safety, mobility, and air quality*) and consider factors such as capital costs, operating and maintenance expenses, users out-of-pocket costs, travel time, fatal crash risks, and air quality implications. Since this approach is intended to be widely applied, only commonly used measurement areas were chosen. Local practitioners may want to independently consider additional performance measures that address other local concerns and goals.

The CPM products are especially useful for rural and small urban transportation planning regions. They are not intended to supplant the more sophisticated tools used in the large MPO areas, although consistent measurement in the core areas is desirable from a statewide perspective.

MOE and EEA Frameworks

The CPM research developed two different means of analyzing information - economic efficiency analysis and measures of effectiveness. These two conceptual frameworks are complementary in many areas, yet they answer different questions. They often use the same data and build upon each other's measures. While the MOEs can be completed independently of the economic efficiency approach, EEA requires the completion of many of the MOE steps. The EEA results present information in a monetized, comprehensive, bottom line fashion. The effectiveness analysis hones in on particular elements that support commonly accepted goals. The effectiveness framework uses measures that may or may not be expressed in monetary terms and it does not calculate a monetary bottom line.

These frameworks are not an examination of the full social costs of transportation except that certain externalities are addressed in the areas of user costs, safety and air quality.

Economic Efficiency Analysis

The concept of economic efficiency is a way of measuring if the people in a region would be in general better off by undertaking a particular transportation investment. Efficiency is interested in finding opportunities to change the way resources are utilized so that the lives of most people in a community would be improved if the investment were made.

Efficiency is only interested in, and therefore only measures, what might significantly change as a result of an investment. It aggregates all elements considered into a single, comprehensive, monetized answer. Efficiency compares the projected change in the monetary value of specific MOEs to a future scenario where no investment were made to determine the investment's costs and benefits in terms of *net social benefit* (NSB). A positive NSB indicates a wise investment—in terms of economic efficiency--while a negative NSB would indicate that the investment should not be made since costs exceed the benefits. EEA may also indicate the relative ranking of certain investments, that is, which one has the greatest net benefit, which has the next best net benefit, etc.

The economic efficiency approach utilized in this research monetizes those things that matter most to many of us:

- The loss of lives due to crashes;
- The value of our time;
- The return on our investment, now and in the future;
- Our out-of-pocket expenses; and,
- The health related consequences due to the polluted air we breath.

The economic efficiency measure is information that decision-makers can use, but it does not mean that a project should be built if the NSB is positive notwithstanding other information. It may happen that a project will show positive benefits in some categories and negative in others. For example, user benefits may be positive because average speed increases with the project but safety benefits may be negative because there are more fatalities at the higher speed. Overall positive benefits would still be considered to be a wise investment if one is interested in the *net effect* that economic efficiency brings to the decision-maker.

The efficiency tool considers the costs and benefits in each year of the planning timeline. It calculates the NSB and then brings the figures to a present value. The methodology proposed here also compares actions as if they were in place *in perpetuity* to correct for the comparison of unequal asset lifetimes and to measure the continuing performance and costs and benefits of an investment once it is made.

Measures Of Effectiveness Approach

The MOE framework first asks the user to determine what goals, standards, and/or benchmarks are of most importance. An effective investment action is one that supports the achievement of a specified goal or goals, so that the investment achieves the intended results.

As a result of the research, it was determined that Colorado decision-makers typically assess projects in terms of their *agency cost, user cost, safety, mobility, and environmental* implications. Therefore, these five "core" measurement areas have been established as the MOE categories for application with this research.

The MOE approach is concerned with how well something is done and does not necessarily imply a maximization approach. Rather, the MOE approach looks to fulfill designated expectations. The effectiveness framework allows the measurement of how certain choices meet specific goals that reflect certain community objectives.

The measures of effectiveness are arranged into five core categories commonly found to be of interest to most decision-makers:

- Agency Cost – capital costs, maintenance and operating costs, administrative costs
- User Cost – out-of-pocket expenses
- Mobility – changes in travel characteristics, (i.e., amount of travel, speeds, and travel time)
- Safety – number of crashes, and number of fatalities
- Air quality – amount of emissions due to a proposed action

For example, one community has a mobility problem along with a goal to improve air quality because it is a non-attainment area. The community considers making an investment in alternative modes before considering traditional highway widening. From a community-wide efficiency standpoint, an investment in a Travel Demand Management (TDM) strategy that mainly impacts large employers provides fewer mobility benefits than widening a long stretch of the interstate. However, the community chooses to implement the TDM strategy in spite of its lower overall efficiency rating because it helps to achieve its air quality goals.

Decision-makers can place more emphasis on one or several components of performance in order to show progress in solving a particular problem. Safety is often a highly visible concern for both decision-makers and the general public. The effectiveness framework allows safety implications of certain investment choices to be considered without monetizing the costs/benefits of accidents.

MOEs could look at trends in accidents or place more importance on accidents that impact certain locations.

The MOE framework results will most often be shown through the use of a matrix. The goals are set out along one axis. The performance measures along another. A score may be developed which allows for numeric calculations and/or weighting of the scores. MOE can also use a more qualitative means with descriptive measures. Scores may also indicate a trend (i.e., decreasing pounds of pollution) without attaching actual numbers to the score.

Application of Methodology and Tools

Practitioner's Guidebook

Chapter One of this guidebook more fully defines the frameworks, the core areas and key definitions. Chapter Two provides the process steps a practitioner would need to follow to perform an MOE or EEA analysis that may, for example, help a Regional Planning Commissioner take a policy-level action. It contains a User Input Table that the practitioner would complete to begin either the MOE or EEA analysis along with suggestions for data sources. Chapter Three contains detailed steps for developing the *manual worksheets* for an MOE analysis, along with copies of the worksheets. Chapter Four is comparable to Chapter Three excepting that it details the EEA process and contains the EEA worksheets. Chapter Five discusses the evaluation of results and contains a process for evaluating the MOEs. It also makes recommendations for conducting sensitivity analyses. *Reference Tables* and *Site Specific Tables* that capture the major assumptions, values and directives by subject area are provided in Appendix One. Finally, Appendix Two shows a bibliography that includes some of the technical references produced along with this research.

Although the tools produced by this research can be accessed, for both the MOE and EEA calculations, via manual worksheets or automated spreadsheets, the use of the spreadsheets is recommended given the savings in data input, flexibility, and speed of processing. Files containing an electronic version of the spreadsheets as well as templates for the manual worksheets are provided in the pocket of this manual.

Summarizing MOE and EEA Results

For the MOE approach, Forms K-2 and M are the final summary forms that will be used to compare the different corridor scenarios considered. These forms tabulate corridor MOEs by analysis period and per year respectively for the Baseline, No-build, and Alternative scenarios. Form K-2 consists only of mobility measures per analysis period whereas Form M includes annual measures for all five core areas.

For the economic efficiency analysis, Form EE-2 (Net Social Benefits Table) is used to collect and display the time profile of benefits and costs for a project. Examples of forms M and EE-2 are next provided.

FORM M
Summary Table for Corridor Annual MOEs (All Segments Both Directions)

CORRIDOR IDENTIFICATION

BASELINE YEAR

ANALYSIS YEAR

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs for BASELINE conditions (both directions)									
MOBILITY									
Annual Number of Pass. Trips									
Annual # of Pass Pk-per Trips*									
Vehicle Miles Traveled									
VMT (Peak period)*									
Passenger Miles Traveled									
PMT (Peak Period)*									
AIR QUALITY									
Emissions (tons of pollutants)									
SAFETY									
Number of Crashes									
Fatalities									
USER COSTS									
Variable User Cost									
Periodic User Cost									

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs for No-Build scenario (both directions)									
MOBILITY									
Annual Number of Pass. Trips									
Annual # of Pass Pk-per Trips*									
Vehicle Miles Traveled									
VMT (Peak period)*									
Passenger Miles Traveled									
PMT (Peak Period)*									
AIR QUALITY									
Emissions (tons of pollutants)									
SAFETY									
Number of Crashes									
Fatalities									
USER COSTS									
Variable User Cost									
Periodic User Cost									

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs under Alternative scenario (both directions)									
MOBILITY									
Annual Number of Pass. Trips									
Annual # of Pass Pk-per Trips*									
Vehicle Miles Traveled									
VMT (Peak period)*									
Passenger Miles Traveled									
PMT (Peak Period)*									
AIR QUALITY									
Emissions (tons of pollutants)									
SAFETY									
Number of Crashes									
Fatalities									
USER COSTS in millions $									
Variable User Cost									
Periodic User Cost									
AGENCY COST in millions $									
Alternative Capital Total **									
Alternative M&O Total									
Service Delivery Component									

Form EE Part 2. Net Social Benefit Table

Project/Alternative Name:

Year	Date	User Benefits	Air Quaility Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
Present Value								
Annual Value								
Perpetuity Value								

* Decision-Making Year
** Difference in yearly User Costs between No-Build and Alternative from MOE Form L
Benefits and Cost are in millions $
Present Value is based on the Interest Rate on Form EE-1, as is Perpetuity Value
Annual Value is based on the Interest Rate and Annualization Period on Form EE-1

Prioritizing Using Measures of Effectiveness

The comparison of alternatives or projects with MOEs is a matter of looking at each MOE side-by-side to see which alternative has the better MOE. Most methods to prioritize (rank) alternatives with MOEs involve some formula to weight and aggregate the MOEs so that conflicting MOEs are reduced to a net result in a single measure. A method that uses weights for selected MOEs to produce and overall index is presented in Chapter Five. It is a type of objective, ordinal index with properties that make it useful and understandable to decision-makers. The analyst can initially select the weights used and refine them to meet the preferences of the decision-makers. For every alternative or project being considered an index value is determined. Based on this index value, projects can be ranked from better to worse.

The MOE index is defined by $I = M_1^{a_1} M_2^{a_2} M_3^{a_3} \ldots\ldots M_n^{a_n}$

where, I = MOE Index
M_n = Measure n
a_n = exponent

The recommended measures for evaluation are:

- ☐ *Mobility:* M_m = Average Speed for all modes considered
- ☐ *Safety:* M_s = 1/Number of highway fatalities
- ☐ *Air Quality:* M_{aq} = 1/Tons of Pollutant
- ☐ *Agency Cost:* M_{ac} = 1/Agency cost

The inverse of the last three measures is taken to indicate that increasing values of the measures are preferred, as explained in Chapter Five. Properties of this index such as the rate of substitution between measures and the index elasticity are also discussed in Chapter Five.

Prioritizing Using Economic Efficiency

Comparing alternatives or projects using EEA must take into account the fact that there may be assets of different useful lifetimes and construction periods. For example, additional lanes on a highway may have a useful life of 30 years, whereas a light rail line along the same corridor may have a useful life of 50 years. Their NSB cannot be directly compared because the expenditure for the rail alternative produces transportation services for a longer number of years. Comparison can be made by assuming each mode would be kept in service in perpetuity by reconstruction whenever necessary in the future. Then the economic efficiency measure is the *perpetuity value* of each project. This is easily calculated from the NSB for each project and can be included on the NSB worksheet. The Perpetuity NSB provides a correct economic efficiency ranking of alternatives for decision-makers to use in their deliberations, if projects of unequal asset lifetimes are being compared.

Sensitivity Analysis

The purpose of sensitivity analysis is to determine the level of confidence in the analysis results. Given the inherent uncertainty in the estimates upon which the MOE and EEA are developed, analyses of sensitivities for the different variables used should be conducted. This would give a better understanding of the effects of increased or lowered values for the variables used in the evaluation. The general idea is to determine how large a change in the variable would have to be to change the results suggested by the analysis. If the size of the change in a given variable is so large that the value for the variable is thought to be extremely unlikely, that would suggests consistent analysis results. A more complete explanation on sensitivity analysis is given in Chapter Five and Appendix Two.

> Since the analysis follows from assumed changes in population and travel demand, it is recommended that the MOE and EE analysis be performed with at least two levels of population and demand assumptions

Chapter 1

Background to Measuring Performance for Project Specific Purposes

Purpose of the Research

The purpose of the Colorado research project "Developing Common Performance Measures to Evaluate Transportation System Investments Across Modal Lines" was to establish a framework and develop simple tools that allow a consistent means of making economic and performance comparisons across passenger modes of transportation within a corridor project.

The Common Performance Measures (CPM) research products analyze information by applying an economic efficiency analysis and/or the measures of effectiveness approach. Different modes operating in a corridor environment can be accommodated in a manner that allows transportation practitioners and decision-makers to compare different modal solutions. CPM results are used to compare a wide variety of alternatives including measures for highways, transit, rail, pedestrians, and bicycles. These results are categorized by core areas including: agency cost, user cost, safety, mobility, and air quality. These core areas consider a variety of measures, that can be used under a broad variety of settings, such as travel time, operating and maintenance expenses, users out-of-pocket expenses, accident risk, and other. Local practitioners may want to consider additional performance measures, which address other local concerns.

The analysis methodology produced by the CPM research is especially useful for rural and small urban transportation planning regions. It is not intended to supplant the more sophisticated methods used to analyze projects in large Metropolitan Planning Organization (MPO) areas. An example case that shows the use of the simplified analysis tools developed by the CPM research is presented in Appendix Two. This approach can be used to evaluate individual corridor projects throughout the region or to compare a number of alternatives within a corridor.

The tools developed are intended to be used at the sketch-planning level. Although economic efficiency analyses and analyses based on MOEs could be applied at the project design level, that was not the charge of this research effort. The proposed calculations apply core measures to produce results that help transportation practitioners see the relative value of making a particular corridor transportation investment. These tools are very helpful because they use a consistent means of comparing a variety of multi-modal projects.

Frameworks

The CPM research has developed two different means of analyzing information--economic efficiency analysis and measures of effectiveness. These two conceptual frameworks are complementary in many areas, yet they answer different questions. They often use the same data and build upon each other's measures. However, the use of one does not supercede the use of the other. The results of the efficiency analysis present information in monetary terms. The effectiveness analysis hones in on particular elements that support goals commonly cited by many Colorado communities.

Economic Efficiency Analysis (EEA)

The concept of economic efficiency is a way of measuring if the people in a region are in general better off by undertaking a particular transportation investment. Efficiency is interested in finding opportunities to change the way resources are utilized so that the lives of most people in a community would be improved compared to the status quo while at the same time no one would be worse off because of the investment.

The term community is included in the efficiency definition. At the sketch-planning level the CPM economic efficiency framework does not recommend what community should encompass. From the regional planning perspective, it could be the whole region or it could be only that portion which is directly impacted by the proposed project. Analysis of the same project can be done from the perspective of different communities and reach different conclusions. Suppose there were two counties and three towns whose residents would be affected by the proposed project. There could be three different efficiency analyses for the towns. It is conceivable that while the project might allow people in the first town to be better off, the people in the second and third towns might be worse off. What helps one community may negatively impact a neighboring community. Given the conflicting information, transportation decision-makers must make the choice.

EEA offers a single, comprehensive answer in terms of net social benefits (NSB). This framework calculates in monetary terms the significant costs and benefits of an investment and determines a bottom line net social benefit. A positive NSB indicates a wise investment while a negative NSB shows that the costs exceed the benefits. EEA may also indicate the relative ranking of certain alternative investments, that is, which one has the greatest net benefit, which has the next best net benefit, etc.

A benefit is defined as the maximum amount a person is willing to pay to get the desired objective. A cost is equal to the minimum amount a person is willing to accept as compensation for being worse off.

The starting point for efficiency is to develop a baseline. The baseline case measures what happens if no new investments are undertaken. Then, cases are built for the suggested investment(s). Because economic efficiency measures the changes from the baseline, one must next determine benefits and costs that represent the changes the proposed investment will bring compared to the baseline. *Only when there are changes from the baseline are costs or benefits included in the calculation of NSB.* When the benefits minus the costs are greater than zero, the investment is efficient. If the benefits minus the costs are less than zero the investment is inefficient and should not be pursued based upon the efficiency results.

The efficiency tool considers the costs and benefits in each year of the planning timeline. It calculates the net social benefit and then brings the figures to a present value. If the NSB number is positive, it indicates the investment will make the community better off. If the figure is negative, the investment over the period will make people in the community worse off. The efficiency tool allows the costs and benefits of the investment to be calculated in perpetuity, which allows alternatives with different investment cycles to be fairly compared.

Measures of Effectiveness (MOEs)

The MOE framework first asks the user to determine what goals, standards, and/or benchmarks are of most importance. An effective investment action is one that supports the achievement of a specified goal or goals so that an investment achieves intended results.

The MOE approach is concerned with how well something is done. MOEs are not always looking for "biggest" or the "most." Rather MOEs look to fulfill designated expectations. The effectiveness framework allows the measurement of how certain choices meet specific goals that reflect certain community objectives. For example, one community chooses a goal to improve air quality because the community is in a non-attainment area and desires to make investments in alternative modes. From a community-wide efficiency standpoint, investment in a Transportation Demand Management (TDM) strategy that mainly impacts large employers provides fewer mobility benefits than widening a long stretch of the interstate. However, the community, as a non-attainment area, could not first implement the widening project without violating federal air quality standards. Therefore, the community may choose to implement the TDM strategy in spite of its lower overall efficiency rating because its offers greater air quality gains.

Some goals may contradict other goals. MOEs allow for the independent consideration of the goals or objectives. Effectiveness presents the community designated important factors for review but does not combine the factors with each other. Safety goals may be reviewed separately from air quality goals and one may be given a higher level of importance than the other.

The effectiveness framework is useful when performance related to particular markets or segments of the community need to be tracked. For example, if the economy is shrinking, sacrifices may be required of the community, but the decision-makers may wish to hold certain individuals or groups (e.g., children, disabled) harmless. MOEs can determine which alternatives support the goals and ensure the designated market segments are not harmed.

MOEs can answer questions that are outside the realm of efficiency. Since economic efficiency compares changes between a baseline and a proposed alternative in terms of costs and benefits, it typically calculates the values in monetary terms. The effectiveness framework uses measures that may or may not be expressed in monetary terms and it does not calculate a monetary bottom line.

Decision-makers can place more emphasis on one or several components of performance in order to show progress in solving a particular problem. Safety is often a highly visible concern for both decision-makers and the general public. The effectiveness framework allows safety implications of certain investment choices to be considered without reducing to monetary terms the costs/benefits of accidents. MOEs could look at trends in accidents or place more importance on reducing accidents that impact certain locations.

The MOE framework results will most often be shown through the use of a matrix. The goals are set out along one axis and the performance measures along another. A score may be developed which allows for numeric calculations and/or weighting of the scores. MOEs can also use a more qualitative means with descriptive measures. Scores may also indicate a trend (i.e., decreasing pounds of pollution) without attaching actual numbers to the score.

Core Measurement Areas

The field of transportation planning and investment often uses conceptual categorizations that can best be described as overlapping rather than discrete groupings. The CPM research has organized its efforts by separating the performance measures into five core areas of interest–Agency Cost, User Cost, Mobility, Safety and Environment. The parameters of each of the areas follow.

AGENCY COST refers to all of the capital, maintenance and operating expenses incurred by agencies responsible for constructing and maintaining transportation facilities. The facilities would include not only the primary facility that is used by the traveling public but also major auxiliary facilities. Capital costs cover the construction and/or purchase of the physical infrastructure and/or asset. It includes design, engineering, ROW and start-up expenses for program implementation. These costs are incurred infrequently yet involve significant levels of investment. Capital also covers major expenses that extend the life of the facility into perpetuity, such as reconstruction of a roadway surface or overhaul of a locomotive engine. Maintenance costs include the expenses to keep the physical structure/asset at the prescribed industry condition standard over the design life of the project. These are recurring costs, such as salary and materials for filling potholes. Operating costs involve the ongoing expenses to keep the facility/service functioning. They include service delivery costs such as the salaries of transit drivers and ticket salespersons. Agency cost also includes the agency's total administrative costs that are often expressed as a percentage of the total costs.

USER COST refers to the total expenses incurred by all individuals impacted by the transportation system. This item includes fixed and variable costs. The former covers such items as ownership/depreciation, insurance and registration. Variable costs are tied to the trip making such as gasoline, parking, tolls, or bus fares.

MOBILITY refers to the elements of travel that are concerned with the actual movement of people, goods and information. Mobility elements can include travel time and delay, speed, number of persons moved, capacity limits of the facilities and the length of travel. Other measures involved include volume to capacity ratio, passenger miles traveled per hour and vehicle occupancy. For efficiency analysis the major component is often the value of the travelers' time.

SAFETY refers to elements that measure the incidence of injury, fatality and risk. Safety performance measures consist on raw numbers of accidents and fatalities. The measures might also be expressed in monetary terms indicating the amount a community is willing to pay to reduce the risk of one fatality.

AIR QUALITY refers to quality of life elements concerned with pollution. The major air quality component considered is the amount of pollutants emitted by vehicles.

Definitions

Unfortunately, there is no standard definition for a number of the terms used in this research, including alternatives, facilities and modes. For instance, modes and alternatives may be used synonymously in one article while these same terms have very different meanings in other contexts.

For the purposes of the CPM research, these terms will have the following narrow definitions.

ALTERNATIVE refers to a transportation investment choice that is viewed as a single unit. An alternative can be comprised of a single mode or multiple modes and it may also include transportation demand strategies such as signal timing improvements or incident management.

ANALYSIS YEARS refers to the years for which data is generated in the evaluation effort. These years usually include the long range planning time frame, for example 20 years in the future with values also calculated for the intermediate points of five, ten and fifteen years.

ANNUAL VALUE *(see Financial Definitions section at the end of these Definitions)*

AVERAGE SPEED is the speed (distance passed per unit of time) at which vehicles or a person travels. For transit vehicles, it includes dwell times at stops or stations, acceleration, and deceleration.

BASE YEAR refers to the most recent past year for which input data is available. For example, it may be 1990 for census data.

CRASH is a traffic crash or accident that involves a single road vehicle (overturns), or it may involve a vehicle in a collision (e.g., between a vehicle and one or more vehicles, a pedestrian, an animal, or a fixed object). Vehicles can be motorized vehicles or bicycles, and the accident may involve an injury to a person (fatal, serious, or slight) or damage only to property.

DECISION-MAKING YEAR refers to the year to which future values are discounted to get their present value. It is usually the year in which the analyst conducts the evaluation.

DISCOUNT RATE refers to the amount to which future values are adjusted to obtain the present value. It is recommended that the U.S. Office of Management and Budget rate of 3.6% be used.

EFFECTIVENESS refers to taking actions that support the achievement of predefined goals.

EFFICIENCY refers to allocating the resources available to a community in a fashion such that it is impossible to increase the well being of at least one person in the community without decreasing the well being of some other person or persons in the community.

EMISSIONS (In Tons of Pollutants) is the level of air pollution contributed by the transportation system in the corridor under study.

FACILITY refers to the physical structures or equipment that are necessary for the movement of people or goods. A facility could be a roadway or the rail tracks. The term facility also refers to capital equipment items needed to complete the travel demands, thus it could include vehicles (including personal autos), other rolling stock, parking lots and other necessary buildings locations.

FATALITY refers to an occurrence which involves a person who dies as a result of an injury sustained in a crash or accident (at the place or within a few days).

FATALITY RISK refers to the dollar amount that people are willing to pay to reduce the risk of an auto fatality.

MEASURE OF EFFECTIVENESS (MOE) is a quantitative measure to determine how well an activity, task, or category of function is being performed. Examples of MOEs are; average speed, VMT, PMT, for mobility and, number of crashes and fatalities for safety.

HIGH OCCUPANCY TOLL (HOT) LANE refers to a facility that allows the use of HOV lanes by vehicles with below the minimum number of occupants when they pay a fee or toll.

MODE refers to the means employed to move people or goods from an origin to a destination. The most common surface transportation modes are driving personal autos, trucking, riding public transit or rail, bicycling and walking.

MODE SPLIT refers to the percentage of trips being taken on each mode when more than one mode is being used.

NET SOCIAL BENEFITS TABLE contains three terms which require clarification with respect to the definitions of benefits and costs. The PresentV row is the sum of the present value of yearly figures in the column above. It is the present value of User Benefits, the present value of Air Quality Benefits, etc. as these terms are defined. AnnualV is the annual equivalent of the present value in the row above over the lifetime of the project. PerpetuityV is the perpetuity value of the benefits or costs in the column above as this term is defined.

NO-BUILD refers to the future planning scenario that considers no changes or improvements to the baseline conditions.

PASSENGER-MILES-TRAVELED (PMT) refers to the total miles traveled by all passengers in a given area or corridor using any travel mode during a specified time period. For transit, it is calculated as the total number of passengers carried by a transit system multiplied by the number of miles they travel. For passenger cars, it is calculated as the product of the VMT times the average occupancy per car.

PERIODIC USER COST refers to the traveler's annual expenditures on goods and services needed to access the transportation system. These expenditures are mainly associated with automobile ownership and include purchase, insurance, repairs/parts/tires, registration/licensing and taxes. The expenditures do not depend directly on the number of miles traveled.

PERPETUITY VALUE *(see Financial Definitions section at the end of these Definitions)*

PRESENT VALUE *(see Financial Definitions section at the end of these Definitions)*

TRAVEL TIME refers to the time duration of a trip from the point of origin to the final destination. Usually includes waiting and walking time at transfer points and trip ends. In the CPM worksheets, travel time is calculated by dividing the segment or corridor length by the average speed of travel.

TRIP is a one-way movement of a person or vehicle between two points for a specific purpose. In the CPM worksheets, every trip considered is assumed to go from the beginning to the end of a segment.

VALUE OF TIME refers to the dollar amount applied to people's time. It is recommended that one-half the gross wage rate (Colorado or local) be used as default.

VARIABLE USER COST refers to the traveler's dollar expenditures which change depending on the number of miles traveled each period, the value of the time spent traveling, and the value of fatality risk for each mile traveled. Dollar expenditures included are those due to gasoline, transit fares, parking, and tolls. Depending on the trip and the corridor, not all categories of expenditures may be incurred. If this MOE goes up from one year to another, it means that the transportation system being studied is more expensive for travelers to use, per mile traveled, in terms of other things they could do with their income and wealth.

VEHICLE-HOURS-TRAVELED (VHT) refers to total hours traveled by all vehicles in a given area or all transit-vehicle hours operated during a specified time period. It is calculated as the number of vehicles multiplied by the average travel time per trip during the time period considered.

VEHICLE-MILES-TRAVELED (VMT) refers to the total miles traveled by all vehicles in a given area or all transit vehicle-miles operated for a specified time period. It is calculated as the number of vehicles multiplied by the length traveled in a given corridor or analysis area, during the time period considered. To estimate VMT in the worksheets it is assumed that every trip considered travels the entire segment length.

Financial Definitions

PRESENT VALUE is the value of a future dollar amount discounted to the decision-making year using an interest rate. The interest rate used is often called the discount rate.

Present value can be thought of as how much a future amount is worth to you today, when you are trying to make a decision. For example, for two investment options: $10,000 today which grows to $50,000 in year 10 and a $10,000 investment today which grows to $75,000 in year 15. At a 10% discount rate, the present value of $50,000 is $19,277, whereas the present value of the $75,000 return is $17,954. The latter investment has the higher present value for a 10% rate.

ANNUAL VALUE is the annual equivalent of the present value of a column of figures defined over the same period of years as the present value and using the same discount rate. Annual value is a concept best defined by illustration. Suppose a project gives benefits in each of 10 future years and the dollar amount of the benefits is different in each year. The present value of each future benefit first needs to be calculated, and then the 10 present values are added together. The sum total is called the present value of the project. Now suppose the benefit amount in each of the 10 future years is replaced by an equal amount. If that number gives the identical present value, it is called the annual value of the project. An annual value is a figure which, in a uniform series of future amounts, is equivalent to the present value. It is used to compare projects of different useful lifetimes, or the perpetuity value of a project.

PERPETUITY VALUE is a present value that assumes the expenditure pattern of benefits and costs of a project is replicated forever. The idea is that once the transportation infrastructure of a project is in place, it is maintained, operated, and reconstructed to keep it in service forever. It is useful to compare alternative projects that have different lifetimes, such as adding highway lanes to a corridor with a 30-year lifetime to a commuter railroad along the same corridor that has a 50-year lifetime. The perpetuity value is calculated by dividing the annual value by the discount rate.

CONSUMER SURPLUS is the difference between what users are willing to pay to use a transportation system and what they actually pay for using it.

Definitions by Core Area

MOEs			EEA	
Agency Cost				
Total Capital Costs	Capital construction and/or purchase cost for an alternative valued for the decision making year		Present Value Capital Cost	Capital cost as defined under MOE except that the value of capital costs today (present value) equals the value of expected future costs, discounted back to the present at the appropriate interest rate
			Perpetuity Value Capital Cost	Same as Present Value Capital Cost excepting that the expenditure pattern of costs and benefits is assumed to be replicated forever. Needed to compare alternatives that have different lifetimes.
Total M&O Costs	The cost of ongoing expenditures to keep the capital asset or service in working order. Includes Service Delivery Costs for the costs that transit operations (bus and rail) incur that could be compared to the out of pocket cost incurred by SOV users.		Present Value M&O Cost	See present value discussion, only applied to M&O costs.
			Perpetuity Value M&O Cost	See perpetuity value discussion, only applied to M&O costs.
Service Delivery Cost	Total M&O costs for transit modes attributed to offering passenger service. Main components are wages for workers and vehicle fuels.		Present Value Service Delivery Cost	The costs that transit operation (bus and rail) incur that could be compared to the out-of-pocket costs incurred by SOV users.
			Perpetuity Value Service Delivery Cost	See perpetuity value discussion, only applied to service delivery costs
User Cost				
Variable User Cost	User costs which change depending upon the amount of travel done (e.g., fuel, parking, tolls, and fares).		Variable User Cost	User costs which change depending upon the amount of travel done (e.g., fuel, parking, tolls, and fares).
Periodic User Cost	User costs which occur on a recurring basis but not directly related to the amount of travel (e.g., vehicle purchase, insurance, maintenance, etc.).		Periodic User Cost	User costs which occur on a recurring basis but not directly related to the amount of travel (e.g., vehicle purchase, insurance, maintenance, etc.).

MOEs			EEA	
Mobility				
Passenger Trips	Vehicle trips times vehicle occupancy, or non-vehicle trips.		Passenger Trips	Vehicle trips times vehicle occupancy, or non-vehicle trips.
Average Trip Travel Time	Summation of the products of PMT times travel time for all segments for both directions divided by total PMT.		Average Trip Travel Time	Summation of the products of PMT times travel time for all segments for both directions divided by total PMT.
Vehicle Hours Traveled	Total number of vehicle trips including all modes multiplied by the average travel time per trip.			
Passenger Miles Traveled	Total number of miles traveled by passengers using motorized or non-motorized modes.			
			Present Value User Benefits	The value of travelers' saving in travel time and increase in consumer surplus* excepting that the value of the savings and increase today (the present value) is the value of expected future savings and increase discounted to present at the appropriate interest rate.
			Perpetuity Value User Benefits	Same as present value User Benefits except that the user benefits are assumed to be replicated forever.
Capacity Utilization	Ratio of the number of passenger trips using motorized modes over the total number of seats available per direction			
Maximum Theoretical Capacity	Maximum theoretical number of passengers that can pass a section of a transportation facility per unit of time under ideal conditions.			
Safety				
Fatalities	Number of deaths occurring in a transportation system due to vehicle crashes or incidents per unit of time. Calculated by multiplying the fatality rate per units of travel by the exposure for each of the modes.		Fatalities	Fatality frequency per exposure per unit of time where exposure is derived from annual VMT per mode by the fatality rate for the respective mode
Crashes	Number of traffic crashes or accidents that occur in a transportation system. Estimated as the frequency per exposure (in units of			

	travel) per unit of time.			
			Present Value Safety Benefits	People's annual willingness to pay to reduce risk of fatality associated with travel, except that the value of the willingness to pay today (the present value) is the value of expected future costs discounted back to the present at the appropriate interest rate
			Perpetuity Value Safety Benefit	Same as present value of safety benefits except that the willingness to pay is assumed to be replicated forever
MOEs			**EEA**	
Air Quality				
Emissions	Total amount of pollutants in tons per year. Equal annual VMT times the emissions rate per VMT.		Emissions Tons	Total amount of pollutants in tons per year. Equal annual VMT times the emissions rate per VMT.
			Present Value Air Quality Benefit	The value of human health damages avoided per ug/m^3 per person, except that the value of the avoidance today (the present value) is the value of expected future costs discounted back to the present at the appropriate interest rate.
			Perpetuity Value Air Quality Benefit	Human health damages avoided per ug/m^3 per person, except that the avoidance is assumed to be replicated forever
Net Social Benefit				
			Present Value Net Social Benefit	Total Value of the agency cost, user costs, air quality, and safety values, where the value of the net benefit (or cost) today (the present value) is the value of expected future costs discounted back to the present at the appropriate interest rate.
			Perpetuity Value Net Social Benefit	Total Value of all measures, except that total benefit or cost is assumed to be replicated forever

Modes of Passenger Travel

To meet the needs of end users, the CPM research team decided to concentrate on a limited number of modes. Selection criteria were applied to the numerous modes cited in the literature in order to limit the CPM modes. The following criteria were used:

(1) A mode is currently used or is a readily accepted means of passenger travel in Colorado, or
(2) A mode can have significant impact on planning and project selection processes.

While other modes may be reasonable and would add to the overall picture of the costs and benefits of the transportation system, these modes have little or no impact on the types of decisions this research attempts to enhance. For instance, the CPM research is only concerned with passenger ground transportation; therefore, trucks, freight rail and air transportation are not included. Modes that do not currently operate in Colorado may be added at a future date.

The Common Performance Measures research will initially limit the modal choices to Single Occupancy Vehicle (SOV) travel, High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) travel, Bus Transit, Light Rail Transit, Commuter Rail, and Bicycle. Travel Demand Management (TDM) is an important component, although strictly speaking, it is not a true mode. A Pedestrian mode is also included although it is expected that it will mainly be involved as a sub component used in the travel time calculations. Definitions of these CPM modes follow:

SINGLE OCCUPANCY VEHICLE (SOV) TRAVEL refers to personal travel in a private vehicle and the vehicle occupancy average is calculated to be one person.

HIGH OCCUPANCY VEHICLE (HOV) TRAVEL refers to personal travel in carpools and vanpools. The impact of this mode involves alternatives that include use of high occupancy vehicle lanes.

HIGH OCCUPANCY TOLL (HOT) TRAVEL refers to personal travel in SOVs that travel in existing HOV lanes by paying a fee or toll.

BUS TRANSIT refers to travel in a professionally operated rubber tired on-road transit vehicle. The size of the vehicle can range from a five passenger van to a 60 passenger articulated coach.

LIGHT RAIL TRANSIT refers to travel in a rail vehicle, which depends on an overhead catenary power system and runs on railroad tracks. The tracks may be located either in a separated rail right of way or within existing roadways.

COMMUTER RAIL refers to travel in passenger rail vehicles running on tracks that meet national railroad system standards and links outlying portions of a region to business activity centers.

BICYCLE refers to travel on a non-motorized, self-propelled two or three wheeled vehicle. This mode is included because certain transportation funding decisions such as building shoulders to accommodate bicycle riders safely or allocating enhancements funds for bicycle projects are a common part of Colorado's transportation system choices.

PEDESTRIAN is the final mode that needs to be factored into calculations. This mode, which refers to travel accomplished by walking, should be considered because a portion of most trips may be completed using the pedestrian mode in combination with other modes listed above. For example, a person may walk from a business to a bus stop and then ride the bus to a park and ride lot where the person drives home in a private car. To accurately account for costs, the walking time is often priced differently from the riding and driving time.

TRANSPORTATION DEMAND MANAGEMENT (TDM) is an element that is relevant to the research tasks, but does not easily fit into the analytic framework. TDM can be broadly defined as a number of strategic actions that can be undertaken to solve particular transportation problems. TDM often includes supporting changes in individual behavior where the desired result is a change in modal share. For example, one TDM strategy might include raising parking fees to encourage use of transit, bicycles or walking and discourage the use of SOVs. TDM can also encompass use of new technologies often referred to as Intelligent Transportation Systems (ITS). An ITS example is providing real-time travel information for a number of modes. TDM can also be directly tied to one mode such as administrative and operating support for ridesharing programs. The relevancy of TDM measures to the success of modal choices is clear. What remains unclear is how the multi-faceted nature of TDM measures can be generically accounted for by this research.

Chapter 2

Developing and Analyzing a Project

Projects and Problems

The most common types of problems that are amenable to analysis are congestion, safety, and air quality.

- Congestion of all forms from stop-and-go traffic on freeways to long queues on main streets. Projects that increase highway capacity (additional SOV, HOV, or HOT lanes) are traditional solutions to congestion problems. New or improved transit systems (Bus, LRT, CRT) and non-motorized modes (bike paths, pedestrian paths) can also be solutions to congestion problems.
- High numbers of accidents and/or fatalities. Projects that change highway geometry or intersection configuration can be solutions to safety problems.
- Environmental problems such as the need to lower vehicle emissions to meet air quality requirements. New or improved transit systems and non-motorized modes can help with air quality problems.

Analysis Hierarchy

The methodology explained here can be used at several levels of decision making:

- At the top level, proposed projects of various actions can be compared to one another in terms of net social benefit.
- The next level down, individual corridors or projects can be analyzed independently of, or compared to, other corridors or projects.
- In the third level, various solutions to a mobility problem within a corridor or project can be compared.

Most of the discussion in this chapter is focused on the third level. The higher levels are not covered in this discussion.

Project Analysis

The process to analyze a project is carried out with the aid of the worksheets described below, which are available in spreadsheet form. A disk with a Microsoft Excel spreadsheet file is contained in the back pocket of this report. The MOE and EEA worksheets and detailed instructions are available in Chapters Three and Four, respectively. The *Evaluation Process Decision Tree* (Figure 2.1) on the following page illustrates the various components to an EEA or MOE analysis.

Choosing a Framework

The analyst must decide which framework(s)--economic efficiency and/or measures of effectiveness--by which to examine the project. It is highly recommended that both the MOE and EEA approaches be applied to a project. In fact, one can not conduct an EEA analysis without having completed the MOE analysis first.

MOE Analysis Process Steps

To begin the analysis of a project, one must conceptualize the alternatives to be examined, collect baseline data pertinent to those alternatives and the chosen framework(s), and aggregate the corridor into logical segments.

A **User Input Table** is provided to organize needed baseline data by framework and alternative type. A description of this table and a copy of the table are provided later in this chapter. Suggestions for aggregating the corridor segments are also described in this chapter, as are sources for retrieving baseline data. **Reference tables** and site specific tables are provided in the appendix.

The process steps for conducting an MOE analysis include the following steps:

1. Complete the User Input Table by describing the corridor and alternatives to be analyzed, and gather baseline data for the chosen framework.

2. Define the corridor segments.

3. Calculate baseline year MOEs for each segment. The baseline year is a recent year for which data needed for the MOEs (e.g., traffic volumes or population counts) are available.

4. Calculate MOEs for future years for each segment. Each year for which MOEs are calculated is called an analysis year. The number of analysis years depends on the useful life of the project, the methodology being employed, and the planning horizon being used in the TPR plan. If *only* the MOE approach is to be applied, one future year is sufficient (e.g., year 2020). However, if the EEA approach is applied, then at least two future years need to be considered to perform the MOE and EEA calculations. Intervals between analysis years must be no longer than 10 years (e.g., years 2010 and 2020).

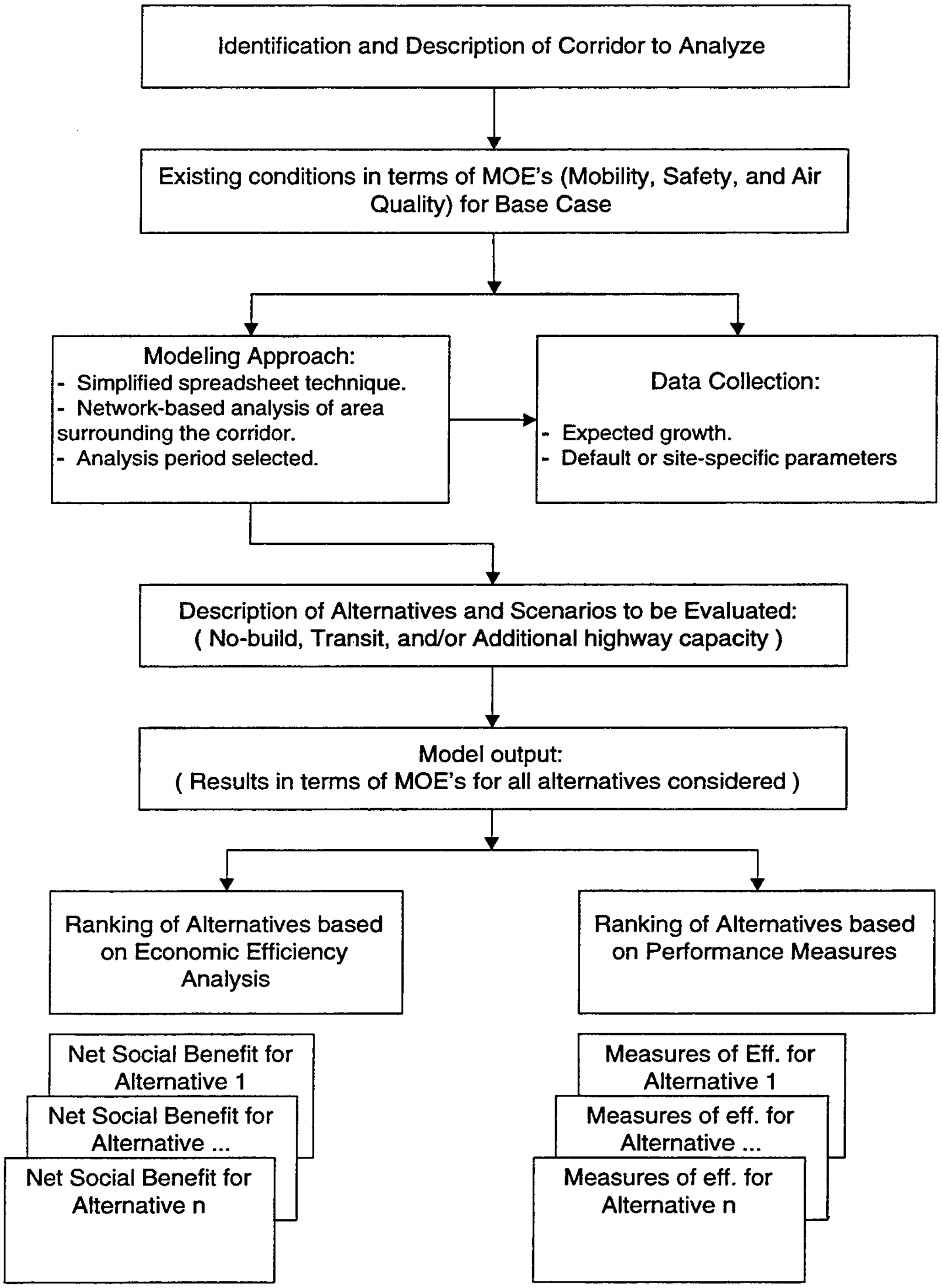

Figure 2.1. Evaluation Process Decision Tree.

5. Calculate the No-Build scenario for each analysis year and segment selected under step four in order to examine the conditions if the project were not built. One pass through the No-Build worksheets is needed for each analysis year.
6. Develop the Project or Alternative ("Build") scenarios for each segment with assumptions about travel patterns as if the project were in place for each of the analysis years. One pass through the Alternative worksheets is needed for each analysis year.

At this point in the process, MOEs will have been calculated for the baseline, build and no-build scenarios for each segment and analysis year. The analyst can summarize the results onto the summary sheets and begin to make comparisons between the scenarios (see Chapter Five), or the analyst can move onto the development of the EEA.

EEA Process Steps

After completing the MOE analysis, the analyst would complete the economic efficiency worksheets to calculate NSB for the project. One pass through these worksheets is needed for each analysis year for user, safety, and air quality benefits. Remember that EEA may require the analysis of more than one future year (e.g., years 2010 and 2020). Agency cost and NSB worksheets are used only once because they summarize for all analysis years. In the case of an analysis with two or more alternatives, the process must be repeated for each alternative.

User Inputs and Project Description Checklist

The purpose of the User Input Table is to provide a convenient place for the analyst to record information that is needed to complete the worksheets and tables for the effectiveness and efficiency analysis. Before a proposed project can be analyzed, a complete description of the corridor or project is needed to determine the conditions under which the analysis will be done. User input falls within the following categories:

- ☐ Analysis Information (e.g., current and future years, analysis period, etc.)
- ☐ General Project Information (e.g., project description, description of alternatives, etc.)
- ☐ Project Information for MOE Analysis (e.g., capacity rates, occupancy rates, volumes, mode splits, cost information, etc.)
- ☐ Project Information for EEA Analysis (e.g., value of time, price elasticity per mode, etc.)

Form UI provides a checklist of most input data required to analyze a project or corridor. It consists of three tables containing general and mode specific information at the corridor and segment levels. Some data items are included in the MOE forms instead of Form UI (e.g., capital, operating, and maintenance costs).

FORM UI: USER INPUT AND PROJECT/ALTERNATIVE DESCRIPTION CHECKLIST

Project Location / Name:____

A. Analysis Information

Analysis Time Period	Analysis Congested Periods / Day	Analysis Congested Days / Year	Baseline Year	Decision Making Year	Analysis Year (1) - Start Construction	Analysis Year (2) - Project Opening	Analysis Year (3)	Analysis Year (4)

B. General Project Information

Project Description	
Future Alternatives Proposed	
Length of Corridor (in miles)	

C. Project Information for MOE Analysis

Number of Corridor Segments					
Analysis Period trips as a % of AADT	SOV	HOV	HOT	LRT	CRT

D. Project Information for EEA Analysis

<table>
<tr><td>Capital cost / lane or track /mile</td><td colspan="6"></td></tr>
<tr><td>ROW Cost / mile as a % of Capital cost</td><td colspan="6"></td></tr>
<tr><td>Annual M&O costs</td><td colspan="6"></td></tr>
<tr><td>Interest rate used for discounting</td><td colspan="6"></td></tr>
<tr><td>Useful life of Asset</td><td colspan="6"></td></tr>
<tr><td>Value of Time in dollars per hour</td><td colspan="6"></td></tr>
<tr><td rowspan="2">Fare per trip in dollars.(for transit modes only)</td><td colspan="2">Bus</td><td colspan="2">LRT</td><td colspan="2">CRT</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Price elasticity (for motorized modes only)</td><td>SOV</td><td>HOV</td><td>HOT</td><td>Bus</td><td>LRT</td><td>CRT</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Form UI (cont'd)

E. Project Information for MOE Analysis* – Mode Specific

	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PED
Occupancy rate per passenger car				NA	NA	NA	NA	NA
Alpha value for highway travel-time function				NA	NA	NA	NA	NA
Beta value for highway travel-time function				NA	NA	NA	NA	NA
Capacity per train car / bus (seats) under alternative	NA	NA	NA				NA	NA
Number of trains / buses per analysis period under alternative	NA	NA	NA				NA	NA
Average speed in miles per hour	NA	NA	NA					
Expected % growth in trips, from baseline to last analysis year								
% of passenger trips to switch to new mode in the analysis year								
% of highway capacity reduction during construction period								
Additional expected % grow in trips due to improved alternative								
Emissions rate per VMT							NA	NA

* All MOE inputs are required to do the Economic Efficiency Analysis

Form UI (cont'd)

F. Segment Specific Information by Mode for MOE Analysis*

	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PED
Crash rate per VMT							NA	NA
Fatality rate per VMT							NA	NA
Number of baseline lanes per direction				NA	NA	NA	NA	NA
Number of lanes / tracks / paths to be added by alternative								
Capacity per lane in vehicles per hour.				NA	NA	NA	NA	NA
Highway free-flow speed				NA	NA	NA	NA	NA
Number of buses under alternative	NA	NA	NA		NA	NA	NA	NA
Number of cars per train under alternative	NA	NA	NA	NA			NA	NA
Segment Length, in miles								
Trips by direction for baseline year **A-B**								
B-A								

Repeat this form for every segment in the corridor

Definition of Corridor Segments

Most of the highway data contained in the CDOT GIS database is organized by relatively short links (about one mile or less). Given that study corridors are usually longer than a few miles, aggregation of the links into longer segments is needed in most cases in order to obtain MOEs or to perform EEA using worksheets. Groups of highway segments can be aggregated according to the following conditions:

Aggregate Corridor Segments by:

- ☐ *Lanes*
- ☐ *Functional Class*
- ☐ *Speed*
- ☐ *Volume*
- ☐ *Congestion Level*
- ☐ *Length of Existing Transit Mode*

- ☐ **Lanes.** Similar number of lanes (i.e., consecutive segments with the same number of lanes can be grouped to form one segment).
- ☐ **Functional Classification.** Similar functional classification (i.e., consecutive segments with the same functional classification can form one segment).
- ☐ **Speed.** Similar speed limits.
- ☐ **Volume.** Similar volume or congestion levels (i.e., consecutive segments with approximately the same volume or congestion level can form one segment).
- ☐ **Length.** Length of existing travel modes (i.e., in rural or suburban areas segment groups based on number of lanes, functional classification, etc., can be split if there are major stops for transit lines within these segments). If different transit modes are considered these should have the same length, with stops at the end of each segment.

Since each corridor segment requires one pass through the set of worksheets, attention should be paid to define segments of appropriate length so as to avoid having an unnecessary large (more than five) number of segments to analyze. When the number of corridor segments obtained by applying the previous conditions is greater than five aggregation into longer segments can be accomplished by the following rules:

- ☐ For cases in which a segment was split based on speed limits, for two or more adjacent segments with speed limits within 5 to 10 mph difference, take the average of the speeds and make only one segment.
- ☐ For cases in which a segment was split based on functional classification, for two or more adjacent segments with speed limits within 0 to 10 mph difference, disregard the difference in functional classification and make only one segment.
- ☐ For cases in which a segment was split based on volume of trips, for two or more adjacent segments with speed limits within 0 to 10 mph difference, take the average of the volumes and make only one segment.

Obtaining Data for Worksheets

Different options for obtaining the input data to estimate MOEs for the scenarios analyzed consist of using: (1) default values, (2) site specific data, (3) existing local data (i.e., county data, transit agency data), and (4) data from CDOT's GIS planning database. Some data items available at CDOT are shown in the next table.

Data from CDOT's GIS planning database

Highways

Beginning Post Mile (BEG_RP)
End Post Mile (END_RP)
Segment Length (SEG_LENGTH)
Average annual Daily Traffic (AADT, AADT20)
VMT-based fatal crash rate (FAT_RATE)
Functional Classification (FUNCCLASS)
Number of lanes (THRU_LANES)
Speed limit (SPEEDLIM)

Public Transit

General data about transit agencies by county or TPR
Service Type (i.e., resort, demand response, fixed route, elderly/disabled)
Service Area
Operating Characteristics
Capital, Administration, and Operating Costs

Reference Tables

A series of reference tables give default values and information regarding many of the variables used in filling out the worksheets. Also, since in some locations or cases, analysts may wish to use values that more closely reflect conditions in the area of the project, some of the reference tables include guidelines to estimate site specific data. These tables can be found in Appendix One.

Reference Tables

Table R1	Crash and Fatality Rates
Table R2	Capital Costs
Table R3	Economic Indicators
Table R4	Elasticities
Table R5	Emissions by Mode
Table R6	Emissions by County
Table R7	Transit Fares
Table R8	Maintenance and Operating Costs
Table R9	Current and Future Travel Volumes by Mode
Table R10	Maintenance and Operating Component Elements
Table R11	Highway Travel Time Relationships
Table R12	User Costs
Table R13	Value of Time
Table R14	Average Travel Speed for Transit
Table R15	Capacity
Table R16	Average Percentage of Daily Trips per Hour
Table R17	Maximum Theoretical Capacity for Highway and Transit Modes
Table R18	Bike and Pedestrians Benefits

Chapter 3

Analyzing a Project Using MOEs

Automated Spreadsheet or Manual Worksheets

Two options are available to obtain the MOEs required to perform the simplified corridor planning analysis; manual forms or automated spreadsheets.

Manual Worksheets Version

Printouts of template worksheets from the "Manual MOEs" spreadsheet file included in the attached floppy disk can be used to perform all calculations by hand. Because of the extensive data input requirements, manual worksheets are not recommended for corridor analyses involving more than three segments.

Spreadsheet Version

An Excel spreadsheet program containing template worksheets by segment is provided to calculate Agency Cost, User Cost, Mobility, Safety, and Air Quality MOEs. The use of the spreadsheet program is recommended over the manual worksheets given the savings in data input, flexibility, and speed of the process.

The user enters segment data for the baseline case and the different alternatives as explained in Chapter Two. Each worksheet is repeated five times (for up to five different segments) in the spreadsheet provided. Once the required data is entered in the colored cells of the different spreadsheet pages, the remaining cells in these pages are automatically filled. Agency Cost, User Cost, Mobility, Safety, and Environmental MOEs for the baseline and analysis years are calculated and tabulated in the corresponding summary worksheets by segment and by direction. Summary worksheets that condense all segment summaries for analysis period and year are then produced to report corridor MOEs.

When there is more than one analysis year one spreadsheet file is completed up to Worksheet C and then copies are produced for each of the analysis years considered. For example an Excel spreadsheet for a particular alternative can be named ProjectName-AlternativeNumber.xls and if the analysis years are 2005, 2010, 2015, and 2020, four copies (one for each analysis year) can be made with names such as ProjectName-AlternativeNumber-2005.xls, ProjectName-AlternativeNumber-2010.xls, etc.

When more than five segments are needed to represent the analysis corridor, worksheet templates can be added at each of the spreadsheet pages. All segment worksheets in the different pages of the spreadsheet are placed at the same separation from each other (every 18 columns). That is, all worksheets for segment 1, segment 2, etc., begin at the same column. Segment 1 worksheets begin at column B, segment 2 worksheets begin at column T, segment 3 worksheets begin at column AL (18 columns after column T), etc. This separation should be maintained when copying additional segment worksheets (after the fifth) in order for the formula cells to be correct. For example, all worksheets for segment 6 can be produced by copying the worksheet for segment five and placing this copy in column CN (18 columns after the beginning of segment worksheet 5, in column BV). For segment 7, the worksheet copied should be placed in column DF (18 columns from column CN), etc.

Sequence of MOE Worksheets

Figure 3.1 shows a flow-chart of the sequence in which the worksheets are processed. The Agency Cost, User Cost, Mobility, Safety, and Environmental MOEs are obtained by sequentially filling the worksheets labeled A through M. Worksheets A through C are filled for each segment in the corridor, whereas Worksheets D through I need to be filled for each segment and for each analysis year. Only one set of Worksheets J-1 through M is filled for each analysis year considered.

Figure 3.1 also describes the purpose behind the first and second letters of the worksheet labels. For example, the second letters of the worksheet label (i.e., a, b, c, d, e, and f in Worksheets B-a, B-b, etc.) refer to worksheets relevant to passenger cars, Bus, LRT, CRT, Bike, and Pedestrian travel modes respectively. The numbers 1 and 2 on the labels (i.e., 1, and 2 in B-a1, and B-a2) refer to parts 1 and 2 of the worksheet. Worksheets B-a1, B-a2, E-a1, E-a2, H-a1, and H-a2 are used to estimate MOEs for passenger vehicles using different highway lanes (SOV, HOV, or HOT). Forms for SOV, HOV, and HOT are vertically arranged in the automated spreadsheet. On the other hand, when manual forms are used, a different worksheet is needed for each of the lane types. That is, one, two, or three sets of Form B-a, E-a, and H-a are used to calculate passenger car MOEs when one, two or three highway lane types exist in a particular alternative.

Description of Worksheets

Description of each of the manual worksheets follows. Manual forms can be found in the "Manual MOEs" spreadsheet file in the attached floppy disk.

FORM A: Baseline Conditions Corridor Data

Form A contains data on baseline corridor conditions and the number of trips by available mode for each direction for each segment. These base data consist of:

Corridor Identification. A label identifying the corridor analyzed. This label is common to all MOE forms.

Baseline Year. The baseline year is the most recent year for which data are available. This entry is common to Forms A through D and also Forms K-1, K-2, and M.

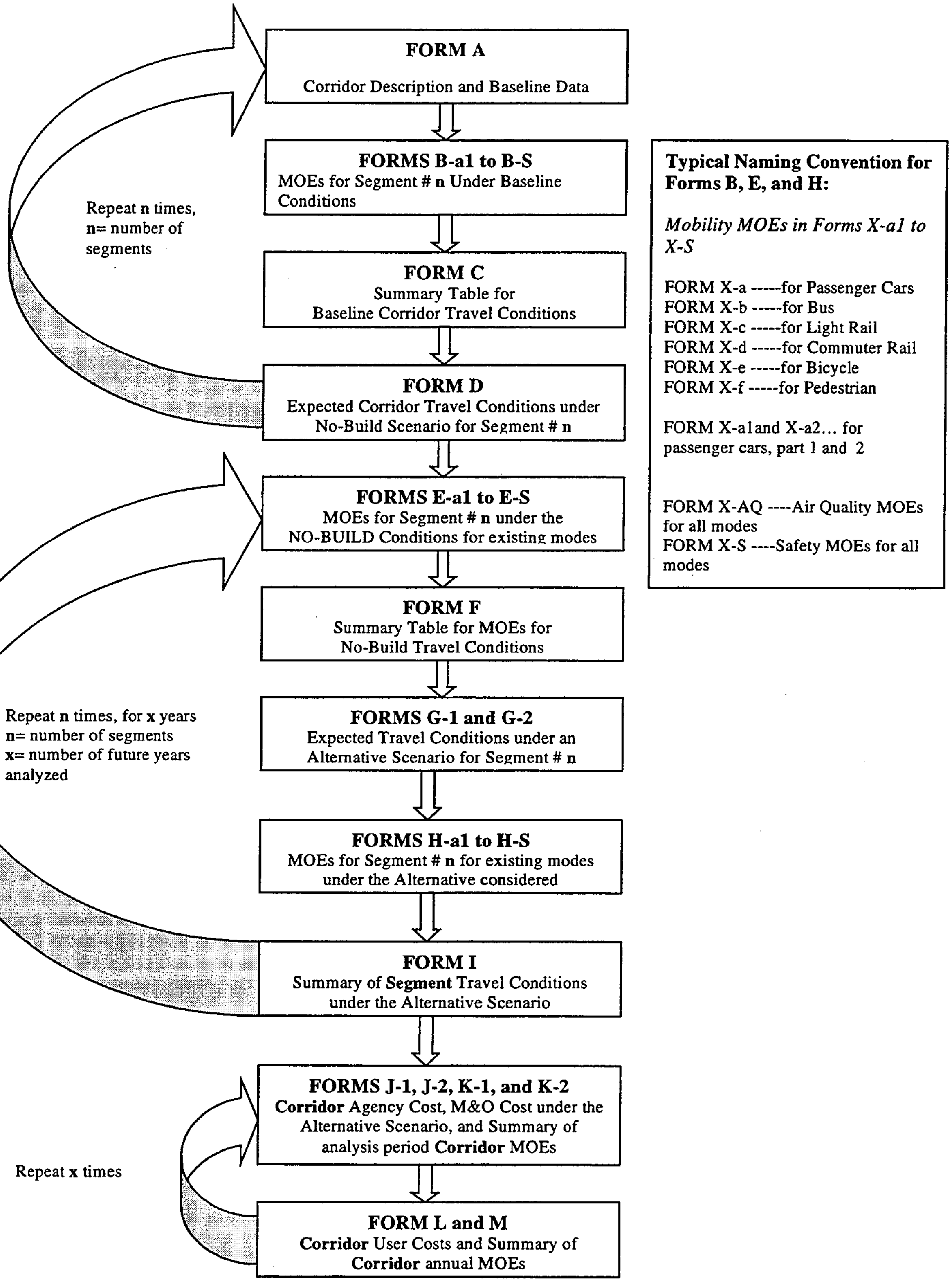

Figure 3.1. Sequence of MOE Worksheets

Number of Hours for Analysis Period. The length of the analysis period will range from 1 to 24 hours. The analysis period chosen will determine the units for some of the baseline data and also, the units in which the MOEs will be calculated. Since congestion is an important factor in the calculation of user costs, mobility, and emissions, analyzing the peak hours is generally preferred instead of all 24 hours. Twenty-four hours analyses do not account for the changing intensity of travel and therefore, congestion is generally not well represented.

Analysis Period Label. This entry is a label which describes the analysis period. For example, it might be 24 hours or a two-hour peak period (i.e., 4:30 to 6:30 PM).

Number of Corridor Segments to be Analyzed. The number of segments in which the corridor is divided. The manual version recommends no more than three and the electronic version is configured for up to five segments.

Baseline Travel Conditions for Available Modes. A tabulation of the number of trips using each of the existing travel modes. Directional trip counts per analysis period by all existing modes must be available or estimated for the baseline year. The numbers of trips are entered per direction of travel for each of the corridor segments in the table of Form A. The volumes for SOV, HOV, and HOT should be given in passenger vehicles, whereas for the transit (LRT, CRT, and Bus) and non-motorized modes, volumes are entered in passengers trips.

FORMS B-a through B-S: Baseline Conditions Forms

Forms B-a through B-S describe the baseline MOEs for each of the existing travel modes one segment at a time. Once the corridor and number of segments are defined, the required baseline MOEs for each segment are calculated for each existing travel mode. For each corridor segment and each travel mode considered, measures of speed, travel time, hours traveled, miles traveled, crashes, fatalities, and emission of pollutants are calculated.

FORM B-a1:

Entry 1 – Length of Segment. In miles (not lane miles). This entry is common to all mode-specific forms.

Entry 2 – Type of Lanes. Entry 2 indicates the lane type of the highway segment. In the automated spreadsheet, forms for three different lane types are vertically aligned beginning with the SOV and following with the HOV and HOT. When manual forms are used, one set of Forms B-a is needed for each highway lane type examined for a particular scenario.

Entries 3 and 4 – Number of Lanes (per segment, by direction).

Entry 5 – Capacity per Lane per Hour. Capacity in number of vehicles per hour per lane. Ranges of capacity values for typical conditions are suggested but the user is referred to the Highway Capacity Manual for a more accurate estimation of capacity involving uninterrupted and interrupted flow facilities (See Reference Table R15).

Entries 6 and 7 – Vehicle Capacity per Direction. Obtained as the product of the number of lanes per direction times the capacity per lane per hour times the number of hour for the analysis period.

Entry 8 – Free-flow Speed. Vehicle speed under very light traffic conditions. Free-flow speed is calculated here as the posted speed limit plus five (in miles per hour).

Entry 9 – Free-flow Travel Time. Travel time under very light traffic conditions obtained by dividing the length of the segment over the Free-flow speed.

Entries 10 and 11 – Parameters for the Travel Time Function. The parameters alpha and beta are used to calculate the highway segment travel time by direction for the scenario considered based on the level of congestion (See Reference Table R11).

Entries 12 and 13 – Volume-to-Capacity Ratio. The volume-to-capacity ratio can be though of as a measure of capacity utilization in terms of passenger cars. Alternatively, if the average occupancy and average maximum occupancy in persons per passenger car is used, a measure of capacity utilization in terms of people moved can be obtained.

Entries 14 and 15 – Segment Travel Time (per direction). Highway segment travel time (in hours) is a function of the Free-flow travel time, the alpha and beta parameters, and the level of congestion represented by the V/C ratio (See Reference Table R11).

Entry 16 – Vehicle Occupancy. The average number of persons using a passenger car during the analysis period. The national average occupancy for all kinds of trips is close to 1.5 persons per vehicle, whereas for trips to work is about 1.1 persons per vehicle. Average occupancy for HOV lanes can be taken as 2.5 persons per vehicle.

FORM B-a2:

Entries 1 and 2 – Average Speed per Direction. Obtained by dividing the segment length over the segment travel time (in miles per hour).

Entries 3 and 4 – Vehicle-Hours Traveled per Direction. Obtained as the product of the volume per analysis period times the segment travel time.

Entries 5 and 6 – Vehicle-Miles Traveled per Direction. Equals the product of the length of the segment times the number of trips for the analysis period.

Entries 7 and 8 – Passenger-Miles Traveled per Direction. Obtained by dividing VMT over the average vehicle occupancy for the period analyzed.

Entry 9 – Total Segment VMT both Directions. Obtained by adding cells 5 and 6.

Entry 10 – Annual VMT. Obtained by dividing total VMT by the percentage of the AADT represented by the volume of trips during the analysis period and by multiplying by 365 (days per year). The total analysis period volume as a percentage of AADT may be obtained from available counts for the corridor analyzed by dividing the analysis period volume over the total daily volume. If counts for the period analyzed are not available, national average hourly percentages can be used (See Table R16).

FORMS B-b, B-c, and B-d (Transit Modes):

Entry 2 – Number of Transit Vehicles (Buses, or LRT/CRT cars). Per direction per analysis period (See Table R15).

Entry 3 – Capacity per Transit Vehicle (Bus, LRT, or CRT). Number of seats per transit vehicle (bus or train car), (See Table R15).

Entry 4 – Average Transit Vehicle Speed (Bus, LRT, or CRT). In miles per hour (See Table R14).

Entry 5 – Transit Vehicle Capacity (Bus, LRT, or CRT). Total number of transit vehicle seats per analysis period per direction.

Entry 6 – Transit Vehicle Travel Time (Bus, LRT, or CRT). The travel time for transit vehicles is assumed fixed (does not vary with the volume of trips), and is obtained by dividing the length of the segment over the specified average speed for the transit mode.

Entries 7 and 8 – Capacity Utilization per Direction. Ratio of the number of passenger trips using transit (per direction) over the total number of seats available per direction.

Entry 9 – Average Occupancy per Transit Vehicle (Bus, LRT, or CRT). Ratio of the total volume of trips using transit over the total number of transit vehicles (both directions).

Entry 10 – Transit Vehicle Hours Traveled per Direction (Bus, LRT, or CRT). Equals the product of the number of transit vehicles per direction times the travel time per transit vehicle.

Entry 11 – Transit Vehicle Miles Traveled per Direction. Equals the product of the number of transit vehicles per direction times the segment length.

Entry 12 – Passenger Miles Traveled per Direction. Obtained as the product of the transit vehicles miles traveled times the average number of passengers per transit vehicle.

Entry 13 – Total Segment VMT both Directions. Obtained by multiplying cell 11 by 2 (two directions).

Entry 14 – Annual VMT. Obtained multiplying total VMT by 365 (days per year) and dividing by the percentage of the AADT represented by the volume of trips during the analysis period. The total analysis period volume as a percentage of AADT may be obtained from available counts for the corridor analyzed by dividing the analysis period volume over the total daily volume. If counts for the period analyzed are not available, national average hourly percentages can be used (See Table R16). Note that an annual amount may be different if service runs less than 365 days per year.

FORMS B-e and B-f (Bike and Pedestrian):

The calculation of MOEs for the Bike and Pedestrian modes is similar to the transit cases, except that no capacity calculation is included.

Entry 2 – Average (Bike or Pedestrian) Speed. In miles per hour. For pedestrians the average speed varies from 150 to 260 feet/min (1.7 to 2.9 mi/hr) as shown in Table 13-3 of the 1994 HCM.

Entry 3 – Travel Time (Bike or Pedestrian). Ratio of the segment length over the average Bike or Pedestrian speed in hours.

Entries 4 and 5 – Hours Traveled per Direction (Bike or Pedestrian). Equals the product of the number of bikes or pedestrians per direction times the travel time.

Entries 6 and 7 – Miles Traveled per Direction (Bike or Pedestrian). Equals the product of the number of bikes or pedestrians per direction times the segment length.

Entry 8 – Total (Bike or Pedestrian) Hours Traveled. Summation of (bike or pedestrian) hours traveled for the two directions.

Entry 9 – Total Segment VMT both Directions. Obtained by adding cells 6 and 7.

Entry 10 – Annual VMT. Obtained dividing total VMT by the percentage of the AADT represented by the volume of trips during the analysis period and by multiplying 365 (days per year). The total analysis period volume as a percentage of AADT may be obtained from available counts for the corridor analyzed by dividing the analysis period volume over the total daily volume. If counts for the period analyzed are not available, national average hourly percentages can be used (See Table R16).

FORMS B-AQ: Air Quality MOEs

Entries 1 to 8 – Emissions per Mode in Tons of Pollutants per Year. Obtained multiplying the annual VMT for each of the modes (PMT for bike and pedestrian) by the emissions rate for the respective mode, and dividing by the number of grams per ton (See Reference Table R5).

FORMS B-S: Safety MOEs

Entries 1 to 8 – Number of Crashes per Mode per Year. Obtained multiplying the annual VMT for each of the modes by the crash rate for the respective mode (See Reference Table R1).
Entries 9 to 16 – Number of Fatalities per Mode per Year. Obtained multiplying the annual VMT for each of the modes by the fatality rate for the respective mode.

FORM C: Summary of Baseline MOEs for each Segment

Form C is a summary table for all MOEs calculated for the baseline scenario for all existing travel modes. The cells in this worksheet are filled from Forms A and B-a through B-f by entering the values of the MOEs indicated. Most MOEs in this Summary Form are entered by direction of travel and by analysis period (i.e., Total trips, Travel time, VHT, VMT, Average speed, Average V/C ratio, and PMT). Other MOEs such as Emissions, Number of crashes, and Fatalities are entered per year by segment (both directions).

FORM D: Expected Percentage Increase in Trips

User input should be entered in Form D to indicate the expected percentage growth in the number of trips. Expected growth forecasts from agencies such as MPOs, DOT, and others are preferred whenever available. If growth factors for the area affecting the corridor and modes analyzed are not obtained from agencies, the user can apply trend extrapolation or use judgement to determine a reasonable estimate of the expected growth. The magnitude of the expected increase in the number of trips is very important, since this will determine congestion levels and will impact the process of alternative selection. Thus, care should be taken when adopting these growth rates to ensure realistic values. Growth percentages for the existing modes are used to estimate the future number of trips as shown in Form D.

Analysis Year. The analysis year indicates the horizon year (usually matching the 20th year planning horizon) where the proposed alternatives will be compared against the No-Build scenario. The analysis year also incorporates intermediate years when calculation of benefits and costs are required (e.g., every fifth or tenth years). This entry is common to Forms D through M.

Entry 1 to 8 – Expected percentage growth in the number of trips for each of the existing modes. The expected percentage growth in trips to occur between the baseline and analysis year for each of the existing modes of travel, and for each segment.

Entries 9 to 24 – Analysis volume per travel mode per direction. Volume of expected trips per travel mode obtained by adding the number of baseline trips plus the expected increase in trips for each of the travel modes.

FORMS E-a through E-S: MOEs under the No-Build Scenario

Forms E-a through E-S describe the No-build scenario MOEs for each of the existing travel modes for each segment. The format of Forms E-a–E-S is similar to the format for Forms B-a through B-S.

FORM F: Summary of No-Build conditions

Form F is a summary table for all MOEs calculated for the No-Build scenario and follow a format similar to the summary Form C for the baseline scenario. The cells in this Form are filled from Forms D and E-a through E-S by entering the values of the MOEs indicated.

FORMS G-1 and G-2: Expected Change in Trips by Mode due to a New or Improved Mode

User input is also required to indicate the expected change (increase/decrease) in the number of trips to occur if a new mode or an alternative were to be implemented. These data are entered in Forms G-1 and G-2. The alternative considered is indicated at the top of the Form, and then, the total passenger trips by all modes during the No-Build scenario is calculated. The user is then requested to enter the percentage of passenger trips that will likely switch to the new or improved mode and then, this percentage is used to calculate the number of trips by direction using the new mode. After this, the expected increase/decrease in trips to occur once the proposed alternative is in place is entered for each of the existing travel modes beginning with highway modes in Form G-1. The rest of the input for all other modes is entered in Form G-2. Finally, with these relative expected changes, the number of trips under the proposed scenario for all travel modes involved is calculated.

For example, assuming only two modes for the future No-Build conditions (200 trips use Bus and 2000 use SOV), if an LRT system is proposed for the analysis scenario year, the expected percentage of the total passenger trips to switch to the new LRT mode may be estimated to be 12 percent. That is, the total passenger trips for the No-Build scenario is 2600, which equals 200 plus 2000*1.2 (assuming occupancy to be 1.2 persons per vehicle). 12 percent of this total will be 312 trips switching to the LRT mode. The user then, has to indicate how many of these 312 trips will be taken from the highway and how many will be taken from bus. For example, we can assume that 216 passenger trips will be removed from the highway and 96 from bus. 216 passenger trips are equivalent to (216/1.2) 180 vehicle trips and therefore, the number of highway trips for this alternative scenario will be 1820 (2000 minus 180), whereas for bus it will be 104 (200 minus 96).

Form G-1: Expected Travel Conditions for Alternative Scenario (Part 1)

Entries 1 to 6 – Number of passenger trips by direction using highway lanes. Obtained by multiplying the number of vehicle trip for SOV, HOT, or HOT modes by the occupancy per vehicle.

Entries 7 to 22 – Number of passenger trips for the No-Build scenario. Per direction per mode.

Entries 23 and 24 – Total number of passenger trips by direction. Obtained by adding up the number of passenger trips by each mode (entries 7 to 22).

Entries 25 and 26 – Percentage of total passenger trips expected to switch to the new mode. The user should enter the proportion of the total number of passenger trips that are likely to move from other existing modes to the new or improved mode. Judgement of the analyst is required to determine this percentage when a formal modal split study is not performed to estimate a more accurate proportion of trips using the proposed mode.

Entries 27 and 28 – Number of trips using the new mode by direction. Obtained multiplying the total passenger trips per direction by the percentages entered in entries 25 and 26.

Entries 29 to 34 – Change in the number of passenger trips using highway modes due to the alternative considered. The user should enter the expected change (increase/decrease) in the number of trips likely to occur if the proposed mode is implemented. To indicate a decrease in the number of trips a minus sign should be used. The expected change in the number of trips, when a new mode is considered, can be obtained for example through stated preference surveys or (for a first approximation) using judgement.

Entries 35 to 40 – Change in the number of highway vehicle trips due to the alternative considered. Obtained multiplying cell 29 to 34 by the occupancy rate per vehicle. A minus sign should be used to indicate a decrease in trips per mode.

FORM G-2: Expected Travel Conditions for Alternative Scenario (Part 2)

Entries 1 to 6 – Change in the number of passenger trips using highway modes due to the alternative considered. From entries 29 to 34 in Form G-1.

Entries 7 to 16 – Expected increase/decrease in trips due to the alternative considered for each existing travel mode other than cars. The expected change in the number of trips by existing mode to occur because of the implementation of a new mode or because of the improvement of an existing travel mode.

Entries 17 to 32 – Future travel conditions for existing modes per direction. Volume of expected trips per travel mode obtained by adding the number of No-Build trips plus the expected increase/decrease in the number of trips for each of the travel modes. In these entries, vehicle trips are used for highway travel and passenger trips for all other modes.

FORMS H-a through H-S: MOEs under an Alternative Scenario

Forms H-a through H-S describe, one segment at a time, the expected MOEs for each of the existing modes under the future alternative considered. The format of Forms H-a through H-S is similar to the format for Forms B-a through B-S and E-a through E-S. The MOEs under an alternative scenario are calculated as described for Forms B-a through B-S.

FORM I: Summary of segment MOEs under an alternative scenario

Form I is a summary table for all MOEs calculated for the case when an alternative is implemented in the analysis year. The cells in this Form are filled from Forms G-2 and H-a through H-S by entering the values of the MOEs indicated. This Form follows a format similar to Forms C and F.

FORM J-1 to J-2: Capital and M&O Costs for the Alternative Scenario

Forms J-1 and J-2 include capital and M&O costs for the proposed alternative. In Form J-1 (capital costs) the Number of Components/Equipment 1 only applies to transit modes and indicate the number of buses or train cars, whereas the Number of Components/Equipment 2 (only for CRT) indicate the number of locomotives needed. In Form J-2, the Administration/Overhead for all modes is taken as 10%.

FORM J-1: Corridor Capital Costs

This worksheet will be filled out for each alternative to be analyzed. The user will first calculate the entire capital construction and/or purchase costs for the Alternative. The total amount can then be divided by the number of years over which the construction or purchase will be implemented to determine annual expenditures.

The entries are broken down by the eight modes. Because an alternative may involve more than one mode, entries can be under as many modes as needed with the Alternative Total showing the full amount.

Corridor Length. This indicates the number of miles of the corridor analyzed. It is calculated by summing all the segment lengths affected by the alternative. It does not mean lane miles.

Number of Additional Lanes/Tracks. Indicates the number of new highway lanes or the number of rail tracks for the alternative considered. This entry will not apply to bus service because it is assumed that bus service will run on existing roadway infrastructure. If dedicated busways are contemplated, that portion of the capital expenditures should be calculated under the HOV heading.

Unit Cost per Lane/Track. This entry refers to generic figures that are multiplied by the two preceding entries. Reference Table R2 offers the user a sampling of default values used in other studies. The user may also insert local figures if they are available. For instance, the addition of a general-purpose lane in each direction on an eight-mile corridor means multiplying 8 miles by 2 lanes (one in each direction). The resulting figure is then multiplied by the unit cost per lane mile to determine a construction cost estimate.

Number of Components/Equipment 1 and 2. These entries are necessary for elements that are not included in a construction cost estimates. For instance the purchase of buses or rail cars would be calculated using this entry. Another example might be tolling equipment. Each entry should only include the quantity of similar pieces of equipment. It may be necessary to calculate this entry several times when the alternative includes several different types of equipment.

Unit Cost per Component/Equipment 1 and 2. The user is once again referred to Table R2 for suggested default values. The unit of measure is most often per a single component or piece of equipment.

Subtotal. The value of this entry equals the sum of the construction costs plus the Component/Equipment costs.

Preliminary Engineering %. This allows the addition of a preset percentage of costs to cover expenses related to early design and engineering components. The suggested amount is 17% which is calculated by CDOT' s Office of Financial Management and Budget (OFMB) using a three year average for CDOT projects.

Construction Engineering %. This allows the addition of a preset percentage of costs to cover expenses related to construction engineering management and oversight. The suggested amount is 11.7% which is an amount calculated by CDOT' s Accounting Office using a combination of 9% of construction costs plus 30% of the 9% to cover indirect costs.

ROW%. This allows for the addition of a preset percentage of costs to cover the acquisition of land for right of way. The suggested amount is 7% which is an OFMB three year average.

Total Capital Cost (per mode). The user adds the construction engineering, the preliminary engineering and ROW percentage amounts to the subtotal to determine a total cost for each mode.

Alternative Capital Total. This entry adds together the different modal totals to show the amount that the capital and equipment purchases for the Alternative as a whole will cost. This total is calculated in millions of dollars.

Number of Years to Construct/Purchase. This refers to the implementation schedule, if known.

Annual Construction/Purchase Costs. This is the total amount for the alternative divided by the number of years to construct to come up with a simplified annual amount.

Total Equipment Cost at end of Construction. This entry shows the product of the number of components/equipment times the unit cost for these components/equipment and also includes a 10% for overhead expenses.

FORM J-2: Corridor Maintenance & Operation Costs

This worksheet gives the user the opportunity to include ongoing expenditures that are necessary to keep the capital asset or service in working order. It includes an item called Service Delivery Costs, which is meant to express the costs that transit operations (bus and rail) incur that could be compared to the out of pocket costs incurred by users of the single occupancy vehicles. Because of the difficulty in obtaining truly comparable data, the worksheet expresses these costs as a percentage of the total operating and maintenance costs.

Corridor Length. This indicates the number of miles of the corridor analyzed as defined in Form J-1.

Number of Additional Lanes/Tracks. Same as described in Form J-1.

M&O Unit Cost per Lane/Track. This entry refers to generic M&O figures that are multiplied by the two preceding entries. Reference Table R8 offers the user a sampling of default values used in other studies.

Subtotal. This entry reflects the basic maintenance and operating costs of the alternative. It is calculated by adding all the corridor segment lengths together and then multiplying the lengths times the number lanes/tracks times the unit cost. In the case of transit, the length of the corridor is multiplied by the number of vehicles traveling in each direction times the unit cost number.

Administration/Overhead %. This entry represents a percentage added on to all projects to account for the costs associated with general administration and overhead. The suggested percentage is 10%.

Total (per mode). The user adds the Administration/Overhead percentage to the ongoing costs to produce a total M&O cost.

Alternative M&O Total (Annual). Summation of all annual M&O totals for all modes.

Service Delivery Component %. The percentage of the Total M&O costs that can be attributed to offering passenger service and would be limited to the transit modes. The major components would be expenses for service delivery workers (i.e., wages and benefits for drivers, dispatchers, toll/fare collectors) and vehicle fuels. The suggested percentages for different types of transit are included in Reference Table R10.

FORMS K-1 and K-2: Summary of Corridor Mobility Conditions for Baseline, No-build, and Alternative Scenarios

Forms K-1 and K-2 show mobility measures per analysis period by each direction (K-1) and both directions combined (K-2). These forms tabulate mobility MOEs for the Baseline, No-build, and Alternative scenarios. MOEs considered include: Number of passenger trips, Corridor travel time, Total VMT, Total VHT, Total PMT, Weighted mean speed, Capacity utilization, and Maximum theoretical capacity. Data to estimate averages and totals for all these measures are obtained from Forms C, F, and I, except for Maximum theoretical capacity by mode. For this measure, values are obtained from Table R17.

FORMS K-1: (Corridor Mobility MOEs for each Direction)

Average Number of Passenger Trips per Direction. An average number of corridor passenger trips is estimated by adding up the product, for each segment, of the number of trips per segment times the length of the segment. This summation is then divided by the total length of the corridor according to the following equation:

$$\sum_n \#of\ Pass.Trips_i * Length_i \Big/ \sum_n Length_i$$

Where $\#of\ Pass.Trips_i$ and $Length_i$ are the number of passenger trips and length of segment i (for $i = 1$ to n).

When vehicle trips are used, the result is multiplied by the average vehicle occupancy to obtain passenger trips.

Corridor Travel Time. The corridor travel time per direction is just the summation of the travel times for each of the segments in the corridor. That is, for the Baseline conditions, the travel times reported in Form C for each of the segments are added together. For the No-Build case, we add the travel times in Form F, and for the Alternative scenario, the travel times in Form I.

Vehicle Hours Traveled, Vehicle Miles Traveled, and Passenger Miles Traveled. These are calculated is a similar fashion as the Travel Time.

Weighted Mean Speed. The weighted mean speed for each of the modes for each direction is calculated as follows:

$$\sum_n Speed_i * Length_i \Big/ \sum_n Length_i$$

Where $Speed_i$ and $Length_i$ are the speed and length of segment i (for $i = 1$ to n).

Weighted Mean Capacity Utilization. This is estimated in similar fashion as the Weighted Mean Speed by replacing the Speed by V/C ratio or Capacity Utilization. For highway-vehicle modes capacity utilization is interpreted as the ratio of volume to highway capacity, whereas for transit modes the capacity considered refers to the transit vehicles.

Maximum Theoretical Capacity. Maximum capacity in passengers per hour per lane/track under ideal conditions. See Reference Table R17.

FORMS K-2: (Corridor Mobility MOEs for both Directions)

Total Number of Passenger Trips both Directions. Summation of average number of passenger trips per direction from Form K-1.

Corridor Average Travel Time per Direction. Weighted average of travel time by direction by number of passenger trips per direction, calculated as follows:

$$\sum_n TTime_i * \#of\ Pass.Trips_i \Big/ \sum_n \#of\ Pass.Trips_i$$

Where $TTime_i$ and $\#of\ Pass.Trips_i$ are the travel time and number of passenger trips for segment i (for $i = 1$ to n).

Total Vehicle Hours Traveled, Total Vehicle Miles Traveled, and Total Passenger Miles Traveled. These totals are calculated by adding up both direction of travel from Form K-1.

Weighted Mean Speed and Average Capacity Utilization. The weighted mean speed for each both directions and average capacity utilization are calculated in a fashion similar to the calculation of corridor average travel time above. Replace Travel Time for Speed and for Capacity utilization respectively.

Weighted Mean Speed for all Modes both Directions. Weighted average of mean speed times PMT for all modes both directions, calculated as follows:

$$\sum_n Speed_i * PMT_i \Big/ \sum_n PMT_i$$

Where $Speed_i$ and PMT_i are the average mean speed and total passenger-miles traveled for mode i (for $i = 1$ to n).

FORM L: Annual User Costs

These costs are intended to identify the annual out of pocket expenses for users of the transportation system. In order to estimate the number of annual VMT or annual number of trips, the analysis period totals are multiplied by 250 (weekdays in a year) and by 2 (two peak-periods in a day). Thus, only annual VMT or trips under congested conditions are considered. Some costs are only attributable to certain modes.

Auto Gasoline. Annual component of variable costs due to gasoline consumption. It is calculated by multiplying a gasoline cost per VMT times the total number of annual vehicle-miles-traveled under the different scenarios evaluated. A default value of $.0625 per VMT is recommended in Table R8.

Auto Parking Cost. The user estimates the number of vehicle trips when parking fees are expected to be charged and multiply that number times an average parking fee cost to calculate the annual parking cost.

Auto Tolls. This element reflects expenses charged to use certain roadway facilities. The number of annual trips likely to use a toll facility is multiplied by the average toll charged to determine the annual cost.

Transit Fares. The user estimates the annual number of trips that will be taken on transit and multiplies that number times the average fare to produce a total cost.

Variable Costs. The expenses which change depending on the amount of travel done annually. This line is the sum of the four previous items by mode.

Capital Cost of Purchase. This item refers to the vehicle purchase expenses incurred by users of the transportation system. It is mainly the purchase of a car for personal use, although it could also be bikes or other motorized vehicles used for commuter type travel. Table R2 offers default values that can be linked to VMT.

Insurance Cost. Refers to insurance cost for travelers using autos. A default rate per VMT is recommended in Table R8.

Maintenance Cost. This item refers to expenses incurred to keep a personal vehicle in working order. See Table R8 for a default value linked to VMT.

Registration/Taxes. This item accounts for the annualized value that individuals must pay to operate a personal vehicle. See Table R8 for a default value linked to VMT.

Periodic Costs. These items refer to expenses incurred by users of the transportation system which occur on a recurring basis but are not directly related to the amount of travel. This line is the sum of the four previous items per mode.

Total Annual User Costs. This line is the sum, for all the modes, of Variable and Periodic costs.

FORM M: Summary Table for Corridor Annual MOEs

Form M summarizes all MOEs by mode and total through all modes in an annual basis. Measures for Mobility, Air Quality, Safety, and User Costs are tabulated for the Baseline, No-Build, and Alternative scenarios. Measures for Capital Costs are only given for the Alternative scenario.

Annual Number of Passenger Trips. Total number of passenger trips per year. Obtained by converting total analysis period trips (from K-2) to all day trips and multiplying by 365 days.

Annual Number of Passenger Peak-hour Trips. Total number of passenger peak-period trips per year. Obtained by converting total analysis trips (from K-2) to total daily peak-period trips and multiplying by the number of weekdays in a year. A recommended number for weekdays in a year is 250. If the analysis period consists of the morning or afternoon peak periods, then the analysis period can be multiplied by 2 to obtain the number of congested trips in a regular weekday.

Annual Vehicle Miles Traveled. For SOV, HOV, and HOT these are obtained – for the Baseline scenario- by adding up entries (10) in Form B-a2 for each of the segments; for the No-Build scenario, by adding up entries (10) in Form E-a2 for each of the segments; and for the Alternative scenario, by adding up entries (10) in Form H-a2 for each of the segments.

For Bus, LRT, and CRT, annual VMT are obtained by adding up entry (14) for each of the segments in Forms B-b, B-c, and B-d, respectively for the Baseline scenario. Forms E-b, E-c, and E-d for the No-build scenario, and Forms H-b, H-c, and H-d for the Alternative scenario.

For Bike, annual miles traveled are obtained by adding up entry (10) for each segment in Forms B-e for the Baseline scenario. Forms E-e for the No-build scenario, and Forms H-e for the Alternative scenario.

Annual Congested Vehicle Miles Traveled. For all the modes and scenarios, these are obtained by multiplying the total VMT in Form K-2 by 250 days 2 analysis (peak) periods.

Annual Passenger Miles Traveled. For SOV, HOV, and HOT these are obtained –for the Baseline scenario- by adding up entries (7) and (8) in Form B-a2 for each of the segments, this total is then divided by the percentage of AADT accounted for during the analysis period and the result is multiplied by 365 (days per year). For Bus, LRT, and CRT, entries (12) in Forms B-b, B-c, and B-d are processed as described above.

For the No-build scenario this calculation involves entries (7) and (8) in Form E-a2 and entries (12) in Forms E-b, E-c, and E-d. For the Alternative scenario it involves entries (7) and (8) in Form H-a2 and entries (12) in Forms H-b, H-c, and H-d.

For Bike and Pedestrian, annual miles traveled are obtained by adding up entries (10) for each of the segments in Forms B-e and B-f, respectively, for the Baseline scenario. Forms E-e and E-f for the No-build scenario, and Forms H-e and H-f for the Alternative scenario.

Annual Congested Passenger Miles Traveled. For all the modes and scenarios, these are obtained by multiplying the total PMT in Form K-2 by 250 days 2 analysis (peak) periods.

Annual Emissions. This is obtained –for the Baseline scenario- by adding up, for each segment, the total emissions reported in Form C. For the No-build scenario, by adding up the total emissions in Form F (for each segment). And, for the Alternative scenario, by adding up the total emissions reported in Forms I.

Annual Number of Crashes and Fatalities. Number of annual crashes and fatalities are obtained –for the Baseline scenario- by adding up, for each segment, the total crashes and fatalities reported in Forms C. For the No-build scenario, by adding up the total crashes and fatalities reported in Forms F. And, for the Alternative scenario, by adding up the totals reported in Forms I.

Annual Variable and Periodic User Costs. These totals are given in millions of dollars and are obtained from Form L and divided over one million.

Alternative Capital Total. This reflects the total project cost in millions of dollars instead of an annual figure. Obtained from Form J-1.

Alternative Annual M&O Total. Summation, in millions of dollars, of all annual M&O per mode. Obtained from Form J-2 and dividing over one million.

Service Delivery Component. Amount of the Total M&O costs that can be attributed to offering passenger service. Only applies to transit modes. Obtained from Form J-2 and dividing over one million.

Chapter 4

Analyzing a Project Using Economic Analysis

Sequence of Efficiency Analysis Worksheets

The economic efficiency base unit of analysis is the project/alternative. In general the project or alternative corresponds with the corridor used in the MOE analysis. If only one segment of a multi segment corridor is to be analyzed by EEA, it is necessary to redo the MOE and EEA worksheets, treating the analysis as a one-segment corridor. Special attention must be paid to downsizing agency costs to one segment if the project started out as construction on a corridor with several segments.

Some project/alternatives may be conceived with more than one new mode. An example is the addition of new lanes along a highway corridor and construction of a parallel bike path or a parallel rail line. The EEA looks at each new mode as if it were a separate project and ignores the minor interdependencies that may exist between the new or expanded modes. A complete worksheet analysis is done for each new or expanded mode assuming that the other new mode is not in place.

Flow of Worksheet Use for Economic Efficiency Analysis

Complete these forms once for each analysis year.

(Usually 2 or 3 analysis years will be used, so the forms must be filled out 2 or 3 times and the MOE forms for each analysis year must be available. Form BB may require more than one Form BB1 Part 1 and BB1 Part 2, according to the modes in the alternative considered.)

Form AA Air Quality Benefits
Forms BB User Benefits
Form CC Safety Benefits

Complete these forms once for each project/alternative.

(Form DD does not depend on other EEA forms. Form EE requires Forms AA, BB, and CC for each analysis year and Form DD. Form DD needs to be completed for each new mode in the alternative considered. Form FF requires completion of all other forms.)

Form DD Capital, Operating, and Maintenance Costs
Forms EE Summary of Net Social Benefits

General Description of EEA Worksheets

Forms AA-EE in the guidebook are copies of the electronic spreadsheets. The forms are best filled using spreadsheet software, however, they can be filled out by hand by following the instructions below and the instructions on the forms. Shaded cells indicate cells that are automatically filled in (if using electronic spreadsheets) or where calculations are needed (if using manual forms). Cells without shading indicate cells that require data input from the analyst. A general description of each of the EEA forms follows.

FORM AA: Air Quality Benefits

The purpose of this worksheet is to calculate the air quality benefit of the proposed project for use in the Net Social Benefits economic efficiency calculations. The general approach is to determine the change in air pollution concentration as a result of the project, and multiply it by the dollar value of human health damages reduced or increased per unit of concentration change--see the technical paper on air quality referenced in Appendix Three for further explanation. This worksheet must be completed once for each of the analysis years that have been selected for the project. Unlike the other types of benefits that directly accrue only to travelers, air quality benefits accrue to all people who live in the area effected by pollution emissions from the transportation system, whether they are traveling or not. In order to calculate air quality benefits it is necessary to know the resident population of the area and the area effected by emissions changes caused by the project. In most locations in the state except for the MPOs, the most detailed level available for area effected by emissions is the county. This is the basis of the population data provided in Reference Table R6. It is important to use the most up-to-date estimates and forecasts for county population in place of the figures provided in Table R6.

A1 – Analysis Year and Decision-Making Year. These are the year chosen for analysis and the year chosen for present-value calculations, respectively. These entries are common to most EEA forms.

A2 – Total Emissions under the No-Build and Alternative. Total emissions including all modes, in tons of pollutants, if the project is not built and under the proposed alternative, respectively.

A3 – Total VMT for all modes for No-Build and Alternative scenarios. Annual vehicle miles traveled by all modes under the no-build case and if the project is built, respectively. These totals are obtained from MOE Form M.

A4 – Total PMT for all modes for No-Build and Alternative scenarios. Annual passenger miles traveled by all modes under the no-build case and if the project is built, respectively. These totals are obtained from MOE Form M.

A5 – Air Quality MOEs under the No-Build and Alternative scenarios. Total emissions in tons of pollutants per VMT and per PMT for the No-Build and Alternative scenarios

A6 – Name of county where project is analyzed and ratio of concentration of pollutants to emissions for the county. See Table R6.

A7 – Change in annual emissions due to the Alternative. Calculated subtracting Cell 2 from Cell 1.

A8 – Change in annual concentration of emissions due to the Alternative. Calculated as the product of Cell 8 times Cell 9.

A9 – Value of human health damages per person per day. A default value of $0.1052 per ug/m3 per person per day, in 1992 dollars, is recommended here. See the technical paper Air Pollution Benefits, Costs, and MOEs Estimates for source.

A10 – Human health damages value updated to decision-making year. This is calculated by multiplying entry 11 times entry 12 (Consumer Price Index for the decision-making year from Table R3) and dividing the result by the default CPI.

A11 – Population of county or counties impacted by emissions. See Table R6.

A12 – Annual Air Quality benefits due to the Alternative considered. Calculated as the product of Cells 10, 13, and 14 times 365 days per year.

FORMS BB1, BB2, BB3, BB-S, and BB: User Benefits

The purpose of these worksheets is to calculate the user benefit to travelers resulting from the proposed project for use in the Net Social Benefits economic efficiency calculations. The user benefit is composed of travel-time savings and consumer surplus changes. Both of these are calculated using the travelers' demand curve for trips and the price of trips. The worksheets estimate the prices and demand curves, and determine changes to them to calculate user benefits - See the technical paper on transportation benefits (reference 2 in Appendix Three) for further explanation. The worksheets must be completed once for each of the analysis years that have been selected for the project. A new mode project uses only Form BB1 and a capacity increasing project uses only Form BB2. A project that includes both, one or more new modes and one or more capacity increases, uses both forms. Projects that improve intersection geometry, and/or safety use the capacity increase form (Form BB2). A new mode bicycle or pedestrian project uses Form BB3.

FORM BB1 (Part 1): Benefits of New Mode

B2 – Elasticity. The mode-specific price elasticity for the new mode.

B3 – Annual Passenger Trips. The number of peak-period passenger trips per year for new mode. Obtained from Form M.

B4 – % of Daily Trips During the Analysis Period. Percentage of daily new mode trips that occur during the analysis period. Obtained from Form K-2.

B5 – Travel Time per Trip. Average travel time per peak-period trip for the new mode considered. Obtained from Form K-2.

B6 – Fare or Toll per Trip. Enter average fare per trip for new transit mode considered or average toll if new mode consist of toll lanes. Enter zero is no fare or tolls.

B7 – Value of Time. Enter value of time in dollars per hour from Form UI.

B8 – Consumer Surplus. Multiply Cell 5 times Cell 3. Add Cell 4 to the product. Divide this result by Cell 1. Multiply this result by entry 2 and then multiply by -0.5.

FORM BB1 (Part 2): New Mode's Impact on other Existing Modes

When a corridor has more than one existing mode, Form BB1, Part 2 is completed for each existing mode separately and the total benefit of each existing mode from B20 is added together and the sum total placed in Form BB.

Speed Limit Check. If the average speed of travel with the existing mode is greater than the speed limit on the corridor under consideration, then the new mode will not improve the level of service in the corridor. In this case the new mode is considered to have no user benefit effect on the existing mode, so it is only necessary to skip to B20 and enter a zero. Compare the corridor speed limit from Form UI to the weighted mean speed under the No-Build case in Form K-2. The no-build case represents travel conditions as they will exist, in each analysis year, if the project is not built. If the weighted mean speed is less than the posted speed limit, proceed to step B10.

B13 – Elasticity. The mode-specific elasticity for the existing mode.

B14 – Number of Annual Congested Passenger Trips for Existing Mode under the No-Build Scenario. The number of annual trips per congested periods for existing mode if the new mode is not built. Obtained from Form M.

B15 – Travel Time per Trip under the No-Build Scenario. Obtained from Form K-2.

B16 – Price per Trip for Existing Mode under the No-Build Case. Obtained multiplying the value of time by the average time per trip (B15).

B17 – Slope of the Trip Demand Curve. Obtained dividing entry B16 over B14 and dividing the result over entry B13.

B18 – Number of Annual Congested Passenger Trips for Existing Mode under the Alternative Scenario. The number of annual trips per congested periods for existing mode under the Alternative proposed.

Speed Limit Check. If the weighted average speed with the new mode built is greater than the speed limit, use Part 3 below to calculate values for B20 and B21.

B20 – Travel Time per Trip under the Alternative Scenario. Obtained from Form I.

B21 – Price per Trip for Existing Mode under the Alternative Scenario. Obtained multiplying the value of time by the average time per trip (B20).

B22 – Intercept of the Trip Demand Curve with the New Mode build. Subtract B17 from B21 and multiple the result by B18.

B23 – Total Benefit for the Existing Mode under the Alternative Scenario. Use the following formula. {[(B22-B21)*B18]-[(B22-B16)*(B16-B22)/B17]}*0.5 and place this result in Form BB-S.

FORM BB1 (Part 3): Speed Limit Constrained Worksheet

B20 – Travel Time per Trip for Existing Mode at the Speed Limit. Divide the length of the corridor over the weighted average speed given in this form.

B21 – Price per Trip at the Speed Limit. Multiply B20 by the value of time given in Form BB1 Part 1.

FORM BB2 (Part 1): User Benefit for Projects that Increase Highway Capacity

Speed Limit Check. If the average speed of travel under the No-Build case is greater than the speed limit on the corridor under consideration, then implementing the alternative considered will not improve the level of service in the corridor. In this case the new mode is considered to have no user benefit effect on the existing mode, so it is only necessary to skip to B216 and enter a zero. Compare the corridor speed limit from Form UI to the weighted mean speed for the No-Build case in Form F. The no-build case represents travel conditions as they will exist, in each analysis year, if the project is not built. If the weighted mean speed is less than the posted speed limit, proceed to step B202.

B206 – Number of SOV Annual Congested Trips under the No-Build Scenario. From Form F.

B207 – Travel Time per SOV Trip under the No-Build Case. From Form F.

B208 – Value of Time. From Form UI.

B209 – Price per Trip for Existing Mode under No-Build Conditions. Multiply the value of time by the average time per trip (B207 times B208).

Speed Limit Check. If the average speed of travel under the Alternative scenario is greater than the speed limit, then calculate the values for B211 and B212 with the Speed Limit Constrained Worksheet below.

B211 – Travel Time per SOV Trip with Increased Capacity Build. From Form I.

B212 – Price per Trip for Existing Mode with Additional Highway Capacity. Multiply B208 times B211.

B213 – Number of Annual Peak-period SOV Trips with Increased Capacity Build. From Form I.

B214 – Benefits of Travel Time Savings. Calculate the dollar value of travel time savings, for travelers if the capacity is increased, according to the following formula: [B209-B212]*B206.

B215 – Additional Consumer Surplus Benefit. Calculate the additional benefits for new travelers if the increased capacity is built according to the following formula. [[B209-B212]*[B213-B206]]*0.5. The result should be a positive number.

B216 – Total User Benefits due to Additional Highway Capacity. Sum B214 and B215. Place this total in Form BB-S.

FORM BB2 (Part 2): Speed Limit Constrained Worksheet

B211 – Travel Time per Highway Trip at the Speed Limit under the Alternative Scenario. Divide the length of the corridor over the corridor average speed limit.

B212 – Price per Trip at the Speed Limit under the Alternative Scenario. Multiply B211 by the value of travel time (B208).

FORM BB3: User Benefits for Recreational Bike/Ped Trips

B302 – Number of Recreational Bike and/or Pedestrian Annual Trips. Number of Bike and/or Pedestrian trips are not the same as the ones reported in Form M. See Table R18.

B303 – Benefits per Trip for Bike and Pedestrians. See Table R18.

B304 – Benefit Value Updated to Decision-Making Year. See Table R3 for Consumer Price Indexes.

B305 – Annual User Benefits for Bike and Pedestrians. Multiply the values in B302 times B304 for Bike and Pedestrian respectively. Place these results in Form BB.

FORMS BB-S: Summation of User Benefits for all segments for projects with new modes or highway expansion

The purpose of this table is to add consumer surplus benefits calculated on Forms BB1 and BB2 for each segment and direction of travel and total them for transfer to summary Form BB. Benefits calculated for each alternative for each direction of travel and each corridor segment are entered in these forms. These benefits are copied from B8 in Form BB1 (Part1), B23 in Form BB1 (Part 2), or B216 in Form BB2, according to the type of benefit evaluated. The total benefits are then transferred to Form BB.

FORM BB: User Benefits Summary Table

The purpose of this table is to accumulate consumer surplus benefits calculated on Forms BB1, BB2, and BB3 and total them for transfer to the Net Social Benefits Table. Benefits calculated for new and existing modes as well as benefits due to additional highway capacity and recreational non-motorized trips, are tabulated in this form. The table must be completed once for each of the analysis years that have been selected for the project.

Entries 1 to 3 – Benefits due to Trips Using New Modes. Benefits calculated for each of the new modes considered are entered here.

Entries 4 to 6 – Benefits of Trips Using Existing Modes. Benefits calculated for each of the existing modes are entered here.

Entry 7 – Benefits due to Additional Highway Capacity. Savings in Travel Time due to increases in highway capacity are entered in this entry. Entries 1 to 7 are copied from total benefits calculated in entries (11) in Forms BB-S.

Entry 8 and 9 – Benefits due Recreational Bike/Pedestrian Trips. Benefits due to recreational non-motorized trips are entered in entries 8 and 9. These benefits are copied from entries B305 if a Form BB3 is used.

Entry 10 – Total User Benefits due to the Alternative Considered. Total benefits (in dollars) obtained by adding up entries 1 to 9. This total (in millions of dollars) is copied to the Net Social Benefits Table into the User Benefits column and the row corresponding to the analysis year shown in Form BB. Since Form BB is completed for each analysis year identified for the project, there will be an entry in the User Benefits column of form EE Part 2 for each analysis year chosen.

FORM CC: Safety Benefits

The purpose of this worksheet is to calculate the safety benefit of the proposed project for use in the Net Social Benefits economic efficiency calculations. The basic approach is to determine the change in the number of fatalities caused by the project and multiply the change by the fatality risk value. The worksheet must be completed once for each of the analysis years that have been selected for the project.

C2 – Total Number of Fatalities under the No-Build and Alternative Scenarios. Total number of fatalities per year from Form M.

C3 – Change in Fatalities due to the Alternative. Subtract the number of fatalities under the Alternative scenario from the No-Build case.

C4 – Fatality Risk Default Value. The default value for fatality risk is $4,200,000, in 1998 dollars. See the technical paper Safety Benefit-Cost Estimates for sources.

C5 – Updated Fatality Risk Value. Obtained by multiplying C4 times the ratio of the decision-making year CPI over the default (1998) CPI. Use Table R3 to obtain decision-making year and default CPIs.

C6 – Annual Safety Benefits of the Alternative. Multiply the change in annual fatalities (C3) by the updated fatality risk value (C5). Transfer this total (in millions of dollars) into the Safety Benefits column of Form EE Part 2 and the row corresponding to the analysis year shown in Form CC. Since Form CC is completed for each analysis year identified for the project, there will be an entry in the Safety Benefits column of Form EE Part 2 for each analysis year chosen after Form CC is completed for all the analysis years.

FORM DD (Part 1): Capital, Operating, and Maintenance Costs

The purpose of this worksheet is to calculate the agency cost of the proposed project for use in the Net Social Benefits economic efficiency calculations. Proposed expenditures on construction and operation of the project are entered in Form DD Part 2. The worksheet is completed only once but expenditures are entered for every year of the project's construction period and useful lifetime. Projects with more than one new mode are treated separately for purposes of the efficiency analysis. Thus the capital, operating, and maintenance costs entered on Form DD Part 2 are always for one new mode or an improvement of an existing mode.

Forms J-1 and J-2 give Capital and O&M costs based on Tables R2 and R8. However, there are three approaches to generating the capital and O&M costs. The first approach is preferred. The second approach is next best and the third approach is used if the other two are not possible. (1) The best approach is actual, local, estimates of the capital and O&M costs and expenditure schedule of the project by engineers, even if they are sketch design level estimates. (2) Next best consists of estimates based on information in Reference Tables R2 and R8 because these tables are based on experience in Colorado. (3) Finally, estimates using averages of national data, taken from the Handbook on Characteristics of Urban Transportation Systems (CUTS), may be used. Often the analyst will be forced to use information from all three sources to generate a complete estimate of capital and O&M costs for a project. For example, a construction expenditure schedule estimate may be available from the regional CDOT office, but the other two sources will be needed to estimate the O&M schedule over the useful life of the project.

D1 – Characteristics of Project. Since projects are classified by these characteristics and costs are given in unit figures such as $/mile, the entries are needed to calculate costs for the project. These entries are found in Form UI.

D2 – Useful Life of Project. This is the number of years the infrastructure being considered for construction will be serviceable until replacement in needed, assuming regular maintenance is performed. Useful Life, Construction Start Date, and Opening Date are given in Form UI.

Start and opening dates are determined by those advocating the project and by the construction or purchase schedule suggested by the design engineers or planners. Otherwise assume construction starts in the decision-making year. The difference between these dates is the construction period.

D3 – Project Capital and M&O Costs. These entries are copied from Forms J-1 and J-2, which give costs for a project by mode. Since Forms DD are only for one new mode, if the project has more than one new mode, be careful to take only data for the mode considered from Forms J-1 and J-2. Form J-1 gives total capital cost. It is necessary to convert this to an annual expenditure schedule for Form DD1. If a specific construction expenditure schedule is not available from local engineers or planners, it is acceptable to divide the total capital cost by the number of years in the construction period and use the result as the annual capital cost over the construction period. Since M&O costs are given in Form J-2 as annual costs, it is only necessary to use that number for each year of the projects useful life.

D5 – Construction Cost Composite Index for Base- and Decision Years. These indexes are found in Table R3.

Updated values for Capital and M&O costs for the Decision-Year from Form DD Part 2 are transferred to Form EE Part 2.

FORM DD (Part 2): Capital and M&O Schedule

Date. This column indicates the actual years for the project schedule. The date for Year 0 is the decision-making year for the project.

Base-Year Capital Costs. This column contains the construction cost expenditures for each year of the construction period. Place a zero in years with no construction expenditures.

Decision-Year Capital Costs. This column contains a formula which uses the decision year and base year CCCIs from Form DD Part 1 to update capital costs to decision-making year dollars. The formula is the figure in the base year column multiplied by the decision year CCCI and the result divided by the Base year CCCI.

M&O Costs. The maintenance and operating cost expenditures for each year of the useful life of the project. Place a zero in the years of the construction period.

Transit service Delivery Costs. This column contains the operation costs which are classified as Service Delivery Components on Form J-2. Place a zero in the years of the construction period.

Total Base-Year M&O Costs. This column is the sum of the values in the M&O and Transit Service Delivery columns by year.

Decision-Year M&O Costs. This column contains a formula which uses the decision year and base year CCCIs from Form DD Part 1 to update M&O costs to decision-making year dollars. The formula is the figure in the base year column multiplied by the decision year CCCI and the result divided by the Base year CCCI.

FORM EE (Part 1): Net Social Benefit Worksheet

The purpose of this worksheet is to guide the analyst in filling in the Net Social Benefits Table, Form EE Part 2 and complete the calculations for the economic efficiency analysis. The benefits and costs in the table are the changes caused by the project and indicate the difference between the no-build case and the alternative case. The worksheet is completed only once for each project/alternative since it includes all modes and all analysis years. Instructions for interpretation and use of the information in the NSB Table are given in Chapter 5. Definitions of Present Value, Annual Value, and Perpetuity Value are given in the Definitions Section of Chapter 1.

Discount Rate. Enter the interest rate for discounting. See Table R3 for discussion and values.

Annualization Period. Use the Construction Start Date and Useful Life values from Form DD Part 1 to calculate the annualization period. This is used to calculate the annual value on Form EE Part 2 and is obtained as the difference between the Last Year of Useful Life and the Construction Start Date.

FORM EE (Part 2): Net Social Benefit Table

The Net Social Benefits Table is used to collect and display the time profile of benefits and costs for a project. More importantly, it automatically calculates net social benefits using the time profiles. Net social benefit is the measure used to judge the economic efficiency of a project.

The Net Social Benefits Table includes benefits and costs values for each analysis year filled in from Forms L and AA through DD-2. Also, the date column should be filled in with the calendar years covering the analysis with year zero as the decision-making year. The construction start year may not be the same as the decision-making year. It may be 1, 2, 3 or so years in the future. Values in the three benefit columns and the three cost columns between decision-making and construction start years should all be zero.

Linear interpolation is used to generate benefit and cost values for the non-analysis years in the Net Social Benefits Table. This is done by calculating a linear increment by first taking the difference in benefits/costs between analysis years. This difference is then divided over the number of years between analysis years. Say user benefits in the first analysis year, 2000, are $90 million and in the next analysis year, 2010, are $190 million. The first step to approximate user benefits in 2001, 2002, …, and 2010, is to obtain the number of years between these two analysis years, 10. Next, the difference between $190 and $90 million is calculated, which is $100 million. This amount is then divided over the number of years between analyses (10 years) and this gives a linear annual increment of $10 million. Thus the value of user benefits for the year 2000 is $90 million, for the year 2001 is $90 plus $10 million or $100 million, for year 2002 is equal to $110 million, etc. If the next analysis year is 2020, the process is repeated to fill in the values of benefits/costs between the years 2010 and 2020.

Once the values of benefits/costs for the years between analyses are calculated, copy them into the respective column in Form EE Part 2. After these steps are completed there should be values in the benefits/costs columns for every year from the decision-making year to end of the useful life.

Since benefits do not occur until the project is constructed, but there might be an analysis year before the project opening date, make sure all values in the benefits column are zero until the opening year of the project. (For staged projects, please consult with CDOT for appropriate methodology.) Also, if the asset's life extends beyond the last analysis year, which will often be the case, assume equilibrium in benefits and use the last analysis year value to fill in the rest of the years.

Net Social Benefit Column. Values for each row of this column are automatically calculated as the summation of air quality, safety, and user benefits minus the summation of capital, user, and M&O costs, year by year. So, the year 10 row indicate benefits in year 10 minus costs in year 10.

Present Value of Net Social Benefits Column. Each cell in this column is the present value of the NSB figure in the cell to its left. The NSB is divided by $(1+r)^{yr}$, where r is the discount rate entered in Form EE <u>Part 1</u>, and yr is the value in the year column from the same row that the NSB figure is from.

Present Value Row. The bottom three rows of the table are calculated automatically using the values in the column above each cell in the rows. The cell in the present value row under the Present Value NSB column is the sum of all the values in all the cells in that column. Likewise, each cell in the row is the sum of the present values of the entries in the column above it. For example, the cell under the User Benefits column is the sum of the present value of the user benefits. However, unlike the case of NSBs, the other cells are not simple summations because the columns above are current values, not present values. The formula used in these cells automatically converts the current values to present values and does the summation. If an analyst needs to calculate the sum of present values by hand, she must first convert each cell to present value by dividing by $(1+r)^{yr}$ as explained above, and then adding the results together. Notice that the cell in the Present Value row under the Net Social Benefits column, automatically converts the column above to present values and sums them. Thus, it should be the same value as the cell to its right which is under the Present Value of NSB column.

Annual Value Row. The cells in this row have a formula that automatically calculates the annual series value which is the equivalent of the present value in the cell above. The present value in the cell above is multiplied by $\left\{r(1+r)^n / \left[(1+r)^{n-1}\right]\right\}$ to calculate the annual value, where n is the annualization period (given in Form EE Part 1) and r is the discount rate. The annual value will be much smaller than the present value from which it is calculated. If each value in the column above the present value row cell is replaced by the annual value figure, the sum of the present values of the column will be identical to that calculated from the original figures. For this reason the annual value is said to be equivalent to the present value.

Perpetuity Value Row. The cells in this row are the perpetuity value series of the figures in the column above, not including the figures in the Present or Annual Value rows. The perpetuity value is calculated by dividing the annual value in the cell above by r (the discount rate). The same discount rate must be used throughout the Table.

Chapter

5

Analyzing and Comparing Results

Using Efficiency Analysis

The goal of economic efficiency analysis (EEA) is to identify the transportation investment projects and policies that will result in the general increase in the well-being of people in the community. It is also fair to say that efficiency analysis seeks to find those transportation projects and policies that will be associated with utilizing a community's resources to produce the most highly valued goods and services. On the surface, such aspirations may be easy to accept as being things everyone would desire, but it is important to understand exactly what EEA does and does not say.

The bottom line with respect to EEA is the comparison of the benefits enjoyed because of the project against the costs incurred in order to have the project. This comparison is commonly known as benefit-cost analysis. Benefits should be thought of as measuring the amount of money people in the community would be willing to pay to obtain the good things resulting from the transportation project or policy. Costs are best thought of as "opportunity costs", or the value which is given up because resources are used for the project rather than in other productive ways in the community. In general, any project or policy can be expected to lead to some people in the community being better off and some people in the community being worse off. The benefit calculated for EEA represents how much money the people who are better off are willing to pay to have the project, while the cost represents how much money the people who are worse off would accept in compensation for their losses because of the project.

EEA is presented in terms of whether NSB is >0 or <0, where

$$\text{NSB} = \text{Benefit} - \text{Cost}.$$

When NSB > 0, then the amount those who benefit from the project are willing to pay to have the project is large enough to more than compensate those who are worse off for their loss. This means that the project can result in the general increase in well-being of the people in the community. When NSB < 0, then those who benefit from the project would not be willing to fully compensate those who lose because of the project. In this case the project *cannot* result in the general increase in the well-being of the people in the community and building the project would lead to using community's resources in less valued uses than they are at present.[1]

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[1] It can be assumed that in general any EEA evaluation of a project will be considered in terms of Present Value of NSB.

It is important to recognize that the estimation of benefits and costs relies on the values of each (adult) member of the community. EEA does not attempt to say something is good or worthwhile independently of the preferences of those living in the community. If someone in a community values something, then that something is also given that value by EEA. As such, EEA is based upon an effort to develop estimates of the choices people would make in the community if a project were built.

Note also that EEA is developed by comparing the estimated effects of a project with the situation expected to occur in the community if the transportation system does not change, which is referred to as the No-Build situation. EEA does not estimate the benefits and costs of making no changes and the benefits and costs of constructing a specific transportation project. Rather, it estimates the benefits and the costs associated with the way in which the project in question changes things from the No-Build situation.

Finally note that EEA is completely consistent with the MOE analysis recommended here. Actually, EEA is "built upon" specific measures of a project's impact which are developed as MOEs. The economic values of benefits and costs are attached to differences in the values of specific MOEs in the No-Build situation, versus the situation with the project in place. Essentially, EEA is one way to use the MOEs to compare projects. The second way of using the MOE information is suggested later in this chapter under *Prioritizing Using MOEs.*

What Economic Information Means and Doesn't Mean

Since the goal of efficiency analysis is to identify the transportation investment projects and policies that will result in a general increase in the well-being of the people in the community, the first way in which to interpret the EEA information is that it distinguishes between two types of projects. One type of project is estimated to be able to result in the general increase in well-being and the other type of project is not. Based on EEA, any project for which NSB < 0 would be undesirable and could not be recommended. After all, such projects are estimated to have costs that are greater than the amount of money people in the community, who benefit from the project, would be willing to pay for the project themselves. So at the first level, EEA could be used to recommend projects that should not be chosen for investment.[2]

Of course, many proposed projects will have NSB > 0. EEA does not recommend that every project with positive net social benefits should be built. At this level of project analysis EEA simply identifies projects which are acceptable because they offer the opportunity for the general increase in the well-being of the people in the community.

There are at least two reasons why EEA does not recommend that a project should be chosen just because the estimated NSB > 0. One is that there may be other ways in which the resources used in the project under consideration could be used to produce even greater increases in community well-being than this project. From a practical point of view, it is never possible to develop an estimate of NSB for every conceivable way in which a community's pattern of resource uses might be changed. The second reason is that EEA only estimates that the project beneficiaries can more than compensate those who are worse off because of the project for their loses. EEA itself cannot insure that the political process by which transportation investments and policies are chosen will also choose

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[2] Note that this statement is not meant to say that efficiency analysis should be the only way in which to evaluate projects. Rather it is meant to say that if you want to use EEA then any project for which NSB < 0 would not be a project that you would want to recommend.

to accomplish full compensation. In general there will be project winners and losers and as such EEA is nothing more than an estimate of which projects will be associated with using community resources in more valuable ways rather than in less valuable ways. Therefore, if one is interested in projects that offer the opportunity for the general increase in well-being of people in the community, EEA information can be used to distinguish projects that are acceptable (NSB > 0) from those projects that are unacceptable (NSB < 0).

Prioritizing Using Efficiency Analysis

At another level of analysis it may be of interest to rank alternative projects. There are two ways to rank projects consistent with the framework of EEA. First, as explained above EEA is used to distinguish between acceptable projects or those with NSB > 0, and those projects that are unacceptable (those with NSB < 0). Any project with NSB > 0 is worthwhile as far as EEA is concerned. As such, as long as one is ranking projects with positive NSB, any criteria for ranking and choosing between these projects is consistent with EEA. For example, one might rank different projects with NSB > 0 by using MOEs as described below. As far as EEA is concerned it is acceptable to rank projects with NSB > 0 with other criteria, even non-economic criteria.

Also, one might rank projects with NSB > 0 based on which project provided the greatest value for NSB. However, care must be taken with this approach to ranking. In general different projects will have different useful lifetimes. In order to make a "fair" comparison between such projects using EEA it is necessary to develop a comparison over the same complete time horizon for each project. Given the different effective lifetimes this involves computing the Perpetuity Value of the benefits and costs over time.[3] Essentially the Perpetuity Value is the present value of benefits and costs of a project assuming that project will be constructed, operated, then reconstructed in exactly the same way at the end of the projects effective life, and then replicated in this way indefinitely into the future. Therefore, if one wants to use the NSB concept to rank alternative projects this should be done using the Perpetuity Value which is calculated on the worksheet for Net Social Benefits. Using EEA in this way, one would rank projects from most desirable to least desirable based on which projects had the largest Perpetuity Value.

Analyzing and Comparing Results using Sensitivity Analysis

The purpose of sensitivity analysis is to answer the following question: How much confidence can be attached to the results of either the MOE and/or economic efficiency analyses? By its nature, transportation planning for the statewide transportation plan is necessarily done at the level of "sketch planning", the goal of which is to develop an acceptable "ballpark" understanding of the effects and costs of alternative transportation investments and policies. Many transportation investments will have expected lifetimes that are decades in length, and the statewide plan itself is looking at a minimum of two decades into the future. The very nature of planning to inform the process of making investment choices today over such lengthy time horizons is one for which there will always be overwhelming uncertainty. It is not possible to "test" the success of estimation methods that are utilized today, unless of course we are willing to wait through the relevant decades before making transportation investment choices.

Even though it is not possible to resolve the inherent uncertainty in the estimates upon which the MOE and EEA are developed, it is possible to assess the degree to which one can be confident in the

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[3] Perpetuity Value is calculated in Form EE Part 2 –Net Social Benefits Table.

conclusions suggested by the analyses. This is done by examining the "sensitivity" of the results to changes in different variables and/or different assumptions. The general idea is to determine how large a change in the variable would have to be to change the results suggested by the analysis. If the size of the change in a given variable is so large that the value for the variable is thought to be extremely unlikely, then that suggests one can be relatively confident in the results of the analysis. Note the imprecision in this description. There is no "crystal ball" to use in seeing the future and no real way to be absolutely certain in the results. Consequently, the confidence or lack of confidence in the results will remain largely a matter of individual judgement and evaluation. However, the sensitivity analysis recommended here can provide a sound basis for developing this individual confidence or lack of confidence in the implications of either the MOE or EEA.

Background to Sensitivity Analysis

There are two key types of assumptions, in developing the MOE and EEA, which should be subject to sensitivity analysis in general.

Some Critical Values to Assess in Sensitivity Analysis

1. Population Projections (Growth Assumptions)
2. Travel Demand resulting from growth assumptions
3. Mode Split for Non-SOV modes with original population forecasts

First, the MOE and EEA for every single transportation project or policy will be developed based upon the projected growth in population and/or transportation demand over the planning period. Because all of the analysis follows from the assumed change in population and/or transportation demand, it is recommended that all calculations for MOE and EEA be developed with a minimum of two different assumptions for population change.

There are at least a couple of ways to choose these two assumed population and transportation demand changes:

- ☐ One approach would be to use the information in the CDOT GIS files on the projected 20 year value for AADT as one assumption. The accompanying assumed change in population could then come from an "official" source for population projections, e.g. Colorado Department of Local Affairs or a local planning agency.
- ☐ A second approach would be to use one of the "official" estimates (e.g. the 20 year AADT value in the CDOT GIS files) as the base case assumption, and then to assume a change in population and transportation demand that was either 25% smaller or larger than the base case.

Whether to assume a larger or smaller change in population should be chosen in order to illustrate how robust the base case MOE and EEA results are. For example, if it is thought that the "official" estimate is likely to be optimistic in assuming more growth than might occur, then assuming a 25% smaller increase in population and transportation demand over the planning period would allow one to conclude that certain proposed projects would still be desirable with much less growth, or that certain projects can perhaps only be desirable if population growth is quite vigorous. Either way, the point is not to pursue the "right" population and transportation demand estimate, but rather to develop an understanding of which projects seem worthwhile even if future population cannot be known with certainty or if there is not common agreement on the best assumption.

Second, proposed projects that involve a new transportation mode will require an assumption about "mode split," i.e. the proportion of people traveling by existing modes that switch to the new mode.

Because past experience with many different modes of transportation is insufficient to provide an empirical basis for projecting mode split for Colorado circumstances, it has been recommended that the mode split be assumed to be some reasonable level (see Reference Table R9), and that a second assumed mode split be utilized to judge the sensitivity of this assumption. This mode split assumption will establish the base case analysis of the proposed project.

The sensitivity analysis would then develop a second set of MOE and/or EEA impacts based upon another assumed value for mode split. This second mode split value would be determined based upon the results of the MOE and EEA analysis in the base case. If the project analysis suggests it is desirable then the mode split in the second case should be reduced, and if the analysis suggests the project is not desirable then the mode split should be increased in value.

Once again the point is to assess how much difference the assumed mode split makes in the assessment of the proposed new mode project. It will not be possible to resolve the uncertainty in the projected mode split, but the exact value of the mode split that results may not be required if the second assumed mode split value does not change the implications of the MOE and/or EEA analysis.

Sensitivity Analysis for EEA

In addition to examining changes in population, transportation demand and mode splits, it will probably also be desirable to assess the sensitivity of other aspects of the efficiency analysis.

The size of any particular aspect of the entire benefit-cost analysis need not be the subject of intense debate in general since the results of the EEA are developed by comparison of all the benefits and costs considered together.

For example, one might look at the estimated benefit (or cost) of a project associated with changes in air pollution and think that the estimated change in pollution was likely to be too large. However, if a smaller, "more reasonable" change in pollution were examined it might be the case that the sign of net benefits was unchanged. Therefore, debating the precise size of the air pollution benefit (or cost) estimate would add little additional understanding with respect to the desirability of the project based on the EEA.

Project Recommendations According to Economic Efficiency

1) ***Good Bet*** - Projects which meet NSB > 0 even after looking at sensitivity are good bets based on EEA.

2) ***Poor Project*** - Projects with a NSB < 0 largely due to very large values for fatality risk or for value of time, or for population increases, etc. should not be chosen based on EEA.

3) ***Reexamine Critical Values*** - When the NSB of projects change from >0 to < 0 or vice versa due to a small change in some benefit or cost, EEA would not recommend such a project unless more confidence could be developed in the EEA critical value(s).

The key question is: How much larger or how much smaller would a benefit or cost have to be in order for the sign of the project's Present Value to change? The answer to this question can be determined by comparing the present value of the benefit or cost item in question, with the present value of the entire project in order to calculate how much this one item would have to change in size in order for the present value of the project to change sign. If the change is too large to be imaginable, then one can be pretty confident in the results of the EEA analysis. If the change is not very large at all, then it might be worthwhile to try to develop more precise estimates of the value in question or it might simply be concluded that confidence in the EEA of the proposed project is lacking.

It is recommended that for each project a calculation be made of the percentage change, in each of the following items, that would be necessary to change the sign of the present value of the project: user benefits, air pollution benefits or costs, fatality risk benefit or cost, agency capital cost and agency M&O cost. If the percentage change in any one of these items of benefit or cost is too large to be credible, then one can be confident of that specific estimate for the EEA. However, if this is not the case for every one of these items in the EEA calculations, then either more work should be done to try to develop an estimate that is generally acceptable, or it should be concluded that one does not have sufficient confidence in the information provided by the EEA for this particular project.

Prioritizing Projects Using Measures of Effectiveness

Transportation investment decisions are usually made based on two types of analyses--economic efficiency analysis that considers the cost and benefit of each alternative under evaluation; and/or a multi-criteria analysis that considers conflicting objectives or measures of effectiveness. Decision-makers are often interested in evaluating alternatives yielding positive NSB based on other criteria, given that not all measures are equally important to a community. Relative difference in importance among the measures is generally expressed with weights.

A multi-criteria ordinal index to evaluate alternatives based on multiple MOEs is presented in this section. This multi-criteria index encodes preference order information without an expression of preference intensity. The weights assigned to each of the MOEs are represented as exponents in the evaluation index. These weights control the impact of each measure on the index. For example, for two measures, to indicate that one measure is four times as important as the other, the corresponding exponents or weights are 0.8 and 0.2. For every alternative or project being considered an index value can be determined to rank projects from better to worse. Projects with higher index values are ranked higher.

Background

Multi-criteria decision methods are used for the evaluation of a finite number of alternatives under a finite number of conflicting objectives. These methods have been developed principally to deal with difficulties involved in reducing conflicting criteria into a single measure. Most of these methods generally incorporate the decision-maker's opinions to identify the preferred set of alternatives instead of attempting to find a single best alternative. In all these methods, the decision problem (i.e., transportation alternative impacts) can be set as a $m \times n$ matrix, for n criteria and m alternatives.

Different classifications of multi-criteria decision methods exist, including mathematical programming, discrete alternatives, and multi-attribute utility theory. These methods can also be classified according to: the alternatives considered (discrete or continuous), the type of data used (quantitative or qualitative), and whether or not uncertainty is considered. The method proposed here assumes: (1) a discrete set of alternatives, (2) availability of cardinal or quantitative data for the measures considered, and (3) that no stochastic effects are involved.

Methodology

The ordinal index proposed to evaluate transportation alternatives encodes preference order information only and not any notion of strength of preference. It is expected that any transportation alternative evaluation process will first involve a NSB analysis, and the proposed methodology will only be applied to alternatives providing positive NSB. The MOE index is defined as follows:

$$MOE\ Index\ I_i = \prod_{j=1}^{n} m_{ij}^{a_j}$$

where,

m_{ij} = measure j for alternative i
n = number of measures
a_j = weight for measure j

For example for an alternative *i* with four measures *j*:

$$I = \prod_{j=1}^{4} m_j^{a_j} = m_1^{a_1} * m_2^{a_2} * m_3^{a_3} * m_4^{a_4}$$

The following considerations should be observed when developing this MOE index:

- Each measure should be independent of the other measures. For example, since the number of fatalities is calculated here by multiplying VMT by a fatality rate, including both the number of fatalities and VMT as separate measures would not be appropriate.

- The magnitude of the measures should consistently indicate desired or undesired effects. That is, if it is chosen to indicate the most desirable alternative as the one with the higher index, then all the measures should indicate desired effects with increasing magnitude. For example, if the number of fatalities is chosen as a measure for Safety, then the inverse of the number of fatalities must be chosen to indicate a positive effect. Alternatives or projects can be ranked from better to worse according to the index value determined. If projects with higher index values are ranked higher, then projects that provide greater mobility and safety with less pollution and lower capital cost will have larger index values.

- The weights of the measures involved (exponents) must all sum to one. That is, $\Sigma\, a_n = 1.0$. In choosing values for the exponents start by considering the measures to be equally important, e.g. $a_1 = a_2 = a_3 = a_4 = 0.25$. If one measure is thought to be of greater importance than another, then this can be reflected by adjusting the values of the exponents. For example, if the first measure is thought to be twice as important as the fourth measure, then the exponents might be changed from being equal to: $a_1 = 0.333, a_2 = a_3 = 0.25, a_4 = 0.167$.

Index Properties

Desirable properties of the proposed index include: a decreasing marginal rate of substitution, constant elasticity measure, independence of value scale, and constant returns to scale. A detailed description of these properties is given in reference number 9,. "An MOE Index to Evaluate Multimodal Transportation Alternatives for Corridor Investment Studies".

Marginal Rate of Substitution (MRS). The proposed index can be described by an indifference curve with respect to any two measures, where different iso-index curves show the relative desirability between a pair of measures. The negative slope of a given iso-index curve at any point is the marginal rate of substitution. The MRS indicates the amount of a measure to be given up for a marginal increase in the amount of another measure or the negative slope of the index curve at some point. The MRS for the proposed index is not constant. It changes with changing levels of the measures considered. For example, if measure M_1 is a mobility measure: average corridor trip speed, and measure M_2 is the inverse of annualized project construction cost, then (as shown in Figure 5.1) the rate of substitution for M_1 and M_2 decreases with decreasing values of the mobility measure. In other words, the amount of mobility to be given up for a small increase in the cost measure varies depending on whether the cost measure is high and the mobility measure is low or vice versa.

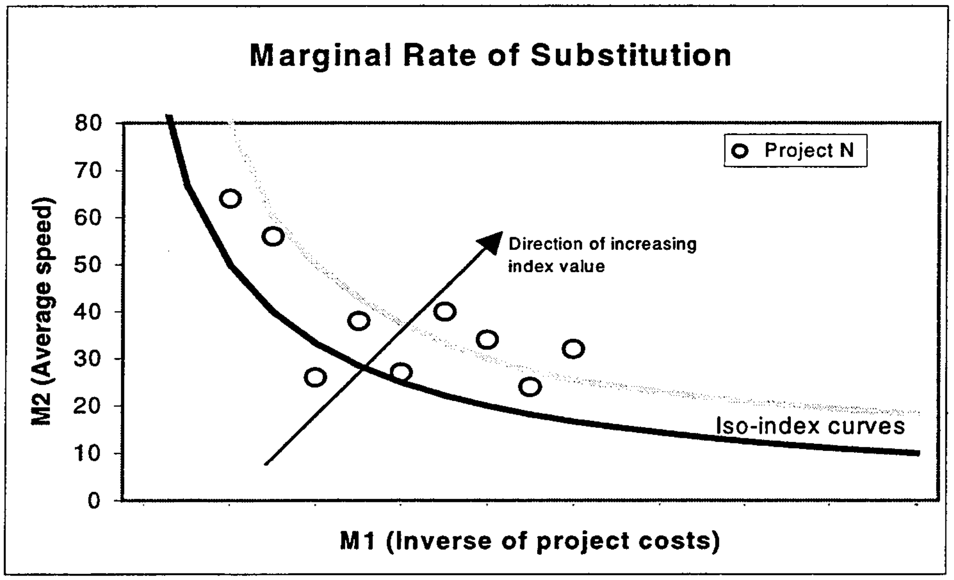

Figure 5.1: Rate of substitution for proposed index

This is an important property that reflects the tendency of people to generally value goods more highly at the marginal when they are in more limited supply than when they are prevalent. A variable MRS, though, is not obtained if the most common linear scoring function is used. In that case, a constant MRS or constant relative trade-off results. Such constant value tradeoffs would imply that any two performance measures of a transportation alternative are perfect substitutes for each other, which is very unlikely.

Constant Measure of Elasticity. Another desirable property is that the exponent of the corresponding measure indicates the elasticity of the index. The elasticity shows how the index responds to a percentage change in one of the measures. That is, the value for the exponent indicates the percentage increase in the index that results from a percentage increase in the measure, holding all the other measures constant. For example, assuming only mobility and cost as the relevant measures and weighting them equally (e.g., exponents are 0.5 each), a 10% increase in one of the measures, assuming the other measure remains unchanged, will cause the index to increase by 5%. When one of the measures is given more weight than another measure, the first measure will have a greater influence on changes in the index. For example, if the exponent (weight) on cost is increased from 0.5 to 0.8 and the exponent on mobility changes from 0.5 to 0.2, then a 10% increase in cost will cause the MOE index to increase by 8%, with mobility unchanged. In contrast, a 10% increase in mobility, with cost unchanged, will cause the index to increase only 2%. These exponents for cost and mobility (0.8 and 0.2 respectively) indicate that the influence of cost on the index is four times as high as the influence due to mobility.

Independence of Value Scale. Because of its product form, the proposed index does not require the measures to be normalized and therefore, no arbitrary scale or transformation of the measures is needed. Scaling measures (commonly done in other ranking methods) imposes an implicit (and perhaps arbitrary) "value" relationship with respect to the trade-off between the measures. Avoiding this scaling process permits decision-makers to better see the changes in relative trade-offs.

Returns to Scale. Given the product form for the MOE index function proposed here, if the exponents sum to one, then the index function is characterized by constant returns to scale. That is, the index value is not dependent on the size of the project. On the other hand, if the index function is characterized by increasing returns to scale, then projects that are larger in scale in terms of providing larger measures for all the relevant attributes would have a proportionately larger index value that smaller projects.

In addition to the advantages of the properties mentioned above, other desired characteristics of the index are: (1) the trade-off between measures is explicit, compared to the outcome given by other analyses, and (2) the index is informative, whereas other methods may not help decision-makers understand the choices they face.

Measures for Evaluation

The measures for evaluation should all consistently indicate a preferred effect as the measures increase or decrease. The measures can be converted (i.e., taking the inverse of the reported value) to comply with this condition. Recommended measures for evaluation (indicating greater benefits for increasing magnitudes of the measures) are as follows:

Mobility : M_m = Speed; the higher the speed the better the project.

Safety : M_s = 1/Number of fatalities; the higher the value of M_s the safer a project because as the number of crashes/fatalities increases this measure will decrease.

Air Quality : M_{aq} = 1/Tons of Pollutant; the higher the value of M_{aq}, the better the air quality impacts because this is associated with a lower amount of pollutant.

Agency Cost : M_{ac} = 1/\$, the higher the value of M_{ac}, the better in terms of agency cost because it is associated with lower agency cost.

Measures for evaluation can also be constructed to indicate higher preference for smaller magnitudes of the measures. Although the recommended index here is build to indicate preference for increasing values of the measures and the index.

Appendix 1

Reference Tables

Defaults and Averages Tables

A series of reference tables give default values and information regarding many of the variables used in filling out the worksheets. Some of these tables include guidelines to estimate site specific data.

__Reference Tables__

Crashes and Fatalities for Highways:

Crash rate is defined as the crash frequency per exposure per unit time, where exposure is usually derived from traffic volume or miles of travel. It is important to use different rates for different functional classifications of highways, at least for the urban and rural highway classification. In the analysis, only information on fatalities is used.

When rates are unavailable, default values in terms of crashes and fatality rates per vehicle-miles-traveled can be used from national or state averages as shown in Tables 1 and 2.

Table 1. National highway fatalities, crashes, VMT, and associated rates[1]

	Crash Rate per 100 million VMT	Fatality/Crash Ratio	Fatality Rate per 100 million VMT
Average	278	0.0066	1.82

Averages were obtained using data from years 1990 through 1995.

Number of crashes = VMT x Crash Rate
Fatality = Number of crashes x Fatality/Crash Ratio **OR** Fatality = VMT x Fatality Rate

Comparable fatality rates are observed more specifically for the state of Colorado as shown in Table 2. These averages were also calculated for years 1990 through 1995. 1995 Colorado fatality rates for urban highways (1.16), and for rural highways (2.61) are very similar to the 1995 national rates (1.20) and (2.57) respectively.

Table 2. Colorado Highway System Fatalities, Crashes, and Vehicle-Miles and Associated Rates[2]

	Crash Rate per 100 million VMT	Fatality / Crash Ratio	Fatality Rate per 100 million VMT
Average	199	0.0094	1.87
Total Rural (1995)	124	0.0211	2.61
Total Urban (1995)	271	0.0043	1.16

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[1] Source: Bureau of Transportation Statistics. National Transportation Statistics, 1997.

[2] Source: Colorado Department of Transportation, Crashes and Rates on State Highways, 1995.

Crashes and Fatalities for Transit Modes:

In general, the estimated number of crashes and fatalities due to a proposed transit mode (i.e., LRT, Bus, Commuter Rail) can be obtained by collecting safety data for the modes considered (crashes, fatalities, VMT) at the local, state, or national level. The estimated number of crashes and fatalities is calculated by multiplying the crash or fatality rate for that mode times the VMT.

Alternatively, default rates can be used as shown in Table 3, where national crash and fatality rates for different transit modes are averages of number of crashes, fatalities and VMT for the years 1990 to 1994.

Table 3. Fatalities and incident rates by transit mode.

	Number of Fatalities Per 100 million VMT			Number of Incidents per 100 million VMT		
	Bus	LRT	Comm Rail	Bus	LRT	Comm Rail
AVG	4.3	23.5	31.2	2480	2924	918

Three sources of **site-specific** crash rates are outlined below:

1) **CDOT-GIS planning data set:** This data set provides VMT-based fatality rates for every highway segment in Colorado. These segment-based rates can be used as follows:

$$\text{Number of Fatalities in a user-defined segment} = \sum_{i} (\text{fatality rate})_i * (\text{segment length})_i$$

where, *i* = number of segments defined by the planning data set

2) **Highway Specific Data:** Site-specific crashes and fatality rates can also be derived for a particular highway, if the data are available, as shown in the table below. This table consists of crash and fatality rates for a segment of the I-25 corridor from 1990 to 1995. I-25 fatality rates for urban highways for 1995 are similar to the national and state rates (1.15 versus 1.16 and 1.20), whereas for rural highways are significantly different (1.22 versus 2.61 and 2.57 for I-25, state, and national, respectively).

TABLE R1 (continued): Crashes and Fatality Rates

I-25 corridor Fatalities, Crashes, Vehicle-Miles and Associated Rates*

	Crash Rate per 100 million VMT	Fatality/Crash Ratio	Fatality Rate per 100 million VMT
Average	146	0.0077	1.13
1995 Rural	86	0.0142	1.22
1995 Urban	186	0.0062	1.15

3) **Regression techniques:** site-specific crash prediction models can be developed to estimate highway crash frequency. The required data normally consist of highway geometry, traffic characteristics, and historical reported crashes.

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* Source: Colorado Department of Transportation, Crashes and Rates on State Highways, 1995.

TABLE R2 : Capital Costs

Capital (Construction/Purchase) Costs

Mode	Cost	Unit	Source	Comments
Commuter rail	$1,900,157	$/mile	CDOT Passenger Rail Study	Core system (642 miles) no ROW
Commuter rail	$9,000,000	$/mile	DRCOG MIS Guidebook	
Commuter rail (CS to Denver)	$5,000,000	$/mile	SFRCAS *	Double freight track
Commuter rail (CS to Denver)	$10,000,000	$/mile	SFRCAS *	New track
Commuter rail	$7,000,000	$/mile	RTD MIS Guidebook	Existing track
Commuter rail	$10,000,000	$/mile	I RTD MIS	New track
High speed rail (Denver to Vail)	$26,000,000	$/mile	I-70 MIS	
LRT (at grade)	$30,000,000	$/mile	DRCOG MIS Guidebook	
LRT (at grade)	$19,715,000	$/mile	NHI Course 15257	Double track 1994 dollars
LRT (inter-regional electric)	$15,000,000	$/mile	SFRCAS *	CS to Denver
LRT (some grade separation)	$45,000,000	$/mile	RTD MIS Guidebook	
Bus/HOV (at grade)	$8,000,000	$/mile/ lane	DRCOG MIS Guidebook	
Bus/HOV (at grade)	$9,000,000	$/mile/ lane	I-70 MIS	
Bus/HOV (at grade)	$4,170,000	$/mile/ lane	NHI Course 15257	Reverse flow/barrier 1994 dollars
Interstate highway (at grade)	$582,500	$/mile/ lane	CDOT 1997 Overview Report	No engineering or ROW, one lane
Interstate highway (at grade)	$1,950,000	$/mile/ lane	NHI Course 15257	Reconstruction – No ROW – 1994 ($)
Interstate highway (at grade)	$8,00,0000	$/mile/ lane	SFRCAS *	One lane, general purpose
Highway(interstate & arterial)	$3,700,000	$/mile/ lane	USDOT Condition & Performance 1995	Average facility expansion
Highway(interstate & arterial)	$2,250,000	$/mile/ lane	CDOT Statewide Plan Estimate	Urban capacity
Interstate highway (at grade)	$6,000,000	$/mile/ lane	DRCOG MIS Guidebook	One lane
Interstate highway (at grade)	$11,500,000	$/mile/ lane	I-70 MIS	One lane

* South Front Range Corridor Analysis

TABLE R2 (continued): Construction Costs

Capital Construction/Purchase Costs

Mode	Cost	Unit	Source	Comments
Interstate highway (at grade)	$582,500	$/mile/ lane	CDOT 1997 Overview Report	No engineering or ROW, one lane
Interstate highway (at grade)	$1,950,000	$/mile/ lane	NHI Course 15257	Reconstruction – No ROW – 1994 ($)
Interstate highway (at grade)	$8,00,0000	$/mile/ lane	SFRCAS *	One lane, general purpose
Arterial (at grade)	$4,000,000	$/mile/ lane	DRCOG MIS Guidebook	One lane
Arterial (at grade)	$644,000	$/mile/ lane	CDOT 1997 Overview Report	No engineering or ROW, one lane
Bike path	$167,000	$/mile/ lane	NHI Course 15257	15 year useful life 1994 dollars
Bike path	$250,000	$/mile/ lane	CDOT Statewide Plan	
Toll collection	$222,000	$/mile/ lane	NHI Course 15257	Automatic - Constr. and equipment
LRT car	$1,400,000	Each	1997 APTA Transit Vehicle Data Book	Average cost
Commuter rail car	$1,500,000	Each	1997 APTA Transit Vehicle Data Book	Average cost
Commuter rail locomotive	$1,200,000	Each	APTA Vehicle Fact Book	Diesel engine 1996 dollars
Commuter rail locomotive	$2,200,000	Each	1997 APTA Transit Vehicle Data Book	Diesel/Electric Engine - 1997 ($)
Commuter rail locomotive	$4,800,000	Each	APTA Vehicle Fact Book APTA Fact	Electric engine 1996 dollars
Bus (40' diesel)	$250,000	Each	1997 APTA Transit Vehicle Data Book	Diesel, 40 passenger 1997 dollars
Van/minibus	$50,000	Each	CDOT 1998 dollars	Gasoline, 12-20 pass
Bike	$450	Each	Boulder Cost of Travel	1995 dollars
Auto (annual depreciation)	$3,759	Each	AAA "Your Driving Costs 1995"	Average car
Auto (annual cost of purchase)	$.267	$/VMT	CDOT	Average car

TABLE R3: Economic Indicators

Consumer Price Index

The Consumer Price Index (CPI) is used, in efficiency analysis, to adjust the monetary value of prices or costs from their dated year to another year, usually to the decision-making year. For example, the average wage rate for a county may be known for 1995 but the decision-making year is 1998. The CPI is used to update the wage rate to 1998 dollars. The CPI is calculated from historical prices and costs, therefore it is not used to adjust to future monetary values. The CPI is available (by month and by year) from the US Bureau of Labor Statistics at www.stls.frb.org/fred/data/cpi/update/cpi01. The table below contains the most recent CPI at the time this guidebook was prepared.

CONSUMER PRICE INDEX US BUREAU OF LABOR STATISTICS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1988	115.7	116	116.5	117.1	117.5	118	118.5	119	119.8	120.2	120.3	120.5	118.3
1989	121.1	121.6	122.3	123.1	123.8	124.1	124.4	124.6	125	125.6	125.9	126.1	124
1990	127.4	128	128.7	128.9	129.2	129.9	130.4	131.6	132.7	133.5	133.8	133.8	130.7
1991	134.6	134.8	135	135.2	135.6	136	136.2	136.6	137.2	137.4	137.8	137.9	136.2
1992	138.1	138.6	139.3	139.5	139.7	140.2	140.5	140.9	141.3	141.8	142	141.9	140.3
1993	142.6	143.1	143.6	144	144.2	144.4	144.4	144.8	145.1	145.7	145.8	145.8	144.5
1994	146.2	146.7	147.2	147.4	147.5	148	148.4	149	149.4	149.5	149.7	149.7	148.2
1995	150.3	150.9	151.4	151.9	152.2	152.5	152.5	152.9	153.2	153.7	153.6	153.5	152.4
1996	154.4	154.9	155.7	156.3	156.6	156.7	157	157.3	157.8	158.3	158.6	158.6	156.9
1997	159.1	159.6	160	160.2	160.1	160.3	160.5	160.8	161.2	161.6	161.5	161.3	160.5
1998	161.6	161.9	162.2	162.5	162.8	163	163.3	163.5	163.6	163.9	164.2	164.4	
1999	164.6	164.7	165.0	166.2									

Composite Construction Cost Index.

The Composite Construction Cost Index (CCCI) is used in the same way the CPI is but it is designed to apply specifically to transportation infrastructure construction costs. It is available annually by state and quarterly for the whole country. It is prepared by the FHWA, Office of Engineering. The latest release for the states is given in the table below.

COLORADO CCCI, FHWA

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
100.0	106.7	105.1	103.8	110.15	114.36	114.12	126.77	114.70	152.25

Discount Rate

The discount rate is an interest rate used in efficiency analysis to calculate the present value of future expenditures or revenues. Present value means the monetary value in the decision-making year. For example, an expenditure of $900,000 to replace some buses in 2020 is worth $422,236 in 1998 at the discount rate of 3.5%. It is worth $110,561 if the discount rate is 10%. The choice of a discount rate in economic efficiency analysis can be very important in determining whether the Net Social Benefits of a project are positive or negative. For further discussion of the use of present value in efficiency analysis see the Technical Paper, "Transportation Economic Costs and Discounting in Economic Efficiency Analysis". Ultimately, the choice of a discount rate is up to the decision-makers using the analysis, but the purpose here is to offer some guidance in choosing a discount rate.

Economic theory suggests two rationales for selecting the correct interest rate. One rational is the opportunity cost of capital and the other is peoples' time preference in consumption. Since state funds for transportation projects come from taxes and fees paid directly by citizens, it is appropriate to use an interest rate based on peoples' time preference in consumption. The real rate of interest is always used, which is a market rate of interest with the current rate of inflation subtracted from it. This corresponds to stating planned expenditures and revenues in real dollars, not inflation-adjusted figures. The appropriate time preference interest rate to use is one based on real interest rates on US Treasury notes and bonds and on the length of the project. These rates are given in Appendix B of the US Office of Management and Budget Circular A-94, and also at www.whitehouse.gov/WH/EOP/OMB/html/circulars/a094/a094.html. The rates in the circular for 1998 are given in the following table.

REAL DISCOUNT RATES, OMB CIR A-94 (JAN 1998)

3-Year	5-Year	7-Year	10-Year	30-Year
3.4	3.5	3.5	3.6	3.8

Interpolation can by used for terms in between those shown and the 30-year rate should be used for projects or plans longer than 30 years. See the above referenced technical paper for a discussion of sensitivity analysis with discount rates.

TABLE R4: Elasticity Values

The concept of demand elasticity is useful in characterizing trip demand. Demand elasticity is defined as the ratio formed by the percentage change in trips divided by the percentage change in price per trip. Demand elasticity is used in the EEA worksheets to calculate the user benefits associated with proposed transportation projects and policies. Many studies have been published in which estimates of trip demand and trip demand elasticity values can be found. A review of that literature forms the basis for the recommended trip demand elasticity values presented below (see technical reference 5 in Appendix Four for this review).

In order to calculate user benefits for many proposed projects it is necessary to use a value for demand elasticity. The recommended elasticity values are presented in the following table. In addition the table reports an acceptable range of values for demand elasticity. If one is interested in assessing the sensitivity of the calculations for the EEA with respect to the value assumed for the demand elasticity, then user benefits should first be calculated using the recommended elasticity. After this, a second set of calculations would be developed, by picking another value for the demand elasticity from the acceptable range reported here. Note that the closer the value for the chosen demand elasticity is to 0, the larger will be the value estimated for the benefit in each analysis year.

Demand Elasticity Values

Mode	Recommended Elasticity	Acceptable Range
SOV	-0.3	-0.1 to -0.5
HOV	-0.3	-0.1 to -0.5
HOT	-0.3	-0.1 to -0.5
Bus Transit	-0.4	-0.2 to -0.6
LRT	-0.4	-0.2 to -0.6
CRT	-0.7	-0.4 to -1.0

TABLE R5: Emissions by Mode

Default values for total emissions rates, in grams per mile, by mode are given in the table below. These are applicable statewide and are an average from various sources. See the Technical Paper, "Air Pollution Benefit/Cost and MOE Estimates", for definition and background on total emissions as a measure of air quality. Notice that these are emissions per VMT. LRT is assumed to be electric so it has no direct emissions. The CRT emissions rate is for one diesel locomotive. A commuter train may have one or more locomotives. The emissions rate per train must be adjusted to reflect the number of locomotives per train.

DEFAULT EMISSION RATES BY MODE

MODE	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PED
g/mile	3.87	3.87	3.87	24.9	0.0	316.5	0.0	0.0

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More **site specific** emissions rates, which reflect differences within modes, can be found by using the categories defined by the EPA in its MOBILE5-A vehicle emissions model. The model has five categories of SOV/HOV/HOT vehicles and two categories for buses. For example, if a TPR believes that a project location has a significantly higher percentage of pickup tuck VMT then the state average, the emission rate for SOVs could be recalculated to adjust for this. It would be necessary to have the Air Pollution Control Division of the Colorado Department of Public Health and Environment run MOBILE5-A to calculate the new emissions rates and to total them following the definition in the Technical Paper referenced above. The Division will consult with analysts, run the model, and provide results. Emission rates are made site specific by a number of classifications available in the model. Some of the classifications are: area type, road class, year, season, time of day, ambient temperature, altitude, speed, and VMT mix. Area type is central business district, fringe, urban, suburban, or rural. Road class is freeway, major regional, principal arterial, minor arterial, collector, ramps, or local. VMT mix refers to the age and vehicle type composition of the area fleet. Other classifications are self-explanatory.

TABLE R6: Emissions by County

	County	*Emissions Total tons/year***	*Concentration PM_{10} avg. annual ug/m^3*	*Ratio*** Ug/m^3 to tons/yr*	*Population*
1	Adams	155533	60.0	0.000386	323430
2	Alamosa	9841	23.5	0.002385	13282
3	Arapahoe	110254	60.0	0.000544	481136
4	Archuleta	6548	22.6	0.003450	6568
5	Baca	10847	19.5	0.001801	3362
6	Bent	9202	20.0	0.002171	4143
7	Boulder	83640	48.1	0.000575	263033
8	Chaffee	8277	18.7	0.002254	13855
9	Cheyenne	15702	21.1	0.001341	2618
10	Clear Creek	3524	20.8	0.005893	9027
11	Conejos	11156	26.5	0.002373	7450
12	Costilla	6740	23.7	0.003523	3129
13	Crowley	3503	19.6	0.005607	4441
14	Custer	4108	21.0	0.005101	2434
15	Delta	12828	16.3	0.001272	25498
16	Denver	188746	60.0	0.000318	523574
17	Dolores	6134	18.3	0.002982	1355
18	Douglas	24263	32.5	0.001338	101182
19	Eagle	22125	18.5	0.000835	29383
20	Elbert	12947	26.6	0.002057	13102
21	El Paso	158949	38.9	0.000245	491826
22	Fremont	18233	21.1	0.001158	34516
23	Garfield	23818	14.9	0.000627	35249
24	Gilpin	1431	23.7	0.016559	3248
25	Grand	10812	18.1	0.001674	11241
26	Gunnison	15769	17.1	0.001087	14408
27	Hinsdale	3965	19.3	0.004858	429
28	Huerfano	8008	21.9	0.002734	6493
29	Jackson	10262	15.4	0.001500	1219
30	Jefferson	133759	60.0	0.000449	485048
31	Kiowa	7251	18.8	0.002594	1450
32	Kit Carson	31687	24.5	0.000774	7418
33	Lake	3180	16.6	0.005232	4815
34	La Plata	20285	22.9	0.001128	36559
35	Larimer	84367	28.4	0.000336	238170
36	Las Animas	21134	20.5	0.000969	12177
37	Lincoln	20710	22.3	0.001076	4339
38	Logan	26074	25.9	0.000992	17487
39	Mesa	52168	17.9	0.000342	109409
40	Mineral	3331	20.6	0.006190	531
41	Moffat	65048	12.7	0.000196	11474
42	Montezuma	16244	21.2	0.001305	17044
43	Montrose	25853	16.9	0.000653	29760
44	Morgan	62882	31.6	0.000503	22585
45	Otero	11912	20.5	0.001724	18773
46	Ouray	3071	17.2	0.005594	2212
47	Park	10061	18.8	0.001866	8363
48	Phillips	13849	25.1	0.001809	4318
49	Pitkin	11429	17.0	0.001488	18932
50	Prowers	9344	18.7	0.002002	12957
51	Pueblo	82851	24.9	0.000301	133911
52	Rio Blanco	15951	13.4	0.000841	4958
53	Rio Grande	10860	23.3	0.002145	10671
54	Routt	43131	14.0	0.000324	18695
55	Saguache	17323	20.8	0.001203	3250
56	San Juan	1540	19.3	0.012542	691
57	San Miguel	7100	16.6	0.002331	5295
58	Sedgwick	8872	24.3	0.002740	2319
59	Summit	7343	19.2	0.002610	19952
60	Teller	4900	22.2	0.004525	15578
61	Washington	31644	26.3	0.000832	3959
62	Weld	81870	38.3	0.000468	170537
63	Yuma	31783	24.7	0.000776	9618
	Colorado				3893886

**Total Emissions = $VOC+NOX+SO_2+PM_{10}+PM_{2.5}+NH_3$

***Multiple county ratios = (sum concentrations) / (sum emissions)

TABLE R7: Transit Fares

The table below shows example of transit fares for different urban providers as well as some national averages. The table does not provide examples for inter-city transit fares and thus, care should be exercised when estimating a default rate for a particular transit corridor.

FARES TABLE

TYPE OF SERVICE	PROVIDER/SOURCE	AMOUNT
Bus fixed route -	Fort Collins	.90
Bus fixed route – Local off peak	RTD	.75
Bus fixed route – Local peak	RTD	1.25
Bus fixed route – Local (in town)	Vail	No charge
Bus fixed route	APTA (natl. average)*	.70
Bus fixed route – Express/commuter	RTD	2.00
Bus fixed route – Regional service	RTD	3.50
Bus fixed route – Regional service	Avon/Beaver Creek	3.25
Bus demand responsive – peak	RTD	2.50
Bus demand responsive	Fort Collins	1.80
Bus demand responsive	Durango	1.00
Bus demand responsive	APTA (natl. average)*	2.21
Light Rail – off peak	RTD	.75
Light Rail – peak	RTD	1.25
Light Rail	APTA (natl. average)*	.55
Commuter Rail	APTA (natl. average)*	3.24

* American Public Transit Association - APTA 1998 Transit Fact Book

Maintenance & Operating Costs

Mode	Cost	Unit	Source	Comments
Commuter Rail	$52,233	$/mile	CDOT Passenger Rail Study	High priority corridors
Commuter Rail (CS to Denver)	$76,800	$/mile	SFRCAS *	Freight track and vehicle operation
Commuter Rail (CS to Denver)	$119,369	$/mile	SFRCAS *	New track and vehicle operation
Commuter Rail	$10.10	$/VRM	1997 APTA Transit Fact Book	Vehicle revenue miles (VRM)
Commuter Rail	$9.96	$/VRM	CUTS tables	1989 dollars
High speed Rail (Denver to Vail)	$1,470,0	$/mile	I-70 Major Investment Study	MIS
LRT (inter-regional electric)	$57,600	$/mile	SFRCAS *	Track + vehicle operation
LRT (RTD service)	$15.57	$/VRM	RTD 1996 Annual FTA Report	
LRT	$9.95	$/VRM	NHI Course 15257	1994 dollars
Transit (RTD bus & LRT)	$4.93	$/VRM	RTD 1996 Annual FTA Report	
Transit (RTD bus)	$5.58	$/VRM	RTD 1996 Annual FTA Report	
Transit (bus service)	$5.76	$/VRM	NHI Course 15257	1994 dollars
Transit (fixed route bus service)	$5.45	$/VRM	1997 APTA Transit Fact Book	1996 dollars
Transit (demand responsive bus)	$2.43	$/VRM	1997 APTA Transit Fact Book	1996 dollars
Bus/HOV (at grade)	$570,000	$/mile/lane	I-70 MIS	
Bus/HOV (at grade)	$92,800	$/mile/lane	NHI Course 15257	Surface and enforcement
Bus/HOV (at grade CS to Den)	$163,901	$/mile/lane	SFRCAS *	Roadway and vehicle operation
Bus/HOV (at grade)	$24,526	$/mile/lane	Texas Transportation	Houston HOV surface and enforc.
Highway(interstate & arterial)	$13,675	$/mile/lane	CDOT Statewide Plan	M&O/surface condition
Highway(interstate & arterial)	$8,439	$/mile/lane	1995 C&P Report	Public roads in 1993 dollars
Highway(interstate & arterial)	$4,201	$/mile/lane	CDOT MMS 96/97 Annual Report	No overhead

TABLE R8 (continued): Maintenance and Operating Costs

Maintenance & Operating Costs

Mode	Cost	Unit	Source	Comments
Highway(interstate & arterial)	$4,649	$/mile/lane	CDOT 1997 Overview Report	No overhead
Highway(interstate & arterial)	$7,505	$/mile/lane	CDOT 1997 Overview Report	Administration, O&M
Highway(interstate & arterial)	$10,000	$/mile/lane	TRB Economic Impacts	
Interstate highway (at grade)	$56,800	$/mile/lane	NHI Course 15257 1994 dollars	Resurfacing $340,000 every 6 yrs
Interstate highway (at grade)	$560,000	$/mile/lane	I-70 MIS	
Interstate highway (at grade)	$30,000	$/mile/lane	SFRCAS *	
Bike Path	$9,250	$/mile	NHI Course 15257	Resurface every 4 years – 1994 ($)
Toll Collection	$43,300	$/mile/lane	TRB Special Report 242	1991 dollars
Toll Collection	$141,900	$/mile/lane	TRB Special Report 242	1991 dollars
Toll Collection	$43,300	$/mile/lane	TRB Special Report 242	1991 dollars
Auto fuel	$.0625	$/VMT	CDOT	20 mpg, $1.25/gallon 1998 dollars
Auto maintenance	$.082	$/VMT	CDOT	
Auto insurance	$.056	$/VMT	CDOT	
Auto registration	$.002	$/VMT	CDOT	
Auto home garage	$.014	$/VMT	CDOT	
Adjustment element PE	17.0	%	CDOT	Add on to project cost
Adjustment element ROW	7.0	%	CDOT	Add on to project cost
Adjustment /Adm. Overhead - (CE)	11.7	%	CDOT	Add on to project cost

TABLE R9: Current and Future Travel Volumes by Mode

For the Baseline scenario the number of trips for each mode should be obtained from available counts. When periods shorter than 24 hours are analyzed but trip counts are only available per day, Tables 41 of the NCHRP report 365, "Travel Estimation Techniques for Urban Planning" can be used to determine the percentage of the daily trips that correspond to the period analyzed. Conversion from analysis period to daily units is required when reporting some MOEs.

In order to estimate a percentage increase in the number of trips from the Baseline to the future No-build scenarios, the expected percentage increase in population between these two years can be used as default for all existing travel modes when more accurate information is not available.

Percentage of trips expected to use a new transit alternative

The expected ridership for a new transit mode will depend in part on the characteristics of the new mode considered as well as those of the existing modes (e.g., speed, comfort, safety, etc.). It will also depend on the fare or cost of the modes, the flexibility of the schedule offered by the transit mode, extent of transit services, and the level of accessibility (e.g., distance from transit stops to final destination and number of transfers needed).

The expected ridership will vary greatly according to the particular context of the proposed transit system from a range of 1-2 %, for a limited schedule rural system; to a 84-92 %, observed for buses in busy arterials in Philadelphia, Chicago, New York, Washington, San Francisco, and Los Angeles (See Table 12-4 of the 1994 HCM). No data is available for Colorado concerning observed percentage of transit trips taking place in a particular corridor. However, the total 1990 share for transit trips to work (Bus and Rail) for some MSAs are as follows: 4.08% for Denver-Boulder-Greeley, 1.00% for Colorado Springs, and 0.92% for Pueblo (Bureau of Transportation Statistics, 1990).

The analyst should consider all the characteristics and the context of the proposed mode when determining the expected share of the total trips likely to occur. In any case, given the suburban and rural nature of most places in Colorado, a range from 1 to 8 % is recommended -when no other information is available- for cases where highway is the only existing alternative and a transit mode is proposed.

TABLE R10: Maintenance & Operations Component Elements

Maintenance and Operations consist of expenditures needed to keep a mode of transportation efficiently running. M&O costs can be divided into three areas; infrastructure M&O, passenger service delivery M&O, and administration and overhead.

The roadway modes (SOV, HOV and even HOT) and the non-motorized modes (BIKE, PED) have the overwhelming majority of their costs loaded into the infrastructure component. The transit modes have a significant portion of their costs loaded into the service delivery component. This is largely due to the labor-intensive nature of passenger service delivery operations. Wages are paid to service delivery employees, which include drivers, dispatcher, fare collectors, etc. In contrast, the roadway modes do not account for the private vehicle operators' value of time under maintenance and operation.

Colorado and national transit figures were reviewed to approximate a percentage of the M&O costs that could be attributed to the Service Delivery Components area. The reported 1998 expenses for wages, benefits and materials for a selection of Colorado bus operators was compared to the total reported operating expenses. The average percentage of the service delivery elements was 75%. A similar comparison was made using national figures from The APTA 1997 Fact Book, which reported operating expenses by mode. The national bus percentage of wages, benefits and fuel/lubricants was 75%, with both light Rail and commuter Rail being calculated at 72%.

The following chart uses these amounts for the service delivery line. The administrative/overhead component is assumed to be 10% across the board.

MAINTENANCE AND OPERATIONS COMPONENT PERCENTAGES

	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PED
Infrastructure Component	90%	90%	85-90%	15%	18%	18%	90%	90%
Service Delivery Component	0%	0%	0-5%	75%	72%	72%	0%	0%
Administrative/Overhead	10%	10%	10%	10%	10%	10%	10%	10%

TABLE R11: Travel Time Relationships for Highways

The time it takes to travel a transportation segment is dependent on the distance and allowed speed and is also affected by the level of congestion present on the segment. The following delay function (first proposed by the Bureau of Public Roads in 1965) is generally used to estimate the travel time for a highway segment (with no signalized intersections):

$$\mathit{Travel\,Time} = \left[\mathit{Free\,Flow\,Travel\,Time} * \left(1 + \alpha \left(\frac{\mathit{Volume}}{\mathit{Capacity}} \right)^{\beta} \right) \right]$$

Where α *and* β , are parameters calibrated to the flow conditions of the highway analyzed, alpha and beta values for freeways range from 0.15 to 1.00 and from 4 to 10, respectively.

The default parameter values suggested in the manual worksheets are 0.84 and 5.5, as recommended for 60 mph design freeways in 'Travel Estimation Techniques for Urban Planning –NCHRP Report 365. Other values for alpha and beta can be used for highways with different design speed as shown in the following table from the report mentioned above.

BPR COEFFICIENTS				
FREEWAYS				
	Basic BPR	Design Speed 70 mph	Design Speed 60 mph	Design Speed 50 mph
Alpha	0.15	0.88	0.83	0.56
Beta	4	9.8	5.5	3.6

The Free-flow Speed used in the formula above is generally estimated as the speed limit for a transportation segment plus 5 miles/hour. The capacity for a particular highway facility is estimated according to the description in Table R15.

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The calibration of **site-specific** travel time functions requires observations of travel times on the segments studied under different flow levels and capacity values computed from the Highway Capacity Manual procedures. This calibration effort is expected to find the alpha and beta site-specific parameters to be used in the above travel time relationship.

TABLE R12: User Costs

User Cost is defined as the total expenses incurred by all individuals that use the transportation system. User costs are commonly divided into variable expenditures and periodic expenditures.

Variable user cost is the sum of those expenditures which vary directly with the number of trips taken. They are expenditures on gasoline, transit fares, parking, and tolls. Often they are referred to as out-of-pocket expenses. The MOE summary tables show variable user cost, on an annual basis, by mode and the EEA summary table shows annual variable user cost for the whole corridor. It is possible to compare variable user cost in the No-Build case with what it will be if a project is built to answer the question - will aggregate out-of-pocket expenditures by individuals using the transportation corridor be smaller or larger with the project completed? Some projects may change variable user cost. A mass transit project may reduce corridor-wide variable user cost if transit fares are lower than what travelers would have spent out-of-pocket using the SOV mode.

Periodic user cost is the sum of those expenditures that are needed for access to the transportation system. These are expenditures to purchase and maintain vehicles that the individual needs to utilize the system. Mostly these are automobiles and other light duty vehicles, but bicycles are also included. Walking shoes are ignored. The distinction between periodic and variable use cost is that once a periodic-type expenditure is made it does not change regardless of the number of trips taken. Periodic user cost includes annual expenditures on auto purchase, auto insurance, auto maintenance, registration/licensing/tax, and other equipment purchase. These may change somewhat over time if mass transit grows significantly, but given the large dependence of the existing transportation system on the automobile, it does not seem significant changes will be seen.

Some of the values used in calculating user cost are site specific and are entered by the analyst on the user input form UI. These are, miles per gallon, gasoline price, transit fares, parking prices, and tolls. If a site-specific value for miles per gallon is not available, a reasonable default for gasoline cost is $0.068/VMT. Site specific values may be used for the other user cost variables or the following default values which are taken from the Boulder Cost of Travel Report (1997). Auto purchase cost, $0.267/VMT; auto insurance cost, $0.056/VMT; auto maintenance, $0.082/VMT; auto registration/licensing/tax, $0.002/VMT; and other equipment purchase. The default values are denominated in $/VMT to take into account variation in the number of travelers over the analysis time horizon, not because they change with the number of trips taken.

TABLE R13: Value of Time

The price of making a trip is determined both, by the monetary expenses that may be incurred for the trip and by the amount of time that must be incurred for the trip. In order to express the price of a trip entirely in monetary terms it is necessary to convert the amount of time to the value of time spent to make the trip. The VOT is an estimate of the monetary equivalent of spending one hour making a trip.

Numerous studies have been published that estimate the VOT. Generally the estimated values fall within the range of 1/3 to 2/3 the wage rate. It is recommended here that an estimate of ½ the wage rate be used to develop the user benefit calculations. In the event that one is interested in assessing the sensitivity of the EA analysis to the assumed VOT it is recommended that one of the end values for the accepted range be chosen for a second set of EA calculations. Note that choosing a larger value for the VOT will lead to larger user benefit estimates.

The recommended source for wage rate information by county is the Bureau of Economic Analysis report on Average Wage Per Job. This report is available online at the following web page address:

http://www.bea.doc.gov/remd2/ca34/cowsavg.htm

Data for Colorado counties in 1995 are summarized in the table below. Given the county measure for average wage, the wage rate can be calculated as follows[1]:

wage rate = average wage ÷ 230 ÷ 8
($/hour) ($/year) (workdays) (hours/day

The VOT is then ½ (or 1/3 or 2/3) this wage. This value will be for the year in which the personal income measure was available and, it will have to be adjusted using the CPI to the value for the same year in which all the monetary values are being expressed for the EEA analysis.

1995 Average Wage Per Job

County	Average Wage
Adams	26099
Alamosa	19470
Arapahoe	30813
Archuleta	16723
Baca	14726
Bent	22640
Boulder	27765

1995 Average Wage Per Job

County	Average Wage
Chaffee	17534
Cheyenne	21195
Clear Creek	23191
Conejos	16602
Costilla	7635
Crowley	20430
Custer	15698

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[1] The number of workdays is 230 because the wage data is annual and includes both full time and part time jobs.

TABLE R13 (continued): Value of Time

1995 Average Wage Per Job			1995 Average Wage Per Job	
County	**Average Wage**		**County**	**Average Wage**
Delta	18605		Mineral	15147
Denver	31196		Moffat	25452
Dolores	16605		Montezuma	19002
Douglas	23659		Montrose	19937
Eagle	23365		Morgan	20116
Elbert	19244		Otero	17870
El Paso	24939		Ouray	17655
Fremont	21685		Park	17739
Garfield	22088		Phillips	17563
Gilpin	21587		Pitkin	24602
Grand	17078		Prowers	17284
Gunnison	17746		Pueblo	21933
Hinsdale	13837		Rio Blanco	23293
Huerfano	16179		Rio Grande	19886
Jackson	18248		Routt	21407
Jefferson	28679		Saguache	17187
Kiowa	18947		San Juan	16098
Kit Carson	16827		San Miguel	20079
Lake	19759		Sedgwick	16529
La Plata	20394		Summit	19396
Larimer	24484		Teller	17941
Las Animas	19957		Washington	17277
Lincoln	19335		Weld	23544
Logan	19344		Yuma	17547
Mesa	22234			
Source: Bureau of Economic Analysis, Table CA34 Average Wage Per Job, For Counties				

TABLE R14: Average Travel Speed for Transit

The average travel speed for transit modes is based on the total time it takes a transit vehicle to cover a route from end to end. In addition to the maximum allowed speed that a transit vehicle can attain, the critical factor is the spacing of stops. Actual average speeds for transit vehicles are relatively low. Based on 1992 data for revenue vehicle-miles (US FTA, 1993), the national average speed for LRT systems was 17.7 mph; for buses it was only 11.9 mph (average for the 20 largest bus systems in USA with operation mostly on city streets); and for heavy Rail systems it varied from 19.8 to 32.1 with a national average of 21.9 mph.

When no information on average transit speed is available to be entered in entry 4 of Worksheets B-b, B-c, and B-d, or Worksheets H-b, H-c, and H-d, default values based on the national averages mentioned above could be used as follows:

18 miles per hour for LRT
12 miles per hour for buses
22 miles per hour for CRT systems

Higher average speeds should be specified for cases where the separation between transit stops is large or when the transit system is located along a rural or suburban corridor.

TABLE R15: Capacity

The most common definition of physical capacity is *the maximum rate of flow of persons, goods, or vehicles that can reasonably be expected during a given time period through a link or node.* See NCHRP Report 399.

HIGHWAY CAPACITY

Capacity for highway links is generally estimated by using the procedures contained in the 1994 Highway Capacity Manual (HCM), which accounts for the physical limitations and other characteristics of the links. General values for some highway types are as follows:

Two-lane Rural Highways. The capacity for two-lane highways (both directions) is affected by directional split and it ranges from an ideal total capacity of 2,800 pcph* for a 50/50 condition to 2,000 pcph* when all the traffic travels in only one direction. In addition to directional distribution, other factors such as; (1) narrow lanes and shoulders, (2) percentage of heavy vehicles, and (3) V/C ratio of the traffic stream, also affect the final capacity.

Freeways. Maximum recommended capacity (at LOS E) for freeways with a free-flow speed of 55 mph to 70 mph varies from 2,200 to 2,300 pcphpl (See Table 3-1 of the 1994 HCM). Ranges of maximum observed capacities for different types of freeways are as follows (See Table 2-2 of the 1994 HCM):

For 4-lane freeways – from 1,900 to 2,650 vphpl with and average of 2,220 vphpl.

For 6-lane freeways – from 1,870 to 2,500 vphpl with and average of 2,170 vphpl.

For 8-lane freeways – from 1,670 to 2,270 vphpl with and average of 2,060 vphpl.

Signalized Arterials. Capacity at intersections is defined for each lane group and is highly dependent upon the signalization present and, therefore, highly variable. The allocation of green time and how the turning movements are accommodated within the phase sequence are the main determinants of capacity of a lane group.

In general, an adjusted saturation rate (in vphg) is obtained using the ideal saturation flow and adjusting it with different factors for; (1) lane width, (2) heavy vehicles, (3) grade, (4) parking, (5) bus blockage, (6) area type, (7) right turns, and (8) left turns. A Lane Group Capacity is then obtained by multiplying this adjusted saturation flow rate times the g/C ratio for the lane group. The ideal or default saturation flow is 1,900 vphgpl. See pages 9-112 and 9-115 of 1994 HCM.

pcph = per car per hour
pcphpl = per car per hour per lane
vphpl = vehicles per hour per lane
vphgpl = vehicles per hour of green per lane.
g/C = green time over cycle time for a lane group or approach

TRANSIT CAPACITY

Transit capacity deals with the movement of both people and vehicles and depends on the size of the transit vehicles and how often they operate. Transit capacity is usually measured by the maximum number of persons that can be moved on a single track or single lane in one hour. Factors that affect transit capacity are (See Chapter 12 of the HCM, 1994):

1. Vehicle characteristics
2. Passenger traffic characteristics
3. Right-of-way characteristics
4. Stop characteristics
5. Operating characteristics
6. Street traffic characteristics, and
7. Method of headway control

Buses. The maximum theoretical capacity for buses is 1450 buses per hour per lane [Rothery et al, 1964]. If each bus has 50 persons, that would come to 72,500 passengers per hour (with no stops or delays). The highest volume ever observed was 735 buses and 32,560 passengers in one hour at the Lincoln tunnel in New York [Black A., 1995]. The number of seats per bus vary for the different bus types as follows:

18-30 seats for minibuses
47-53 for regular buses
66-72 for articulated buses

The default number of seats suggested is 50 per bus.

Rail Transit. The capacity of a Rail line depends mostly on the minimum spacing (headway) between trains, and station (or stop) capacity. The maximum train length is governed by peak hour demand and should be compatible with the length of station platforms or loading areas. Commuter Rail trains commonly have 4 to 11 cars, whereas LRT trains are limited to a maximum of three cars. Rail cars generally vary from 50 to 75 seats per car.

The number of buses or train cars to be entered in worksheets B, E, and H, in cells B-b, B-c, B-d, etc., can be calculated using two different approaches:

Dividing the higher segment volume of bus trips per direction by the capacity of the bus. The number of trains (LRT or CRT) can be calculated dividing the higher segment volume of LRT/CRT trips per direction by the capacity of the train. Train capacity equals the number of cars per train multiplied by the seat capacity of a car. The number of transit units to run will determine the headway.

Determining the desired headway for bus or train runs and then performing the above calculations. The volume of bus or LRT/CRT trips will be per headway period in this case. That is, if transit runs are made every 20 minutes, the number of trips considered should be per 20 minutes.

In either case, these calculations should be performed for each different scenario and the result should be rounded to the next integer number. For example, if the number of bus trips divided by the capacity of a bus is equal to 2.3 then 3 buses should be considered. If the number is only 0.55, the 1 bus unit should be used.

TABLE R16: Average Percent Daily trips by Hour and Trip Purpose

Time-of-day tables showing the distribution of hourly trips through the day are shown below for areas with different population ranges. These tables are reproduced from the NCHRP Report 365.

Urban Size 50,000 to 199,999

Hour Beginning	HBW	HBO	NHB	ALL
0:00 a.m.	0.33	0.4	0.49	0.41
1:00 a.m.	0.07	0.17	0.12	0.12
2:00 a.m.	0.5	0.23	0.27	0.33
3:00 a.m.	0.61	0.07	0.12	0.27
4:00 a.m.	1.00	0.08	0	0.36
5:00 a.m.	2.79	0.18	0.06	1.01
6:00 a.m.	8.34	1.1	0.46	3.3
7:00 a.m.	13.57	5.53	2.07	7.06
8:00 a.m.	7.84	5.64	2.27	5.25
9:00 a.m.	3.36	4.27	3.76	3.8
10:00 a.m.	2.79	5.86	5.4	4.68
11:00 a.m.	2.65	6.44	7.22	5.44
12:00 a.m.	3.72	6.4	11.26	7.13
1:00 p.m.	3.26	6.34	8.77	6.12
2:00 p.m.	4.12	7.7	8.31	6.71
3:00 p.m.	8.3	8.06	9.74	8.7
4:00 p.m.	10.31	7.25	9.28	8.95
5:00 p.m.	10.66	7.32	8.56	8.85
6:00 p.m.	5.01	7.44	7.19	6.55
7:00 p.m.	2.79	6.71	5.52	5.01
8:00 p.m.	1.72	5.24	3.46	3.47
9:00 p.m.	2.29	3.95	3.06	3.1
10:00 p.m.	2.26	2.25	1.55	2.02
11:00 p.m.	1.69	1.37	1.06	1.37

Source: 1990
NPTS

TABLE R16: (continued) Average Percent Daily trips by Hour

Urban Size 200,000 to 499,999

Hour Beginning	HBW	HBO	NHB	ALL
0:00 a.m.	0.35	0.29	0.48	0.37
1:00 a.m.	0.22	0.26	0.16	0.21
2:00 a.m.	0.35	0.15	0.38	0.29
3:00 a.m.	0.06	0.22	0.1	0.13
4:00 a.m.	1.03	0.17	0.16	0.45
5:00 a.m.	2.57	0.29	0	0.95
6:00 a.m.	8.58	1.2	0.48	3.42
7:00 a.m.	14.46	5.28	1.33	7.02
8:00 a.m.	8.06	5.43	2.45	5.31
9:00 a.m.	3.03	4.72	3.08	3.61
10:00 a.m.	2.63	5.15	4.62	4.13
11:00 a.m.	2.29	5.09	8.39	5.26
12:00 a.m.	2.86	6.43	10.04	6.44
1:00 p.m.	2.86	6.19	9.08	6.04
2:00 p.m.	4.4	7.5	9.2	7.03
3:00 p.m.	6.58	8.25	10.36	8.4
4:00 p.m.	9.78	7.45	10.25	9.16
5:00 p.m.	12.24	7.23	9.2	9.55
6:00 p.m.	6.86	8.47	5.84	7.06
7:00 p.m.	2.63	6.72	4.31	4.55
8:00 p.m.	1.94	5.36	3.67	3.66
9:00 p.m.	2.29	3.96	3.14	3.13
10:00 p.m.	2.05	2.47	2.02	2.18
11:00 p.m.	1.89	1.76	1.28	1.64

Urban Size 500,000 to 999,999

Hour Beginning	HBW	HBO	NHB	ALL
0:00 a.m.	0.35	0.32	0.34	0.34
1:00 a.m.	0.21	0.19	0.25	0.22
2:00 a.m.	0.36	0.26	0.32	0.31
3:00 a.m.	0.37	0.19	0.12	0.23
4:00 a.m.	0.88	0.06	0.06	0.33
5:00 a.m.	2.94	0.24	0.07	1.08
6:00 a.m.	7.9	1.058	0.31	3.1
7:00 a.m.	14.06	4.79	1.05	6.63
8:00 a.m.	9.63	6.18	2.25	6.02
9:00 a.m.	4.3	4.88	3.32	4.17
10:00 a.m.	2.26	5.55	5.39	4.4
11:00 a.m.	1.86	5.61	7.47	4.98
12:00 a.m.	2.92	6.06	11.37	6.78
1:00 p.m.	2.68	5.72	8.92	5.77
2:00 p.m.	3.8	7.63	9.15	6.86
3:00 p.m.	6.78	9.1	9.51	8.46
4:00 p.m.	9.31	6.9	8.64	8.28
5:00 p.m.	12.04	7.37	9.01	9.47
6:00 p.m.	6.61	7.04	6.82	6.82
7:00 p.m.	3.26	6.92	5.61	5.26
8:00 p.m.	2.2	5.38	3.89	3.82
9:00 p.m.	1.91	4.25	3.04	3.07
10:00 p.m.	1.75	2.48	1.67	1.97
11:00 p.m.	1.61	1.79	1.42	1.61

Source:
1990 NPTS

TABLE R17: Maximum Theoretical Capacity for Highway and Transit Modes

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Theoretical Transit Line Capacity. The maximum number of spaces that can ideally be carried over a transit line or highway segment during a given time period with every transit unit operating at the minimum headway that the control system permits.

For transit, the capacity (in passengers per hour) can be calculated using equations 12-2 in the 1994 HCM as follows:

$$C_p = nSC_v$$

where,

$C_p =$ maximum transit passengers per hour
$n =$ vehicles per unit (1 for buses, 1-11 for Rail vehicles)
$S =$ passengers per vehicle
$C_v =$ maximum number of vehicles per hour per channel. This is calculated as

$$C_p = \frac{3{,}600nSR}{D + t_c}$$

where,

$R =$ reductive factor to compensate for dwell time and arrival variations
$h = D + t_c =$ headway between successive units in seconds
$D =$ dwell time at stops in seconds (the time that a transit vehicle is stopped for the purpose of serving passengers).
$t_c =$ clearance between successive vehicles in seconds

Maximum recommended R values are 1.00 for Rail transit and 0.833 for bus.

Maximum theoretical capacity for Bus per lane per hour:

1. On exclusive bus roadways with uninterrupted flow and no stops for passengers (see Table R15)
   1450 buses * 50 persons/bus = 72,500 passengers per hour

2. Number of bus passengers is obtained from $C_p = \frac{3{,}600nSR}{D + t_c}$
   (Assuming platoons of six buses, 50 passengers per bus, R=0.833, and dwell time and clearance time equal to 30 seconds and 15 seconds, respectively)

   Maximum bus passenger capacity = (3600*6*50*0.833) / (30+15) = 20,000 passengers per hour

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Maximum theoretical capacity for CRT per track per hour:

Assuming a headway of 90 seconds between trains, 11 cars per train, and 75 passengers per car,

3,600(11)(75) / 90 = 33,000 CRT passengers per hour

Maximum theoretical capacity for LRT per track per hour:

Assuming a headway of 60 seconds between trains, 3 cars per train, and 75 passengers per car,

3,600(3)(75) / 60 =13,500 CRT passengers per hour

Maximum theoretical passenger capacity for highway lanes per hour:

Theoretical Highway Capacity. The maximum number of vehicles that can pass over a given section of a lane or roadway in one or both directions during a given period under ideal environmental, roadway, and traffic conditions.

1. Assuming a capacity per highway lane of 2,400 vehicles per hour and occupancy equal to 4 persons per vehicle.

   2,400*4 = 9,600 passenger per hour/lane

2. Assuming an occupancy of five persons per vehicle.

   2,400*5 = 12,000 passengers per hour/lane

TABLE R18: Bike and Pedestrian Benefits

Unfortunately, there are no previously published studies that estimate demand elasticities for bike or walking trips, as is the case with automobiles, bus, and Rail transit. Therefore a different approach may have to be taken in order to estimate benefits associated with projects that impact bike and pedestrian modes. There might be three types of projects related to bike and pedestrian modes for which benefits can be calculated.

(1) Many proposed projects involve creation of a new bike/pedestrian path. Often these projects involve greenways or other parklands. The bike/pedestrian paths which are created may be used for work commuting trips as well as for recreational biking and walking activities, both of which provide economic benefits to those making use of the new bike/pedestrian path. The benefits of these recreational biking/walking uses of the new paths can be calculated based on the following estimates of benefits per recreational day (in March 1998 dollars): $18.68 for biking and $12.78 for walking.[2] Given an estimate of the number of biking and walking recreational trips on the path annually, the economic benefit is calculated by multiplying the number of days for each type of use multiplied by the appropriate benefit value. There are no similar values for commuting trips by bike or pedestrian modes. Therefore, the benefit calculated for these projects should represent a lower bound estimate of the benefits of such projects.

(2) If a project is expected to decrease the average time required to make a trip by bike or by walking, then the benefit of the project can be calculated using Form BB2 User Benefit Worksheet for Project That Increases Capacity.

(3) If a project's purpose is to increase the safety of bike or pedestrian trips, then there should be estimates of fatalities that would be entered in Form CC Safety Benefit Worksheet in order to calculate the benefits of this type of project.

John C. Bergstrom and H. Ken Cordell, An analysis of the demand for and value of outdoor recreation in the United States, **Journal of Leisure Research** 23(1) 67-86 (1991)

Appendix 2

Illustration of MOE and EEA Analysis

Example Project Analysis

The purposes of this appendix are first, to illustrate the information provided by both the MOE and EEA calculations described in this guidebook, and second, to illustrate the derivation of this information. Both these purposes will utilize a "case study" which involves the I-25 corridor from Lincoln Avenue on the south side of the Denver metro area to North Academy Blvd. on the north side of the Colorado Springs metro area. At present, specific segments of the I-25 highway experience significant rush hour traffic. The case illustration assumes that as part of the long range planning process there is an interest in examining alternatives that might ease the congestion problems now and in the future.

Baseline Projection

The analysis will be conducted in terms of three segments which seem natural in view of trip demands and posted speed limits: (1) between Lincoln Avenue and Castle Rock, (2) between Castle Rock and Monument, and (3) between Monument and North Academy. The basic analysis is developed with respect to four analysis years: 2000, 2010, 2020, and 2030. It is assumed that the analysis is developed to support a decision in 1998 with respect to the proposed project alternatives. Data for the analysis comes from traffic counts with 1990 as the reference year. Projections of number of trips during rush hour for each of the segments were developed based on population projections, and it is assumed that the number of trips will increase by the same percentage as the population is projected to increase. The specific percentage increases in trips by segment and relative to the 1990 baseline are summarized in Table A3-1.

CORRIDOR SEGMENT	2000	2010	2020	2030
Lincoln - Castle Rock	45%	95%	154%	200%
Castle Rock - Monument	36%	74%	112%	150%
Monument - Academy	24%	46%	68%	120%

Table A3.1. Projected increases in population and rush-hour trips relative to 1990.

The baseline and projected peak-period trips (in both directions) by segment are presented in Figure A3.1. The number of morning peak-period trips, both directions, in 1990 between Lincoln and Castle Rock were 6650, between Castle Rock and Monument were 5075, and between Monument and North Academy were 7350. The projected increase in the number of trips by the year 2030 will result in an increase of 13300 in morning peak-period trips between Lincoln and Castle Rock, an increase of 7613 trips between Castle Rock and Monument, and an increase of 8820 trips between Monument and North Academy.

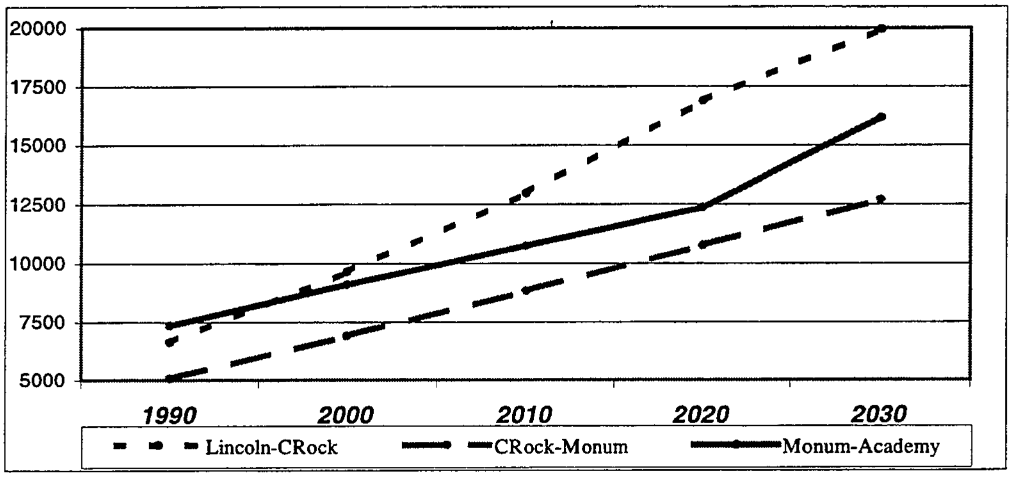

Figure A3.1 Baseline and expected peak-period trips by corridor segment.

While the number of trips and the increase in number of trips may seem to be significantly large, it is difficult to judge what the number of trips means with respect to travel conditions without taking the highway capacity into account. One way to characterize the baseline conditions, given the projected growth in the number of trips, is to examine what can be expected to happen to average speed on each of the segments. Note that since the number of trips for each segment of the I-25 corridor is not uniform in each direction, the problems associated with rush hour congestion are more or less severe depending on the segment and the direction.

Presently there are 2 lanes (with an assumed capacity of 2000 vehicles per hour) in each direction for the entire I-25 segment under consideration. The baseline conditions for rush hour trips along the I-25 corridor can be described in terms of the average speed for a rush hour trip along each segment. This is illustrated in Figure A3.2 for each segment in terms of the direction of travel (for the morning rush hour) which is characterized by the most severe congestion in each case. The projected conditions for the corridor suggests that by 2010 there will be a significant decrease in average speed during the morning rush hour for trips between Castle Rock and Lincoln Avenue. Speeds for this segment would reach a minimum of 17 mph and 8 mph (if current is not increased) for the years 2020 and 2030 respectively. For the segment between Monument and Academy, speeds would fall (from a free-flow present condition of about 80 mph) to 60 mph by the year 2020 and to 32 mph by the year 2030. The segment between castle Rock and Monument, on the other hand, will not experience impacts on speeds until the year 2030.

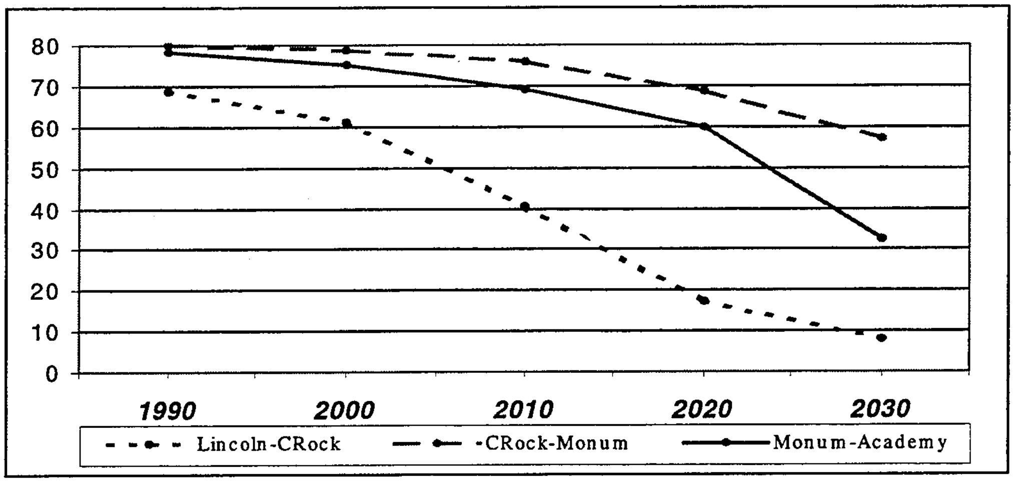

Figure A3.2. Baseline projections of average speed (two directions).

Project Description

The analysis considers two proposed projects for this I-25 corridor between Lincoln and North Academy: (1) to increase the highway capacity by adding one lane in each direction, and (2) to create a commuter rail line between Lincoln and North Academy.

Added Highway Capacity Alternative

This alternative would add one lane to both the northbound and southbound lanes of I-25 from Lincoln Avenue to North Academy Avenue. This will increase capacity from 4000 vehicles per hour to 6000 vehicles per hour in each direction. It is assumed that construction would begin in the year 2000 and that it will take five years to complete the entire project for the length of the corridor which is 42.8 miles. Construction costs are estimated at $8 million per mile per lane, plus 35.7% for ROW and preliminary and construction engineering. This amounts to $929.2 million for the 42.8 miles, or $185.85 million annually during the construction period[1].

No benefits are assumed to flow from the Added Capacity Alternative until construction is completed. Therefore, benefits begin to be enjoyed for this project in the year 2005. Annual M&O costs (including periodic resurfacing) are assumed at $60,000 per mile per lane plus 10% overhead. This gives an annual M&O total of $5.65million for the 42.8 miles.

Given the differences in the number of trips for each of the three segments by direction it is also of interest to consider the Added Capacity Alternative as being composed of three separate projects, one for each segment. Significant congestion is expected for the segment between Lincoln Avenue and Castle Rock, especially by the year 2030. In contrast, congestion problems for the segment between Castle Rock and Monument are expected to be minor, even by 2030.

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[1] For the purposes of analysis it is assumed that the total capital costs are expended in equal increments for each of the five years of the construction period.

It is quite possible that while the added capacity might not be a good investment for the entire corridor length, it could be a good investment for only one or perhaps two of the three segments analyzed. As such, the analysis of alternatives will consider not only the entire corridor but also each of the specific sections of the corridor.

Commuter Rail Alternative

This project would create a commuter rail alternative to car travel in the I-25 corridor between Lincoln Avenue and North Academy Avenue. It is assumed that the project will take 10 years to complete (year 2010 for first operation). The project would have two rail lines and operate with trains consisting of two 75-seat cars. Headways would be 20 minutes during the morning and evening peak periods and 30 minutes off peak. Fares would be $3.00 for each of three segments or $9.00 for the entire corridor length. The average speed for the trains would be 50 mph.

It is assumed that construction would begin in the year 2000 and that it will take 10 years to complete the entire project for the length of the corridor which is 42.8 miles. Construction costs are estimated at $10 million per mile per lane, plus 35.7% for ROW and preliminary and construction engineering. This amounts to $1161.6 million ($1998) for the 42.8 miles, or $116.16 million ($1998) for each of the ten construction years.

No benefits are assumed to flow until construction is completed (year 2010). In the year of completion there will also be a cost of $40.04 million ($1998) to obtain the equipment that will make up the trains. Annual M&O costs are assumed at $120,000 per mile per lane plus 10% overhead. This gives an annual M&O total of $11.3 million ($1998) for the 42.8 miles. It is assumed that every ten years it will be necessary to "refurbish" the new equipment at a cost of $19.25 million ($1998).

As explained in the description of the added capacity alternative, the differences in highway congestion for each of the three segments suggests consideration of the rail alternative for each segment separately.

Economic Efficiency Analysis

Added Highway Capacity Alternative

The efficiency analysis calculates benefits and costs associated with this alternative in terms of project costs and user benefits. Note that the user benefits are calculated assuming the same number of trips are taken annually during rush-hour with and without the project. That is, it is assumed that the project itself does not induce any increase in the number of trips. Changes in congestion and travel time were calculated in terms of user benefits for each of 4 analysis years: 2000, 2010, 2020, and 2030. Values for user benefits for non-analysis years are interpolated between the analysis years. Since the lifetime of this project is assumed to be 30 years, the EEA calculations are carried out from 1998 to 2034, and since the last analysis year is 2030, it is assumed that the benefits and costs in the year 2030 are repeated annually into the indefinite future. While this is a conservative assumption, since the planning horizon for which population or transportation demand growth projections are made ends in the year 2030, without taking the projections of population and trip increases farther into the future this assumption seems the most prudent.[2]

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[2] Of course other assumptions could be made in the context of EEA. However, given the mathematical nature of discounting, increments in undiscounted benefits for additional future years add increasingly smaller

EEA is based on a comparison of the discounted present value of benefits and costs for the project over the lifetime of the project or in this case from 1998 to 2034. This is done here assuming a discount rate of 3.8%. Table A3.2 illustrates the specific calculation of the present value of net social benefits for this project. The present value of NSB for the added highway capacity project is - $509.40 million. Since the present value of NSB is negative EEA recommends against this added highway capacity project along I-25 from Lincoln to Academy. The results of the EEA suggest that construction of an additional lane for the entire I-25 corridor can be expected not to provide the people in the community with increased well-being compared with taking no action at all along this corridor. Of course this does not mean that another project for this corridor might not be consistent with EEA.

Table A3.2. Net Social Benefit Table
Add Lane Alternative For Entire Corridor (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0	1998	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	1999	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2	2000	$0.00	$0.00	$0.00	$185.85	$0.00	($185.85)	($166.18)
3	2001	$0.00	$0.00	$0.00	$185.85	$0.00	($185.85)	($160.10)
4	2002	$0.00	$0.00	$0.00	$185.85	$0.00	($185.85)	($154.24)
5	2003	$0.00	$0.00	$0.00	$185.85	$0.00	($185.85)	($148.59)
6	2004	$0.00	$0.00	$0.00	$185.85	$0.00	($185.85)	($143.15)
7	2005	$1.34	$0.00	$0.00	$0.00	$5.65	($4.31)	($3.20)
8	2006	$1.82	$0.00	$0.00	$0.00	$5.65	($3.83)	($2.74)
9	2007	$2.31	$0.00	$0.00	$0.00	$5.65	($3.34)	($2.30)
10	2008	$2.79	$0.00	$0.00	$0.00	$5.65	($2.86)	($1.90)
11	2009	$3.28	$0.00	$0.00	$0.00	$5.65	($2.37)	($1.52)
12	2010	$3.76	$0.00	$0.00	$0.00	$5.65	($1.89)	($1.16)
13	2011	$5.60	$0.00	$0.00	$0.00	$5.65	$0.05	$0.03
14	2012	$7.43	$0.00	$0.00	$0.00	$5.65	$1.79	$1.02
15	2013	$9.27	$0.00	$0.00	$0.00	$5.65	$3.62	$1.99
16	2014	$11.11	$0.00	$0.00	$0.00	$5.65	$5.46	$2.90
17	2015	$12.95	$0.00	$0.00	$0.00	$5.65	$7.30	$3.73
18	2016	$14.78	$0.00	$0.00	$0.00	$5.65	$9.13	$4.50
19	2017	$16.62	$0.00	$0.00	$0.00	$5.65	$10.97	$5.20
20	2018	$18.46	$0.00	$0.00	$0.00	$5.65	$12.81	$5.85
21	2019	$20.30	$0.00	$0.00	$0.00	$5.65	$14.65	$6.45
22	2020	$22.13	$0.00	$0.00	$0.00	$5.65	$16.48	$6.99
23	2021	$27.79	$0.00	$0.00	$0.00	$5.65	$22.14	$9.04
24	2022	$33.44	$0.00	$0.00	$0.00	$5.65	$27.79	$10.94
25	2023	$39.09	$0.00	$0.00	$0.00	$5.65	$33.44	$12.68

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amounts to the Present Value of NSB. For example, in Table A3.2, notice the change in the present value of NSB between the year 2033 and 2034. Therefore, regardless of the assumptions about what happens after the last analysis year, there will be very little difference in the "bottom line" provided in the Present Value of NSB.

Table A3.2. Net Social Benefit Table -- (Contd')
Add Lane Alternative For Entire Corridor (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
26	2024	$44.75	$0.00	$0.00	$0.00	$5.65	$39.10	$14.28
27	2025	$50.40	$0.00	$0.00	$0.00	$5.65	$44.75	$15.75
28	2026	$56.05	$0.00	$0.00	$0.00	$5.65	$50.40	$17.09
29	2027	$61.71	$0.00	$0.00	$0.00	$5.65	$56.06	$18.31
30	2028	$67.36	$0.00	$0.00	$0.00	$5.65	$61.71	$19.42
31	2029	$73.01	$0.00	$0.00	$0.00	$5.65	$67.36	$20.42
32	2030	$78.67	$0.00	$0.00	$0.00	$5.65	$73.02	$21.33
33	2031	$78.67	$0.00	$0.00	$0.00	$5.65	$73.02	$20.55
34	2032	$78.67	$0.00	$0.00	$0.00	$5.65	$73.02	$19.79
35	2033	$78.67	$0.00	$0.00	$0.00	$5.65	$73.02	$19.07
36	2034	$78.67	$0.00	$0.00	$0.00	$5.65	$73.02	$18.37
Present Value		$339.90	$0.00	$0.00	$772.30	$77.10	($509.40)	($509.40)
Annual Value		$17.70	$0.00	$0.00	$40.30	$4.00	($26.60)	($26.60)
Perpetuity Value		$466.40	$0.00	$0.00	$1,059.40	$105.80	($698.90)	($698.90)

Finding a negative value for the present value of NSB for a project this alternative does not mean that increasing the capacity of the interstate would not be efficient if considered for shorter segments. As noted above, the entire 42-mile length of the corridor experiences different levels of trip demand on each of the segments. Thus, it is also possible to define a project that would add a lane in each direction for each of these three segments. If this is done, it turns out that only one segment, i.e. Lincoln to Castle Rock, would have results that suggest it would be efficient to expand highway capacity. The present value calculations of NSB for this smaller project are summarized in Table A3.3. Note that since only this shorter segment is now being considered the length of the time period assumed for construction is reduced from five years to three years. Capital costs and M&O costs are also adjusted to reflect the much shorter segment length of only 11.2 miles. The bottom line in this case is that a project that would increase the capacity of I-25 by one lane in each direction only between Lincoln and Castle Rock would have a present value for NSB that is positive ($15.5 million). This suggests that by expanding highway capacity between Lincoln and Castle Rock, the benefits of the reduced congestion would be efficient and could be consistent with people in the communities served by this corridor segment being better off as a result (compared to continuing with the status quo). Therefore, efficiency analysis would recommend this smaller project to expand highway capacity.

Table A3.3. Net Social Benefit Table
Add Lane Alternative For Lincoln to Castle Rock Segment (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0	1998	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	1999	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2	2000	$0.00	$0.00	$0.00	$81.60	$0.00	($81.06)	($72.48)

Table A3.3. Net Social Benefit Table – (Contd')
Add Lane Alternative For Lincoln to Castle Rock Segment (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
3	2001	$0.00	$0.00	$0.00	$81.60	$0.00	($81.06)	($69.82)
4	2002	$0.00	$0.00	$0.00	$81.60	$0.00	($81.06)	($67.27)
5	2003	$0.72	$0.00	$0.00	$0.00	$1.48	($0.76)	($0.61)
6	2004	$1.10	$0.00	$0.00	$0.00	$1.48	($0.38)	($0.29)
7	2005	$1.49	$0.00	$0.00	$0.00	$1.48	$0.01	$0.01
8	2006	$1.87	$0.00	$0.00	$0.00	$1.48	$0.39	$0.28
9	2007	$2.25	$0.00	$0.00	$0.00	$1.48	$0.77	$0.53
10	2008	$2.63	$0.00	$0.00	$0.00	$1.48	$1.16	$0.77
11	2009	$3.02	$0.00	$0.00	$0.00	$1.48	$1.54	$0.98
12	2010	$3.40	$0.00	$0.00	$0.00	$1.48	$1.92	$1.18
13	2011	$5.07	$0.00	$0.00	$0.00	$1.48	$3.59	$2.13
14	2012	$6.74	$0.00	$0.00	$0.00	$1.48	$5.26	$3.01
15	2013	$8.41	$0.00	$0.00	$0.00	$1.48	$6.93	$3.82
16	2014	$10.08	$0.00	$0.00	$0.00	$1.48	$8.61	$4.56
17	2015	$11.76	$0.00	$0.00	$0.00	$1.48	$10.28	$5.25
18	2016	$13.43	$0.00	$0.00	$0.00	$1.48	$11.95	$5.88
19	2017	$15.10	$0.00	$0.00	$0.00	$1.48	$13.62	$6.46
20	2018	$16.77	$0.00	$0.00	$0.00	$1.48	$15.29	$6.99
21	2019	$18.44	$0.00	$0.00	$0.00	$1.48	$16.96	$7.47
22	2020	$20.11	$0.00	$0.00	$0.00	$1.48	$18.63	$7.90
23	2021	$24.09	$0.00	$0.00	$0.00	$1.48	$22.61	$9.24
24	2022	$28.06	$0.00	$0.00	$0.00	$1.48	$26.58	$10.46
25	2023	$32.04	$0.00	$0.00	$0.00	$1.48	$30.56	$11.59
26	2024	$36.02	$0.00	$0.00	$0.00	$1.48	$34.54	$12.62
27	2025	$39.99	$0.00	$0.00	$0.00	$1.48	$38.51	$13.55
28	2026	$43.97	$0.00	$0.00	$0.00	$1.48	$42.49	$14.41
29	2027	$47.95	$0.00	$0.00	$0.00	$1.48	$46.47	$15.18
30	2028	$51.92	$0.00	$0.00	$0.00	$1.48	$50.44	$15.87
31	2029	$55.90	$0.00	$0.00	$0.00	$1.48	$54.42	$16.50
32	2030	$59.88	$0.00	$0.00	$0.00	$1.48	$58.40	$17.06
33	2031	$59.88	$0.00	$0.00	$0.00	$1.48	$58.40	$16.43
34	2032	$59.88	$0.00	$0.00	$0.00	$1.48	$58.40	$15.83
Present Value		$246.80	$0.00	$0.00	$209.90	$21.70	$15.50	$15.50
Annual Value		$13.50	$0.00	$0.00	$11.40	$1.20	$0.80	$0.80
Perpetuity Value		$354.20	$0.00	$0.00	$300.70	$31.20	$22.20	$22.20

Commuter Rail Alternative

EEA calculates benefits and costs associated with this rail project in terms of the project impacts described by the MOE analysis: (a) change in travel time, (b) change in air pollution, (c) change in fatalities, (d) project capital costs, and (e) maintenance and operation costs for the commuter rail. Since the project would not be completed until 2010, the changes in travel time, air pollution, and fatalities were calculated for only three analysis years: 2010, 2020, and 2030. Values for benefits and costs were interpolated between the analysis years. Since the lifetime of the commuter rail is assumed to be 50 years the EEA calculations are carried out for this entire lifetime, i.e. the last year in the calculations is 2059. Since the last analysis year is 2030 it is assumed that the benefits and costs in the year 2030 continue annually into the indefinite future.

EEA is based on a comparison of the discounted present value of benefits and costs for the project over the lifetime of the project or in this case from 1998 to 2059. This is done here assuming a discount rate of 3.8%. Table A3.4 illustrates the specific calculation of the present value of NSB for the commuter rail project, which is - $205.2 million. Since the present value of NSB is negative, EEA recommends against this commuter rail project along I-25 from Lincoln to Academy. The results of the EEA suggest that construction of commuter rail in this case can be expected not to provide the people in the community in general with increased well-being compared with taking no action at all along this corridor.

Table A3.4. Net Social Benefit Table
Commuter Rail Alternative -- (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0	1998	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	1999	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2	2000	$0.00	$0.00	$0.00	$116.16	$0.00	($116.16)	($103.86)
- -	- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -	- -
11	2009	$0.00	$0.00	$0.00	$116.16	$0.00	($116.16)	($74.25)
12	2010	$26.90	($0.08)	$3.68	$40.04	$11.30	($20.84)	($12.80)
13	2011	$28.24	$0.39	$3.80	$0.00	$11.30	$21.13	$12.54
- -	- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -	- -
21	2019	$38.96	$4.11	$4.80	$0.00	$11.30	$36.57	$16.10
22	2020	$40.30	$4.58	$4.92	$19.25	$11.30	$19.25	$8.17
23	2021	$43.00	$5.14	$5.07	$0.00	$11.30	$41.91	$17.12
- -	- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -	- -
52	2050	$67.25	$10.18	$6.42	$19.25	$11.30	$72.55	$7.38
53	2051	$67.25	$10.18	$6.42	$0.00	$11.30	$72.55	$9.68
- -	- -	- -	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	- -	- -	- -
61	2059	$67.25	$10.18	$6.42	$0.00	$11.30	$72.55	$7.18
Present Value		$717.60	$89.50	$76.50	$928.20	$160.60	($205.20)	($205.20)
Annual Value		$30.50	$3.80	$3.30	$39.50	$6.80	($8.70)	($8.70)
Perpetuity Value		$803.40	$100.20	$86.60	$1,039.10	$179.80	($229.70)	($229.70)

A negative present value of NSB for a project that would create a commuter rail line along the entire 42-mile length corridor, does not mean that a rail project along a shorter segment of the corridor might not be an efficient investment. The different congestion levels for each of the segments suggests that construction along the entire corridor may be too costly given that the benefits of the project aren't very large for some portions of the corridor. However, benefits could be greater than costs for segments with extreme congestion. Developing an EEA for a rail line for each of the segments separately results in only the segment between Lincoln and Castle Rock having a positive present value of NSB. The present value of NSB calculations for creating a rail line only between Lincoln and Castle Rock are summarized in Table A3.5. Note that it is assumed that this project would take five years to complete (rather than the 10 years assumed for the entire corridor). A project that would create a rail line between Lincoln and Castle Rock would have a positive present value for NSB of $108.7 million ($1998). This means that creating a rail line between Lincoln and Castle Rock would be recommended by an economic efficiency analysis.

Table A3.5. Net Social Benefit Table
Commuter Rail Alternative – Lincoln to Castle Rock -- (Millions $1998)

Year	Date	User Benefits	Air Quality Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0	1998	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	1999	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2	2000	$0.00	$0.00	$0.00	$60.79	$0.00	($60.79)	($54.36)
3	2001	$0.00	$0.00	$0.00	$60.79	$0.00	($60.79)	($52.37)
4	2002	$0.00	$0.00	$0.00	$60.79	$0.00	($60.79)	($50.45)
5	2003	$0.00	$0.00	$0.00	$60.79	$0.00	($60.79)	($48.60)
6	2004	$0.00	$0.00	$0.00	$60.79	$0.00	($60.79)	($46.82)
7	2005	$8.71	$0.25	$1.19	$17.16	$2.96	($9.97)	($7.40)
8	2006	$9.11	$0.27	$1.24	$0.00	$2.96	$7.67	$5.48
9	2007	$9.52	$0.30	$1.28	$0.00	$2.96	$8.14	$5.61
10	2008	$9.92	$0.32	$1.33	$0.00	$2.96	$8.62	$5.72
11	2009	$10.32	$0.35	$1.38	$0.00	$2.96	$9.09	$5.81
12	2010	$10.73	$0.37	$1.42	$0.00	$2.96	$9.56	$5.89
13	2011	$11.69	$0.40	$1.48	$0.00	$2.96	$10.61	$6.29
14	2012	$12.65	$0.43	$1.53	$0.00	$2.96	$11.65	$6.66
15	2013	$13.61	$0.46	$1.59	$0.00	$2.96	$12.69	$6.99
16	2014	$14.57	$0.49	$1.64	$0.00	$2.96	$13.73	$7.29
17	2015	$15.52	$0.52	$1.69	$9.90	$2.96	$4.88	$2.49
18	2016	$16.48	$0.54	$1.75	$0.00	$2.96	$15.82	$7.79
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
52	2050	$38.08	$0.89	$2.39	$0.00	$2.96	$38.40	$5.32
53	2051	$38.08	$0.89	$2.39	$0.00	$2.96	$38.40	$5.13
54	2052	$38.08	$0.89	$2.39	$0.00	$2.96	$38.40	$4.94
55	2053	$38.08	$0.89	$2.39	$0.00	$2.96	$38.40	$4.76
56	2054	$38.08	$0.89	$2.39	$0.00	$2.96	$38.40	$4.58
Present Value		$394.30	$10.60	$32.30	$277.90	$50.60	$108.70	$108.70
Annual Value		$17.20	$0.50	$1.40	$12.10	$2.20	$4.70	$4.70
Perpetuity Value		$452.50	$12.20	$37.10	$318.90	$58.10	$124.70	$124.70

EEA Summary

Efficiency analysis has been used here to evaluate two projects defined for the entire I-25 corridor from Lincoln Avenue to North Academy Blvd: (a) the addition of one lane to the highway in each direction, and (b) the creation of a commuter rail line. Each of these proposed projects could be expected to have negative values for the present value of NSB: (a) - $509 million for the added highway capacity for the entire segment, and (b) - $205 million for the new commuter rail alternative to automobile travel between Lincoln and North Academy. Therefore, based on efficiency analysis alone, neither of these projects could be recommended. This efficiency analysis suggests that, even though segments of this corridor can be expected to become significantly congested by the 2030 analysis period, there are alternative uses for the resources that would be of greater value to the community than the benefits provided by either of these projects. In other words, the benefits of either of these transportation projects are not sufficiently large to justify their costs, and efficiency analysis would recommend that neither of these investment projects for the entire corridor be chosen.

However, it is also possible to think of there being six additional investment projects to consider if each of these corridor projects is broken into a separate project for each of the three segments analyzed. Specifically, three possible investment projects can be defined by considering adding a lane in each direction for the separate segments between Lincoln and Castle Rock, Castle Rock and Monument, and Monument and North Academy. Similarly, three additional investment projects can be defined with respect to commuter rail. Analysis of these additional six projects reveals that both increased highway capacity and creating a rail line for the segment between Lincoln and Castle Rock would be consistent with economic efficiency, while each of the other four projects fail to pass the efficiency test. In particular, building an additional lane in each direction between Lincoln and Castle Rock would have a present value of NSB of about $16 million ($1998), while creating a rail line for the same segment (with a 10% share of highway trips) would have a present value of NSB of about $109 million ($1998).

Essentially, EEA has been used to evaluate eight different investment projects related to the I-25 corridor between Denver and Colorado Springs. Of those eight projects, EEA would recommend rejecting six of them because the resources that would be used in each of those projects would be of greater value to the communities served by this transportation corridor, than the benefits that would be enjoyed because of any of these six projects. Yet, two of these eight projects would be accepted based on EEA since the benefits enjoyed because of each of the projects would exceed the costs of each of the projects. But this is as far as EEA is usually intended to go. EEA divides proposed projects between those that are recommended against and those that are recommended in favor of. EEA itself is not a good means of choosing between acceptable projects such as added highway capacity and a rail alternative for the segment between Lincoln and Castle Rock. One reason is the practical difficulty to consider all possible alternatives to the status quo with respect to the corridor (or problem) being considered. Therefore, those who have developed and recommended the use of EEA are generally content to "advice" that certain projects are unacceptable while other projects are acceptable, and that the choice between acceptable projects can be made with other criteria. The recommendation here is to evaluate different EEA acceptable projects with the MOE index which is presented for this case study below.

Note that by considering the six additional projects it is possible to point out why the projects for the entire corridor seem bad investments from the perspective of efficiency analysis, even though a limited version of each project would be a recommended investment based on EEA. While congestion is already significant for the Lincoln to Castle Rock portion of the highway, it is significant at this time for the rest of the corridor under consideration. Even with substantial increases in population along the corridor in the future, the drives between Castle Rock and Monument and between Monument and North Academy do not become sufficiently congested (relative to existing capacity) to justify either a new rail alternative or additional highway capacity. In contrast, the already congested segment of the highway between Lincoln and Castle Rock is projected over the analysis period to become severely congested. While this one segment of the highway can justify either increased capacity or a rail alternative to automobile travel, the positive net benefits for this segment are not large enough to overwhelm the negative net benefits on each of the segments in the rest of the corridor where congestion is not significant. Perhaps another way to look at these issues is in terms of timing. Finding that EEA analysis would not recommend added highway capacity or a rail alternative for the entire corridor at this time (i.e. in 1998), and given the projected increases in trip demand, does not mean that such investment would never be able to pass the test of EEA. Waiting five or ten years to reconsider the projects, even given the same undiscounted values for benefits and costs in each of the relevant time periods, may result in the present value of NSB having a positive sign. In an important sense, the EEA for a decision in 1998 is saying that the congestion along specific segments of this I-25 corridor are not yet sufficiently severe for either alternative to be an efficient investment and that such projects are not "good bets" at this time. Waiting another five or ten years to invest in a project or projects for the segment from Castle Rock to North Academy probably makes more sense based on EEA.

Finally, there is considerable uncertainty surrounding any of the values used in any efficiency analysis, and as such, it might be the case that an economic efficiency analysis would yield different results (i.e. different present values of NSB) if the variables considered are different than forecasted. For this reason, it is recommended that at least a limited sensitivity analysis be undertaken to provide some information about how robust the conclusions for the basic efficiency analysis presented above should be regarded.

MOE Analysis

The MOE analysis calculates different measures for each of the five core areas chosen to evaluate multi-modal projects. The final output of this MOE analysis consists of summaries of measures per year and per analysis period. These are measures for Mobility, Air Quality, User Cost, Safety, and Capital Cost for the different scenarios evaluated. The process for conducting an MOE analysis is explained in detail in chapters 2 and 3 and consists, in general, of the following steps:

Definition of corridor segments.
Completion of User Input Tables describing the corridor and each alternative to be analyzed, as well as other relevant data required for the analysis.
Calculation of baseline year MOEs for each corridor segment.
Calculation of MOEs for each segment under the No-Build scenario for each analysis year.
Calculation of MOEs for each segment, for each alternative scenario, and each analysis year.

After these steps, the results are tabulated in summary worksheets (MOE forms M) which are then used to perform economic efficiency calculations and to calculate an MOE index.

As discussed in the EEA Summary section above, two alternatives (Add-a-lane and CRT rail) were considered under four different scenarios (all three segments, and each segment separately). As an example, some filled-out MOE forms are shown at the end of this appendix for one of these scenarios (Add-a-lane for the three segments). Summaries of annual MOEs given in Form M can also be used to directly compare the estimated measures during project ranking exercises. Although, it is recommended to complete the economic analysis and to rank alternatives with positive NSB based on the MOE index.

Out of the eight different scenarios mentioned above, only two produced positive NSB results—Add-a-lane and CRT rail for the Lincoln to Castle Rock segment. The row measures and the measures recommended to calculate the MOE index for these two alternatives are presented in Table A3.6 below.

Alternative	**Commuter Rail** (Lincoln-Castle Rock Segment)	**Add-a-lane** (Lincoln-Castle Rock Segment)
Fatalities per year	6.0	6.6
Tons of pollutants per year	2336.4	2485.0
Agency Cost ($ million)	304.0	243.2
Weighted Mean Speed (mi/hr)	29.3	48.7
--Safety measure	0.1663	0.1519
--Air Quality measure	0.00043	0.00040
--Cost measure	0.00329	0.00411
--Speed measure	29.3	48.7

Table A3.6. MOEs and measures used to evaluate the MOE index

Three of the index measures—Safety, Air quality, and Cost—are taken as the inverse of the corresponding row MOE to indicate a desired effect, as explained in Chapter Five. Thus, the preferred alternative will be the one with the higher index.

Five combinations of weights for the measures involved are used to indicate different decision makers' preferences when selecting among many alternatives. These weights *a* are used along the measures in Table A3.6 above to estimate the relative indexes with the following formula

$$I = \prod_{j=1}^{4} m_j^{a_j} = m_1^{a_1} * m_2^{a_2} * m_3^{a_3} * m_4^{a_4}$$

as explained in Chapter Five. The weights and estimated indexes are shown in Table A3.7 below. All indexes in this table are affected by a factor of 100.

	Weights	Commuter Rail Index	Add-a-lane Index
--Safety measure	0.25	**5.12**	**5.91**
--Air Quality measure	0.25		
--Cost measure	0.25		
--Speed measure	0.25		
--Safety measure	0.70	**10.38**	**10.42**
--Air Quality measure	0.10		
--Cost measure	0.10		
--Speed measure	0.10		
--Safety measure	0.10	**0.29**	**0.30**
--Air Quality measure	0.70		
--Cost measure	0.10		
--Speed measure	0.10		
--Safety measure	0.10	**0.99**	**1.19**
--Air Quality measure	0.10		
--Cost measure	0.70		
--Speed measure	0.10		
--Safety measure	0.10	**231.19**	**332.03**
--Air Quality measure	0.10		
--Cost measure	0.10		
--Speed measure	0.70		

Table A3.7. MOE indexes for different weights.

The first set of weights indicates equal importance for each of the four measures considered, whereas the other four groups of weights indicate that a higher concern is placed to safety, air quality, cost, and speed considerations respectively.

For these two alternatives, the indexes are always higher for the Add-a-lane case, indicating a strong preference of one of the alternatives. This may not always be the case and, thus, care should be exercised when selecting the appropriate weights—as explained in Chapter Five.

Sensitivity Analysis

Sensitivity analysis is used to evaluate how much confidence can be placed in the basic analysis of a project. The entire analysis, whether MOE or EEA, follows from the first assumption made with respect to population and/or transportation demand growth. Therefore it is recommended that at least two different growth assumptions be examined. In addition, since the commuter rail project examined in this appendix involves a new transportation mode along the I-25 corridor it is recommended that two assumptions with respect to mode split be utilized.

Added Highway Capacity

The baseline assumptions with respect to population growth lead to a negative present value of NSB for adding highway capacity for the entire corridor. In order to assess how much confidence to place in this result, changes in the magnitude of the measures required to reverse the sign of NSB should be explored. A way in which to explore such an issue consists of developing a second analysis assuming greater population growth. A second efficiency analysis may assume that, for each of the analysis years, population is 25% larger than assumed under the baseline conditions. Analyses under this assumption result in substantially more lifetime benefits for the project. Specifically, the present value of user benefits for the project assuming the original baseline population is about $340 million ($1998), while this value is about $918 million ($1998) if population grows more rapidly than anticipated in the baseline--25% higher increase in each analysis year. Given that the project costs are unchanged, assuming the 25% larger population yields a present value of NSB which is $68.5 million ($1998) and which would allow one to recommend the added capacity project for the entire corridor. If the results of the second analysis assuming a significantly larger population growth had also produced a negative value for the present value of NSB, then one could be confident in the result that efficiency analysis would not recommend added highway capacity at this time. On the other hand, since the larger expected population yields a positive value for NSB, one would be confident in the conclusion that EEA does not recommend adding highway capacity for the entire corridor, only to the extent that a 25% greater expected population increase is outside the realm of possibility. Note also the results of the efficiency analysis, or any analysis of transportation alternatives for that matter, depend heavily on the basic baseline assumptions for population and travel demands over the planning and analysis time horizon. Regardless of what other assumptions must be made in order to analyze and compare alternatives, such comparisons will always be based fundamentally on assumptions and/or projections made about the demand for travel in a region.

Of course there are many assumptions that are made in order to develop this EEA of the added highway capacity project for the entire corridor. All of the assumptions would individually be difficult to analyze with sensitivity analysis. However, it is possible to gain some degree of confidence in the EEA for this project by calculating how much larger (smaller) a benefit (cost) would have to be in order for the present value of NSB to change signs. For example, returning to the original projection for trip demand, the present value of user benefits alone, over the life of the project, is $339.9 million. If the present value of user benefits were increased to $849.4 million, then the present value of NSB for the project itself would be $0. Therefore, assuming the original projection for increased trip demand, if benefits in each analysis year were increased by about 2 ½ times, then the result of the EEA would be changed to a recommendation in favor of the added capacity project for the entire corridor. One of the key economic assumptions in the user benefit calculation is the value of time. Since the value of time utilized in the calculation is 50% of the wage rate, it would be necessary to more than double it to a value of greater than the wage rate. However, estimates of the value of time found in the literature range between 25% and 75% of the wage rate. This suggests that changes in the value of travel time used in calculating user benefits are unlikely to change the result of the EEA for this project.

Consider the cost side of the present value of the NSB calculation. The value estimated for O&M annual costs, even if grossly inaccurate, cannot cause the results of the efficiency analysis of this project to be different. Since the present value of O&M costs is only $76.4 millions while the present value of NSB is -$506 million, for this to happen, O&M costs would have to be negative (i.e. a benefit instead of a cost). In the other hand, the capital costs for the project would have to be about 2/3 smaller than the costs used in order for the added highway capacity project to pass the test of efficiency analysis, i.e. $262.8 million in present value rather than $772.3 million. In other words, if the capital costs per mile were more like $3 million per lane mile instead of the about $8 million per lane mile used in this analysis.

The conclusion with respect to the added lane in each direction along the entire length of the corridor is that, given the population growth assumptions, one can be confident in the result that this project should not be recommended based on efficiency analysis. On the other hand, if one believes that population is likely to be at least 25% larger in each of the analysis years, then the added lane project for the entire corridor would pass the test of efficiency analysis.

The efficiency analysis discussed above has also suggested that adding a lane in each direction between Lincoln and Castle Rock could be recommended. How confident can we be in this conclusion? First, the estimate of annual O&M costs would have to be about 71% times larger for the sign of the present value of NSB to be negative rather than positive. This would be about 2.5 million ($1998) annually rather than the $1.5 million ($1998) estimated for the basic NSB calculation. This does not seem likely to be the case. Second, capital costs for the project would only have to be about 7% larger for the project not to be recommended based on efficiency analysis. This suggests that, in order to develop greater confidence in the conclusion of the analysis, it might be worth the additional time and cost to develop estimates of the project capital cost that were more associated with the specific characteristic of the project than is allowed by transportation sketch planning. Third, if the user benefits were about 7% less than the value estimated for the efficiency analysis discussed above, then the present value of NSB would be negative which would mean a recommendation against this project. Here again the issue can be expressed in terms of the value assumed for the value of travel time. Reducing the value from 50% of the wage by about 7% still leaves the value of time within the range found in the literature. Finally, since the present value of NSB for the project on this segment is positive it is suggested that the assumed population in each analysis year be decreased to 75% of the value assumed in the analysis years. Under this population assumptions, the present value of NSB for the project would be - $152.5 million ($1998). In this case efficiency analysis would not recommend the project above described. Of course, the efficiency analysis results presented above result from assumptions believed to be the best "ballpark" estimates. As a "sketch planning" exercise, this project is certainly worth continued consideration, and perhaps it might be worth the time and effort to develop more detailed and specific estimates of project benefits and costs that would be specific to the project.

Commuter Rail Alternative

The baseline assumptions with respect to population and a 10% mode split from auto trips to rail trips leads to a present value of NSB for the commuter rail project which is negative. In order to assess how much confidence to place in this result, it is possible to explore what changes would be required to change the present value of NSB to be positive. Therefore, a second assumption about population growth will be explored by assuming an expected growth 25% higher than the original assumption. This significantly larger population growth by the year 2030 increases the present value of NSB for the commuter rail project to $318.6 million. Under this population growth the commuter rail project could be recommended based on efficiency analysis. The level of confidence in the conclusion that efficiency analysis recommends against the commuter rail project depends to a large extent on the confidence one places in the population growth assumptions.

Since mode split is a key assumption in the analysis that cannot be estimated based on Colorado transportation experience, the assumption for mode split will be increased from 10% to 15% for sensitivity analysis while returning to the original expected population growth assumption. This larger mode split would substantially increase the lifetime benefits enjoyed because of the commuter rail project. User benefits increase by $287.2 million, air quality benefits increase by $193.3 million, and safety benefits increase by $51.6 million. Here again, it is found that the commuter rail project could be recommended based on efficiency analysis if the percentage of people switching from trips by auto along I-25 to commuter rail is considerably larger than originally considered. Confidence in the original conclusion that would not recommend the commuter rail project based on efficiency analysis would rely on the extent to which it was believed that 15% of trips switching to rail was too high. Other assumptions may be analyzed, to determine the degree of confidence in the results, as described above for the Add-a-lane alternative.

The efficiency analysis discussed above has also suggested that creating a rail alternative to auto travel between Lincoln and Castle Rock could be recommended. How confident can we be in this conclusion?

First, the estimate of annual O&M costs would have to be about 3 times larger for the sign of the present value of NSB to be negative rather than positive. This does not seem likely to be the case.

Second, capital costs would have to be about 40% larger for the project not to be recommended based on efficiency analysis. This would be a substantially larger capital cost, but perhaps not outside the realm of possibility given that the capital costs assumed for the efficiency analysis aren't calculated with many of the specific attributes of route between Lincoln and Castle Rock in mind. Therefore, this may be one area that would justify additional time and effort to develop project specific details if the proposed project is to be carried beyond the sketch planning level.

Third, if the user benefits were about 28% less than the value estimated for the efficiency analysis discussed above, then the present value of NSB would be negative which would mean a recommendation against this project. Here again the issue can be expressed in terms of the value assumed for the value of travel time. Reducing the value from 50% of the wage by about 28% still leaves the value of time within the range found in the literature (i.e. at about 1/3 the wage rate). While a value of time equal to 50% of the wage rate seems a good estimate, confidence in the EEA analysis result would depend on the degree of confidence one has that the value of time is greater than about 35% of the wage rate.

Fourth, both the air quality impacts and the safety impacts of the project would have to be reversed in sign. That is, the project would have to have substantial increases in both air pollution and fatality risk for this aspect of the EEA presented above to change the outcome of the efficiency test of the project. Therefore, it seems reasonable to conclude that one should have confidence that the recommendation does not rely on these aspects of the analysis.

Fifth, since the present value of NSB for the project on this segment is positive it is suggested that the assumed population in each analysis year be decreased to 75% of the value originally assumed for each of the analysis years. In this case the present value of user benefits for the lifetime of the project would be reduced from $394.3 million to $233.8 million, and the present value of NSB for the project would be - $60.7 million. In this case efficiency analysis would not recommend the project that would add a lane to I-25 in each direction between Lincoln and Castle Rock. Here again, the projection for population and trip demand increases play a critical role with respect to the results of the evaluation of transportation investments. If one is confident that the expected growth in trip demand will not be 25% lower than forecasted, then one can be fairly confident of the recommendation provided by efficiency analysis for this project. On the other hand, if the lower expected growth seems within the realm of possibility, then perhaps a prudent course would be to develop more specific details of the project costs and benefits before proceeding. Another possibility would be to recognize that there could be value in waiting another planning period to make the decision, since waiting may allow for a better understanding of the growth experience of the community.

Finally, since this is a project that creates a new transportation mode, it is recommended that the assumption with respect to mode split be examined. Specifically, it is suggested that the EEA for the project also be developed assuming only a 5% mode split. In this case the present value of user benefits are reduced from $394.3 million to $220.5 million and the present value of NSB would be - $94.9 million. The smaller proportion of travelers switching from auto travel to rail travel between Lincoln and Castle Rock would result in the EEA conclusion to recommend against this rail project.

Of course, the results presented above are due to assumptions believed to be the best "ballpark" estimates. However, since the sensitivity analysis suggests that the proposed rail project would be recommended against if trip demand growth is slower than projected, or if a mode split of 10% is considered to be high, or if the value of time is most likely about 35% of the wage rate; then one might be a bit cautious in accepting the conclusion that efficiency analysis would recommend this project. In order to produce a more accurate estimation of economic efficiency for this project, more effort is required to develop better estimates of project benefits and costs that would be specific to the project.

Sensitivity Analysis Summary

The sensitivity analysis described here illustrates how one might test the confidence in the results of the EEA and the resulting recommendations in favor or against proposed corridor investment alternatives. The basic EEA suggests that neither a project to expand highway capacity, nor a project to create a rail alternative between Lincoln and North Academy can be recommended at this time. The sensitivity analysis primarily suggests that one can be quite confident in this conclusion in general, with one caveat. That, if trip demand in the communities served by this corridor can be expected to experience a significantly larger growth than assumed by the basic analysis, then both projects would be recommended by efficiency analysis. The basic EEA analysis also suggests that smaller versions of these projects for only the Lincoln to Castle Rock segment would be recommended. The sensitivity analysis suggests that the recommendations to expand highway capacity or to create a rail alternative are sensitive to changes in the basic assumptions that generate the user benefits for the projects. One might therefore be cautious in accepting the conclusions that these projects are recommended by EEA. In terms of "sketch planning" each of these smaller projects would certainly be worth continued consideration now or perhaps, in the not too distant future.

Example MOE and EEA Forms

Filled-out MOE and EEA forms are shown next for the scenario that adds a lane to the entire corridor. Although this case consists of three segments, filled-out forms are only shown for segment 1. The present value of NSB for this case is negative as explained in the previous sections.

FORM A
Corridor Description and Baseline Data - Segment #1

CORRIDOR IDENTIFICATION: Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR: 1990

NUMBER OF HOURS FOR ANALYSIS PERIOD: 2 (1)

ANALYSIS PERIOD LABEL (i.e., 24-hr, 7-8 AM, 3:30-6:30 PM): 6:30 - 8:30 AM

NUMBER OF CORRIDOR SEGMENTS TO BE ANALYZED: 3 (2)

(One to three segments are recommended when using worksheets. When more than three segments are to be analyzed, a spreadsheet program will facilitate the calculations)

BASELINE TRAVEL CONDITIONS FOR AVAILABLE MODES BY CORRIDOR SEGMENT

(Trips for analysis period — from available counts)

MODE		TOTAL TRIPS SEGMENT 1 Dir A-B	TOTAL TRIPS SEGMENT 1 Dir B-A	
SOV	(vehicle trips)	2660	3990	(a)
HOV	(vehicle trips)			(b)
HOT	(vehicle trips)			(c)
BUS	(passenger trips)			(d)
LRT	(passenger trips)			(e)
CRT	(passenger trips)			(f)
BIKE	(passenger trips)			(g)
PED	(passenger trips)			(h)
		(3)	(4)	

Note: Shaded cells require user input

FORM B-a1 SOV
MOEs for Segment # 1 under Baseline Conditions for Passenger Cars (Part 1)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990

LENGTH OF SEGMENT 11.20 (Miles) **(1)**

TYPE OF LANES SOV **(2)**
(Indicate lane type: SOV, HOV, or HOT)

NUMBER OF LANES 2 DIR A-B **(3)** 2 DIR B-A **(4)**

CAPACITY PER LANE (Veh / Hr) 2000 **(5)**
See Reference Table R-11

VEHICLE CAPACITY PER DIRECTION

	From (3)		From (5)		From A (1)		DIR A-B	
(	2	*	2000	*	2	) =	8000	**(6)**
	N. of Lanes		Cap. per Lane		N. of Hours		Capacity in Vehicles per analysis period	
	From (4)		From (5)		From A (1)		DIR B-A	
(	2	*	2000	*	2	) =	8000	**(7)**
	N. of Lanes		Cap. per Lane		N. of Hours		Capacity in Vehicles per analysis period	

FREE-FLOW SPEED 70 (Mi / Hr) **(8)**
(Posted speed + 5)

		From (1)		From (8)			
Free-Flow Travel Time	= (	11.2	/	70	)=	0.160	**(9)**
		Length of Segment		FF Speed		FFTT (hrs)	

Parameters for the Highway Travel Time Function Alpha = 0.84 **(10)** Beta = 5.5 **(11)**
(Values recommended for freeways are 0.84 for Alpha and 5.5 for Beta respectively. See Table R11)

		From A (a,3)		From (6)			
V/C Ratio A-B	= (	2660	/	8000	) =	0.33	**(12)**
		A-B Volume		Capacity		V/C Ratio A-B	
		From A (a,4)		From (7)			
V/C Ratio B-A	= (	3990	/	8000	) =	0.50	**(13)**
		B-A Volume		Capacity		V/C Ratio B-A	

		From (9)		From (10)		From (12)		From (11)		Dir. A-B	
Travel Time	= (	0.16	* (1+	0.84	* (	0.33	) ^	5.5	)) =	0.160	**(14)**
		FFTT (hrs)		Alpha		V/C Ratio A-B		Beta		Travel Time	
		From (9)		From (10)		From (13)		From (11)		Dir. B-A	
Travel Time	= (	0.16	* (1+	0.84	* (	0.50	) ^	5.5	)) =	0.163	**(15)**
		FFTT (hrs)		Alpha		V/C Ratio B-A		Beta		Travel Time	

Vehicle Occupancy = 1.2 **(16)**
Pass. / Vehicle

FORM B-a2 SOV
MOEs for Segment # 1 under BASELINE Conditions for Pass. Cars (Part 2)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990

		From B-a1(1)		From B-a1(14)		**Dir. A-B**	
Avg. Speed	= (	11.2	/	0.160	) =	69.9	**(1)**
		Segm Length		Travel Time		(Miles / Hour)	
		From B-a1(1)		From B-a1(15)		**Dir. B-A**	
Avg. Speed	= (	11.2	/	0.163	) =	68.7	**(2)**
		Segm Length		Travel Time		(Miles / Hour)	
		From A (a,3)		From B-a1(14)			
VHT Direction A-B	= (	2660	*	0.160	) =	426.4	**(3)**
		A-B Volume		Travel Time		VHT Dir. A-B	
		From A (a,4)		From B-a1(15)			
VHT Direction B-A	= (	3990	*	0.163	) =	650.1	**(4)**
		B-A Volume		Travel Time		VHT Dir. B-A	
		From A (a,3)		From B-a1(1)			
VMT Direction A-B	= (	2660	*	11.2	) =	29792.0	**(5)**
		A-B Volume		Segm. Length		VMT Dir. A-B	
		From A (a,4)		From B-a1(1)			
VMT Direction B-A	= (	3990	*	11.2	) =	44688.0	**(6)**
		B-A Volume		Segm. Length		VMT Dir. B-A	
		From (5)		From B-a1(16)			
PMT Direction A-B	= (	29792	*	1.2	) =	35750.4	**(7)**
		VMT Dir. A-B		Pass. / Vehicle		PMT Dir. A-B	
		From (6)		From B-a1(16)			
PMT Direction B-A	= (	44688	*	1.2	) =	53625.6	**(8)**
		VMT Dir. B-A		Pass. / Vehicle		PMT Dir. B-A	
		From (5)		From (6)			
Total VMT	= (	29792	+	44688	) =	74480	**(9)**
(Both Directions)		VMT Dir. A-B		VMT Dir. B-A		Total VMT	

		From (9)		Table R16					
Annual VMT	= (	74480	/	0.14	*	365	) =	194180000	**(10)**
(Both Directions)		Total VMT		Total Volume as a % of AADT		Days per year		Annual VMT	

FORM B-AQ
Air Quality MOEs for Segment #1 under BASELINE Conditions per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990

Emissions for SOV mode	= (	From B-a2(10) 194180000 SOV Annual VMT	*	3.87 Emissions rate (grams / SOV VMT)	/	907,200 grams/Ton	) =	828.35 Tons of pollutants per year	**(1)**
Emissions for HOV mode	= (	From B-a2(10) 0 HOV Annual VMT	*	3.87 Emissions rate (grams / HOV VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(2)**
Emissions for HOT mode	= (	From B-a2(10) 0 HOT Annual VMT	*	3.87 Emissions rate (grams / HOT VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(3)**
Emissions for Bus mode	= (	From B-b(14) 0 Bus Annual VMT	*	24.9 Emissions rate (grams / Bus VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(4)**
Emissions for LRT mode	= (	From B-c(14) 0 LRT Annual VMT	*	0 Emissions rate (grams / LRT VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(5)**
Emissions for CRT mode	= (	From B-d(14) 0 CRT Annual VMT	*	316.5 Emissions rate (grams / CRT VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(6)**
Emissions for Bike mode	= (	From B-e(10) 0 Bike Annual VMT	*	0 Emissions rate (grams / Bike VMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(7)**
Emissions for Ped mode	= (	From B-f(10) 0 Ped Annual PMT	*	0 Emissions rate (grams / Ped PMT)	/	907,200 grams/Ton	) =	0.00 Tons of pollutants per year	**(8)**

Emission rates per mode are given in Table R5 in grams per mile. These are:
3.87 for SOV, HOV, and HOT modes.
24.9 for Bus.
0.0 for LRT, Bike, and Pedestrian modes.
316.5 for CRT with one diesel locomotive.

FORM B-S
Safety MOEs for Segment #1 under BASELINE Conditions per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990

Crashes for SOV mode	= (	From B-a2(10) 194180000 SOV Annual VMT	*	0.00000146 Crash rate for SOV (crashes per VMT)	) =	283.5028 Crashes per year	(1)
Crashes for HOV mode	= (	From B-a2(10) 0 HOV Annual VMT	*	 Crash rate for HOV (crashes per VMT)	) =	0 Crashes per year	(2)
Crashes for HOT mode	= (	From B-a2(10) 0 HOT Annual VMT	*	 Crash rate for HOT (crashes per VMT)	) =	0 Crashes per year	(3)
Crashes for Bus mode	= (	From B-b(14) 0 Bus Annual VMT	*	0.0000248 Crash rate for Bus (crashes per VMT)	) =	0 Crashes per year	(4)
Crashes for LRT mode	= (	From B-c(14) 0 LRT Annual VMT	*	0.00002924 Crash rate for LRT (crashes per VMT)	) =	0 Crashes per year	(5)
Crashes for CRT mode	= (	From B-d(14) 0 CRT Annual VMT	*	0.00000918 Crash rate for CRT (crashes per VMT)	) =	0 Crashes per year	(6)
Crashes for Bike mode	= (	From B-e(11) 0 Bike Annual VMT	*	0 Crash rate for Bike (crashes per VMT)	) =	0 Crashes per year	(7)
Crashes for Ped mode	= (	From B-f(11) 0 Ped Annual PMT	*	0 Crash rate for Ped (crashes per PMT)	) =	0 Crashes per year	(8)

Fatalities for SOV mode	= (	From B-a2(10) 194180000 SOV Annual VMT	*	1.13E-08 Fatality rate for SOV (fatalities per VMT)	) =	2.194234 Fatalities per year	(9)
Fatalities for HOV mode	= (	From B-a2(10) 0 HOV Annual VMT	*	 Fatality rate for HOV (fatalities per VMT)	) =	0 Fatalities per year	(10)
Fatalities for HOT mode	= (	From B-a2(10) 0 HOT Annual VMT	*	 Fatality rate for HOT (fatalities per VMT)	) =	0 Fatalities per year	(11)
Fatalities for Bus mode	= (	From B-b(14) 0 Bus Annual VMT	*	0.000000043 Fatality rate for Bus (fatalities per VMT)	) =	0 Fatalities per year	(12)
Fatalities for LRT mode	= (	From B-c(14) 0 LRT Annual VMT	*	0.000000235 Fatality rate for LRT (fatalities per VMT)	) =	0 Fatalities per year	(13)
Fatalities for CRT mode	= (	From B-d(14) 0 CRT Annual VMT	*	0.000000312 Fatality rate for CRT (fatalities per VMT)	) =	0 Fatalities per year	(14)
Fatalities for Bike mode	= (	From B-e(11) 0 Bike Annual VMT	*	0 Fatality rate for Bike (fatalities per VMT)	) =	0 Fatalities per year	(15)
Fatalities for Ped mode	= (	From B-f(11) 0 Ped Annual PMT	*	0 Fatality rate for Ped (fatalities per PMT)	) =	0 Fatalities per year	(16)

Crashes and fatality rates per million miles traveled per mode are given in Tables R1 and S1. Crash rates are as follows:
0.00000124 and 0.00000271 for Rural and Urban highways, respectively.
0.0000248 incidents per Annual VMT for Bus.
0.00002924 incidents per Annual VMT for LRT.
0.00000918 incidents per Annual VMT for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

Fatality rates are as follows:
0.0000000261 and 0.0000000116 for Rural and Urban highways, respectively.
0.000000043 incidents per Annual VMT for Bus.
0.000000235 incidents per Annual VMT for LRT.
0.000000312 incidents per Annual VMT miles for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

FORM C
Summary Table for BASELINE Corridor Travel Conditions
Segment #1

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990

MOEs **PER ANALYSIS PERIOD**	**SOV**	**HOV**	**HOT**	**BUS**	**LRT**	**CRT**	**BIKE**	**PEDS**
MOBILITY								
	From A(3,a)	From A(3,b)	From A(3,c)	From A(3,d)	From A(3,e)	From A(3,f)	From A(3,g)	From A(3,h)
Total Trips Segm 1 A-B	2660	0	0	0	0	0	0	0
	From A(4,a)	From A(4,b)	From A(4,c)	From A(4,d)	From A(4,e)	From A(4,f)	From A(4,g)	From A(4,h)
Total Trips Segm 1 B-A	3990	0	0	0	0	0	0	0
	From B-a1(14)	From B-a1(14)	From B-a1(14)	From B-b(6)	From B-c(6)	From B-d(6)	From B-e(3)	From B-f(3)
Travel Time Segm 1 A-B (hrs)	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	From B-a1(15)	From B-a1(15)	From B-a1(15)	From B-b(6)	From B-c(6)	From B-d(6)	From B-e(3)	From B-f(3)
Travel Time Segm 1 B-A (hrs)	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	From B-a2(3)	From B-a2(3)	From B-a2(3)	From B-b(10)	From B-c(10)	From B-d(10)	From B-e(4)	From B-f(4)
Veh. Hours Traveled Segm 1 A-B	426	0	0	0	0	0	0	0
	From B-a2(4)	From B-a2(4)	From B-a2(4)	From B-b(10)	From B-c(10)	From B-d(10)	From B-e(5)	From B-f(5)
Veh. Hours Traveled Segm 1 B-A	650	0	0	0	0	0	0	0
	From B-a2(5)	From B-a2(5)	From B-a2(5)	From B-b(11)	From B-c(11)	From B-d(11)	From B-e(6)	
Veh. Miles Traveled Segm 1 A-B	29792	0	0	0	0	0	0	
	From B-a2(6)	From B-a2(6)	From B-a2(6)	From B-b(11)	From B-c(11)	From B-d(11)	From B-e(7)	
Veh. Miles Traveled Segm 1 B-A	44688	0	0	0	0	0	0	
	From B-a2(1)	From B-a2(1)	From B-a2(1)	From B-b(4)	From B-c(4)	From B-d(4)	From B-e(2)	From B-f(2)
Average Speed Segm 1 A-B (mi/hr)	70	0	0	0	0	0	0	0
	From B-a2(2)	From B-a2(2)	From B-a2(2)	From B-b(4)	From B-c(4)	From B-d(4)	From B-e(2)	From B-f(2)
Average Speed Segm 1 B-A (mi/hr)	69	0	0	0	0	0	0	0
	From B-a1(12)	From B-a1(12)	From B-a1(12)	From B-b(7)	From B-c(7)	From B-d(7)		
Average Capacity Utilization Segm 1 A-B	0.33	0.00	0.00	0.00	0.00	0.00		
	From B-a1(13)	From B-a1(13)	From B-a1(13)	From B-b(8)	From B-c(8)	From B-d(8)		
Average Capacity Utilization Segm 1 B-A	0.50	0.00	0.00	0.00	0.00	0.00		
	From B-a2(7)	From B-a2(7)	From B-a2(7)	From B-b(12)	From B-c(12)	From B-d(12)	From B-e(6)	From B-f(6)
Pass. Miles Trav. Segm 1 A-B	35750	0	0	0	0	0	0	0
	From B-a2(8)	From B-a2(8)	From B-a2(8)	From B-b(12)	From B-c(12)	From B-d(12)	From B-e(7)	From B-f(7)
Pass. Miles Trav. Segm 1 B-A	53626	0	0	0	0	0	0	0
AIR QUALITY								
	From B-AQ(1)	From B-AQ(2)	From B-AQ(3)	From B-AQ(4	From B-AQ(5	From B-AQ(6	From B-AQ(7	From B-AQ(8)
Emissions Segm 1 (tons of pollutant/yr)	828.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SAFETY								
	From B-S(1)	From B-S(2)	From B-S(3)	From B-S(4)	From B-S(5)	From B-S(6)	From B-S(7)	From B-S(8)
Crashes Segm 1 (Per Year)	284	0	0	0	0	0	0	0
	From B-S(9)	From B-S(10)	From B-S(11)	From B-S(12)	From B-S(13)	From B-S(14)	From B-S(15)	From B-S(16)
Fatalities Segm 1 (Per Year)	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FORM D
Expected Corridor Travel Conditions under the NO-BUILD Scenario (Segment #1)

CORRIDOR IDENTIFICATION: Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR: 2020 BASELINE YEAR: 1990

EXPECTED % GROWTH IN SOV VEHICLE TRIPS (Between baseline and analysis years) 154 / 100 = 1.54 (1)

EXPECTED % GROWTH IN HOV VEHICLE TRIPS (Between baseline and analysis years) / 100 = 0 (2)

EXPECTED % GROWTH IN HOT VEHICLE TRIPS (Between baseline and analysis years) / 100 = 0 (3)

EXPECTED % GROWTH IN BUS PASSENGER TRIPS (Between baseline and analysis years) / 100 = 0 (4)

EXPECTED % GROWTH IN LRT PASSENGER TRIPS (Between baseline and analysis years) / 100 = 0 (5)

EXPECTED % GROWTH IN CRT PASSENGER TRIPS (Between baseline and analysis years) / 100 = 0 (6)

EXPECTED % GROWTH IN BICYCLE PASSENGER TRIPS (Between baseline and analysis years) / 100 = 0 (7)

EXPECTED % GROWTH IN PEDESTRIAN PASSENGER TRIPS (Between baseline and analysis years) / 100 = 0 (8)

FUTURE TRAVEL CONDITIONS FOR AVAILABLE MODES FOR SEGMENT #1
(Trips for analysis period)

(Reference columns 3 and 4 from form A are for segment 1. For segments 2 and 3 these will be 5, 6 and 7, 8 respectively)

SOV	=	From A(a,3) 2660 * (1 + Trips A-B Dir.	From (1) 1.54) = Exp. % Growth	A-B Dir 6756.4 Future Volume	(9)	= From A(a,4) 3990 * (1 + Trips B-A Dir.	From (1) 1.54) = Exp. % Growth	B-A Dir 10134.6 Future Volume	(10)
HOV	=	From A(b,3) 0 * (1 + Trips A-B Dir.	From (2) 0) = Exp. % Growth	A-B Dir 0 Future Volume	(11)	= From A(b,4) 0 * (1 + Trips B-A Dir.	From (2) 0) = Exp. % Growth	B-A Dir 0 Future Volume	(12)
HOT	=	From A(c,3) 0 * (1 + Trips A-B Dir.	From (3) 0) = Exp. % Growth	A-B Dir 0 Future Volume	(13)	= From A(c,4) 0 * (1 + Trips B-A Dir.	From (3) 0) = Exp. % Growth	B-A Dir 0 Future Volume	(14)
BUS	=	From A(d,3) 0 * (1 + Trips A-B Dir.	From (4) 0) = Exp. % Growth	A-B Dir 0 Future Bus Volume	(15)	= From A(d,4) 0 * (1 + Trips B-A Dir.	From (4) 0) = Exp. % Growth	B-A Dir 0 Future Bus Volume	(16)
LRT	=	From A(e,3) 0 * (1 + Trips A-B Dir.	From (5) 0) = Exp. % Growth	A-B Dir 0 Future LRT Volume	(17)	= From A(e,4) 0 * (1 + Trips B-A Dir.	From (5) 0) = Exp. % Growth	B-A Dir 0 Future LRT Volume	(18)
CRT	=	From A(f,3) 0 * (1 + Trips A-B Dir.	From (6) 0) = Exp. % Growth	A-B Dir 0 Future CRT Volume	(19)	= From A(f,4) 0 * (1 + Trips B-A Dir.	From (6) 0) = Exp. % Growth	B-A Dir 0 Future CRT Volume	(20)
BIKE	=	From A(g,3) 0 * (1 + Trips A-B Dir.	From (7) 0) = Exp. % Growth	A-B Dir 0 Future Bike Volume	(21)	= From A(g,4) 0 * (1 + Trips B-A Dir.	From (7) 0) = Exp. % Growth	B-A Dir 0 Future Bike Volume	(22)
PED	=	From A(h,3) 0 * (1 + Trips A-B Dir.	From (8) 0) = Exp. % Growth	A-B Dir 0 Future Ped Volume	(23)	= From A(h,4) 0 * (1 + Trips B-A Dir.	From (8) 0) = Exp. % Growth	B-A Dir 0 Future Ped Volume	(24)

FORM E-a1 SOV
MOEs for Segment #1 under the NO-BUILD Conditions for Passenger Cars (Part 1)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

LENGTH OF SEGMENT From B-a1(1) 11.2 (Miles) **(1)**

TYPE OF LANES SOV **(2)**
(Indicate lane type: SOV, HOV, or HOT)

NUMBER OF LANES From B-a1(2) 2 DIR A-B **(3)** From B-a1(3) 2 DIR B-A **(4)**

VEHICLE CAPACITY PER DIRECTION
From B-a1(6) 8000 **(5)** DIR A-B
Capacity in vehicles per analysis period

From B-a1(7) 8000 **(6)** DIR B-A
Capacity in vehicles per analysis period

FREE-FLOW SPEED (Posted speed + 5) 70 (Mi / Hr) **(7)**

		From (1)		From (7)		
Free-Flow Travel Time	= (	11.2	/	70	) =	0.16 **(8)**
		Length of Segment		FF Speed		FFTT (hrs)

Parameters for the highway travel time function Alpha = 0.84 **(9)** Beta = 5.5 **(10)**
(Values recommended for freeways are 0.84 for Alpha and 5.5 for Beta respectively. See Table R11)

		From D (9)		From (5)		
V/C Ratio	= (	6756.4	/	8000	) =	0.84 **(11)**
		Analysis A-B Volume		Capacity		V/C Ratio A-B
		From D (10)		From (6)		
V/C Ratio	= (	10135	/	8000	) =	1.27 **(12)**
		Analysis B-A Volume		Capacity		V/C Ratio B-A

(References D(9) and D(10) are for SOV. For HOV and HOT these will be D(11), D(12), and D(13), D(14), respectively.

		From (8)		From (9)		From (11)		From (10)		**Dir. A-B**
Travel Time	= (	0.16	* (1+	0.84	* (	0.84455	) ^	5.5	)) =	0.21307 **(13)**
		FFTT (hrs)		Alpha		V/C Ratio A-B		Beta		Travel Time
		From (8)		From (9)		From (12)		From (10)		**Dir. B-A**
Travel Time	= (	0.16	* (1+	0.84	* (	1.26683	) ^	5.5	)) =	0.65356 **(14)**
		FFTT (hrs)		Alpha		V/C Ratio B-A		Beta		Travel Time

FORM E-a2 SOV
MOEs for Segment #1 under the NO-BUILD Conditions for Pass. Cars (Part 2)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

		From E-a1(1)		From E-a1(13)		**Dir. A-B**	
Speed	= (	11.2	/	0.21306874	) =	52.57	**(1)**
		Segm Length		Travel Time		(Miles / Hour)	
		From E-a1(1)		From E-a1(14)		**Dir. B-A**	
Speed	= (	11.2	/	0.65356086	) =	17.14	**(2)**
		Segm Length		Travel Time		(Miles / Hour)	
		From D (9)		From E-a1(13)			
VHT Direction A-B	= (	6756.4	*	0.21306874	) =	1439.58	**(3)**
		Future A-B Volume		Travel Time		VHT Dir. A-B	
		From D (10)		From E-a1(14)			
VHT Direction B-A	= (	10134.6	*	0.65356086	) =	6623.58	**(4)**
		Future B-A Volume		Travel Time		VHT Dir. B-A	

(References D(9) and D(10) are for SOV. For HOV and HOT these will be D(11), D(12), and D(13), D(14), respectively.)

		From D (9)		From E-a1(1)			
VMT Direction A-B	= (	6756.4	*	11.2	) =	75671.68	**(5)**
		Future A-B Volume		Segm. Length		VMT Dir. A-B	
		From D (10)		From E-a1(1)			
VMT Direction B-A	= (	10134.6	*	11.2	) =	113507.52	**(6)**
		Future B-A Volume		Segm. Length		VMT Dir. B-A	
		From (5)		From B-a1(16)			
PMT Direction A-B	= (	75671.68	*	1.2	) =	90806.016	**(7)**
		VMT Dir. A-B		Pass. / Vehicle		PMT Dir. A-B	
		From (6)		From B-a1(16)			
PMT Direction B-A	= (	113507.52	*	1.2	) =	136209.024	**(8)**
		VMT Dir. B-A		Pass. / Vehicle		PMT Dir. B-A	
		From (5)		From (6)			
Total VMT	= (	75671.68	+	113507.52	) =	189179.2	**(9)**
(Both Directions)		VMT Dir. A-B		VMT Dir. B-A		Total VMT	

		From (9)							
Annual VMT	= (	189179.2	/	0.14	*	365	) =	493217200	**(10)**
(Both Directions)		Total VMT		Total Volume as a % of AADT		Days per year		Annual VMT	

FORM E-AQ
Air Quality MOEs for Segment #1 under NO-BUILD Conditions per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

		From E-a2(10)							
Emissions for SOV mode	= (	493217200	*	3.87	/	907,200	) =	2104.00	(1)
		SOV Annual VMT		Emissions rate (grams / SOV VMT)		grams/Ton		Tons of pollutants per year	
		From E-a2(10)							
Emissions for HOV mode	= (	0	*	3.87	/	907,200	) =	0.00	(2)
		HOV Annual VMT		Emissions rate (grams / HOV VMT)		grams/Ton		Tons of pollutants per year	
		From E-a2(10)							
Emissions for HOT mode	= (	0	*	3.87	/	907,200	) =	0.00	(3)
		HOT Annual VMT		Emissions rate (grams / HOT VMT)		grams/Ton		Tons of pollutants per year	
		From E-b(14)							
Emissions for Bus mode	= (	0	*	24.9	/	907,200	) =	0.00	(4)
		Bus Annual VMT		Emissions rate (grams / Bus VMT)		grams/Ton		Tons of pollutants per year	
		From E-c(14)							
Emissions for LRT mode	= (	0	*	0	/	907,200	) =	0.00	(5)
		LRT Annual VMT		Emissions rate (grams / LRT VMT)		grams/Ton		Tons of pollutants per year	
		From E-d(14)							
Emissions for CRT mode	= (	0	*	316.5	/	907,200	) =	0.00	(6)
		CRT Annual VMT		Emissions rate (grams / CRT VMT)		grams/Ton		Tons of pollutants per year	
		From E-e(10)							
Emissions for Bike mode	= (	0	*	0	/	907,200	) =	0.00	(7)
		Bike Annual VMT		Emissions rate (grams / Bike VMT)		grams/Ton		Tons of pollutants per year	
		From E-f(10)							
Emissions for Ped mode	= (	0	*	0	/	907,200	) =	0.00	(8)
		Ped Annual PMT		Emissions rate (grams / Ped PMT)		grams/Ton		Tons of pollutants per year	

Emission rates per mode are given in Table R5 in grams per mile. These are:
3.87 for SOV, HOV, and HOT modes.
24.9 for Bus.
0.0 for LRT, Bike, and Pedestrian modes.
316.5 for CRT with one diesel locomotive.

FORM E-S
Safety MOEs for Segment #1 under NO-BUILD Conditions per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

Crashes for SOV mode	= (	From E-a2(10) 493217200 SOV Annual VMT	*	0.00000146 Crash rate for SOV (crashes per VMT)	) =	720.097112 Crashes per year	(1)
Crashes for HOV mode	= (	From E-a2(10) 0 HOV Annual VMT	*	0 Crash rate for HOV (crashes per VMT)	) =	0 Crashes per year	(2)
Crashes for HOT mode	= (	From E-a2(10) 0 HOT Annual VMT	*	0 Crash rate for HOT (crashes per VMT)	) =	0 Crashes per year	(3)
Crashes for Bus mode	= (	From E-b(14) 0 Bus Annual VMT	*	0.0000248 Crash rate for Bus (crashes per VMT)	) =	0 Crashes per year	(4)
Crashes for LRT mode	= (	From E-c(14) 0 LRT Annual VMT	*	0.00002924 Crash rate for LRT (crashes per VMT)	) =	0 Crashes per year	(5)
Crashes for CRT mode	= (	From E-d(14) 0 CRT Annual VMT	*	0.00000918 Crash rate for CRT (crashes per VMT)	) =	0 Crashes per year	(6)
Crashes for Bike mode	= (	From E-e(10) 0 Bike Annual VMT	*	0 Crash rate for Bike (crashes per VMT)	) =	0 Crashes per year	(7)
Crashes for Ped mode	= (	From E-f(10) 0 Ped Annual PMT	*	0 Crash rate for Ped (crashes per PMT)	) =	0 Crashes per year	(8)

Fatalities for SOV mode	= (	From E-a2(10) 493217200 SOV Annual VMT	*	1.13E-08 Fatality rate for SOV (fatalities per VMT)	) =	5.57335436 Fatalities per year	(9)
Fatalities for HOV mode	= (	From E-a2(10) 0 HOV Annual VMT	*	0 Fatality rate for HOV (fatalities per VMT)	) =	0 Fatalities per year	(10)
Fatalities for HOT mode	= (	From E-a2(10) 0 HOT Annual VMT	*	0 Fatality rate for HOT (fatalities per VMT)	) =	0 Fatalities per year	(11)
Fatalities for Bus mode	= (	From E-b(14) 0 Bus Annual VMT	*	0.000000043 Fatality rate for Bus (fatalities per VMT)	) =	0 Fatalities per year	(12)
Fatalities for LRT mode	= (	From E-c(14) 0 LRT Annual VMT	*	0.000000235 Fatality rate for LRT (fatalities per VMT)	) =	0 Fatalities per year	(13)
Fatalities for CRT mode	= (	From E-d(14) 0 CRT Annual VMT	*	0.000000312 Fatality rate for CRT (fatalities per VMT)	) =	0 Fatalities per year	(14)
Fatalities for Bike mode	= (	From E-e(10) 0 Bike Annual VMT	*	0 Fatality rate for Bike (fatalities per VMT)	) =	0 Fatalities per year	(15)
Fatalities for Ped mode	= (	From E-f(10) 0 Ped Annual PMT	*	0 Crash rate for Ped (crashes per PMT)	) =	0 Fatalities per year	(16)

Crashes and fatality rates per million miles traveled per mode are given in Tables R1 and S1. Crash rates are as follows:
0.00000124 and 0.00000271 for Rural and Urban highways, respectively.
0.0000248 incidents per Annual VMT for Bus.
0.00002924 incidents per Annual VMT for LRT.
0.00000918 incidents per Annual VMT for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

Fatality rates are as follows:
0.0000000261 and 0.0000000116 for Rural and Urban highways, respectively.
0.000000043 incidents per Annual VMT for Bus.
0.000000235 incidents per Annual VMT for LRT.
0.000000312 incidents per Annual VMT miles for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

FORM F
Summary Table of MOEs for NO-BUILD Travel Conditions

Segment #1

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY								
Total Trips Segm 1 A-B	From D (9)	From D (11)	From D (13)	From D (15)	From D (17)	From D (19)	From D (21)	From D (23)
	6756	0	0	0	0	0	0	0
Total Trips Segm 1 B-A	From D (10)	From D (12)	From D (14)	From D (16)	From D (18)	From D (20)	From D (22)	From D (24)
	10135	0	0	0	0	0	0	0
Travel Time Segm 1 A-B (hrs)	From E-a1(13)	From E-a1(13)	From E-a1(13)	From E-b(6)	From E-c(6)	From E-d(6)	From E-e(3)	From E-f(3)
	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Travel Time Segm 1 B-A (hrs)	From E-a1(14)	From E-a1(14)	From E-a1(14)	From E-b(6)	From E-c(6)	From E-d(6)	From E-e(3)	From E-f(3)
	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Veh. Hours Traveled Segm 1 A-B	From E-a2(3)	From E-a2(3)	From E-a2(3)	From E-b(10)	From E-c(10)	From E-d(10)	From E-e(4)	From E-f(4)
	1440	0	0	0	0	0	0	0
Veh. Hours Traveled Segm 1 B-A	From E-a2(4)	From E-a2(4)	From E-a2(4)	From E-b(10)	From E-c(10)	From E-d(10)	From E-e(5)	From E-f(5)
	6624	0	0	0	0	0	0	0
Veh. Miles Traveled Segm 1 A-B	From E-a2(5)	From E-a2(5)	From E-a2(5)	From E-b(11)	From E-c(11)	From E-d(11)	From E-e(6)	
	75672	0	0	0	0	0	0	
Veh. Miles Traveled Segm 1 B-A	From E-a2(6)	From E-a2(6)	From E-a2(6)	From E-b(11)	From E-c(11)	From E-d(11)	From E-e(7)	
	113508	0	0	0	0	0	0	
Average Speed Segm 1 A-B (mi/hr)	From E-a2(1)	From E-a2(1)	From E-a2(1)	From E-b(4)	From E-c(4)	From E-d(4)	From E-e(2)	From E-f(2)
	53	0	0	0	0	0	0	0
Average Speed Segm 1 B-A (mi/hr)	From E-a2(2)	From E-a2(2)	From E-a2(2)	From E-b(4)	From E-c(4)	From E-d(4)	From E-e(2)	From E-f(2)
	17	0	0	0	0	0	0	0
Average Capacity Utilization Segm 1 A-B	From E-a1(11)	From E-a1(11)	From E-a1(11)	From E-b(7)	From E-c(7)	From E-d(7)		
	0.84	0.00	0.00	0.00	0.00	0.00		
Average Capacity Utilization Segm 1 B-A	From E-a1(12)	From E-a1(12)	From E-a1(12)	From E-b(8)	From E-c(8)	From E-d(8)		
	1.27	0.00	0.00	0.00	0.00	0.00		
Pass. Miles Trav. Segm 1 A-B	From E-a2(7)	From E-a2(7)	From E-a2(7)	From E-b(12)	From E-c(12)	From E-d(12)	From E-e(6)	From E-f(6)
	90806	0	0	0	0	0	0	0
Pass. Miles Trav. Segm 1 B-A	From E-a2(8)	From E-a2(8)	From E-a2(8)	From E-b(12)	From E-c(12)	From E-d(12)	From E-e(7)	From E-f(7)
	136209	0	0	0	0	0	0	0
AIR QUALITY								
Emissions Segm 1 (tons of pollutant/yr)	From E-AQ(1)	From E-AQ(2)	From E-AQ(3)	From E-AQ(4)	From E-AQ(5)	From E-AQ(6)	From E-AQ(7)	From E-AQ(8)
	2104.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SAFETY								
Crashes Segm 1 (Per Year)	From E-S(1)	From E-S(2)	From E-S(3)	From E-S(4)	From E-S(5)	From E-S(6)	From E-S(7)	From E-S(8)
	720	0	0	0	0	0	0	0
Fatalities Segm 1 (Per Year)	From E-S(9)	From E-S(10)	From E-S(11)	From E-S(12)	From E-S(13)	From E-S(14)	From E-S(15)	From E-S(16)
	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FORM G-1
Expected Corridor Travel Conditions under an Alternative Scenario for Segment #1 (Part 1)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

NEW MODE OR ALTERNATIVE CONSIDERED SOV

(Enter one of: Additional capacity (SOV, HOV, or HOT) Lanes, Transit system (Bus, LRT, or CRT), Bike path, or Pedestrian walkway)

Convert vehicle trips to passenger trips

				Direction A-B								Direction B-A		
SOV trips (NO-Build scenario)	=	From D(9) 6756.4 (Vehicle trips)	*	From B-a1(16) 1.2 SOV veh. occupancy	=	8107.68 (Passenger trips) A-B	(1)	=	From D(10) 10134.6 (Vehicle trips)	*	From B-a1(16) 1.2 SOV veh. occup.	=	12161.52 (Passenger trips) A-B	(2)
HOV trips (NO-Build scenario)	=	From D(11) 0 (Vehicle trips)	*	From B-a1(16) 2.5 HOV veh. occupancy	=	0 (Passenger trips) A-B	(3)	=	From D(12) 0 (Vehicle trips)	*	From B-a1(16) 2.5 HOV veh. occup.	=	0 (Passenger trips) A-B	(4)
HOT trips (NO-Build scenario)	=	From D(13) 0 (Vehicle trips)	*	From B-a1(16) 2.5 HOT veh. occupancy	=	0 (Passenger trips) A-B	(5)	=	From D(14) 0 (Vehicle trips)	*	From B-a1(16) 2.5 HOT veh. occup.	=	0 (Passenger trips) A-B	(6)

Calculate the total number of passenger trips for the No-Build scenario.

		Direction A-B			Direction B-A	
SOV trips (NO-Build scenario) (Passenger trips)	=	From (1) 8107.68	(7)	=	From (2) 12161.52	(8)
		+			+	
HOV trips (NO-Build scenario) (Passenger trips)	=	From (3) 0	(9)	=	From (4) 0	(10)
		+			+	
HOT trips (NO-Build scenario) (Passenger trips)	=	From (5) 0	(11)	=	From (6) 0	(12)
		+			+	
Bus trips (NO-Build scenario) (Passenger trips)	=	From D(15) 0	(13)	=	From D(16) 0	(14)
		+			+	
LRT trips (NO-Build scenario) (Passenger trips)	=	From D(17) 0	(15)	=	From D(18) 0	(16)
		+			+	
CRT trips (NO-Build scenario) (Passenger trips)	=	From D(19) 0	(17)	=	From D(20) 0	(18)
		+			+	
Bike trips (NO-Build scenario) (Passenger trips)	=	From D(21) 0	(19)	=	From D(22) 0	(20)
		+			+	
Pedestrian trips (NO-Build scenario) (Passenger trips)	=	From D(23) 0	(21)	=	From D(24) 0	(22)
Total number of trips		8107.68 Total pass. trips A-B	(23)		12161.52 Total pass. trips B-A	(24)
Percentage (in decimal) of total pass. trips expected to switch to the new or improved mode alternative.	=		(25)	=		(26)

Number of trips using the new alternative by direction	=	From (23) 8107.68 (Total pass. trips)	*	From (25) 0 % of A-B trips	=	0 Pass. trips for alt. A-B	(27)	=	From (24) 12161.52 (Total pass. trips)	*	From (26) 0 % of B-A trips	=	0 Pass. trips for alt. B-A	(28)

Enter change in the number of passenger trips for the highway modes due to the alternative considered.

Increase/decrease in SOV pass. trips	=	0 Change in pass. trips A-B	(29)	=	0 Change in pass. trips B-A	(30)
Increase/decrease in HOV pass. trips	=	 Change in pass. trips A-B	(31)	=	 Change in pass. trips B-A	(32)
Increase/decrease in HOT pass. trips	=	 Change in pass. trips A-B	(33)	=	 Change in pass. trips B-A	(34)

Convert passenger trips for the highway modes to vehicle trips

				Direction A-B								Direction B-A		
Inc./dec. in SOV veh. trips	=	From (29) 0 Change in pass. trips	/	From B-a1(16) 1.2 SOV veh. occupancy	=	0 Change in SOV veh. trips A-B	(35)	=	From (30) 0 Change in pass. trips	/	From B-a1(16) 1.2 SOV veh. occup.	=	0 Change in SOV veh. trips	(36)
Inc./dec. in HOV veh. trips	=	From (31) 0 Change in pass. trips	/	From B-a1(16) 2.5 HOV veh. occupancy	=	0 Change in HOV veh. trips A-B	(37)	=	From (32) 0 Change in pass. trips	/	From B-a1(16) 2.5 HOV veh. occup.	=	0 Change in HOV veh. trips	(38)
Inc./dec. in HOT veh. trips	=	From (33) 0 Change in pass. trips	/	From B-a1(16) 2.5 HOT veh. occupancy	=	0 Change in HOT veh. trips A-B	(39)	=	From (34) 0 Change in pass. trips	/	From B-a1(16) 2.5 HOT veh. occup.	=	0 Change in HOT veh. trips	(40)

FORM G-2
Expected Corridor Travel Conditions under an Alternative Scenario for Segment #1 (Part 2)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

NEW MODE OR ALTERNATIVE CONSIDERED SOV
(Enter one of: Additional capacity (SOV, HOV, or HOT Lanes), Transit system (Bus, LRT, or CRT), Bike path, or Pedestrian walkway)

Percent of generated highway traffic due to Alternative 0

	Increase or Reduction in Trips – A-B Direction		**Increase or Reduction in Trips – B-A Direction**	
Expected increase/decrease in the number of SOV passenger trips due to the alternative considered	From G-1 (29) 0	(1)	From G-1 (30) 0	(2)
Expected increase/decrease in the number of HOV passenger trips due to the alternative considered	From G-1 (31) 0	(3)	From G-1 (32) 0	(4)
Expected increase/decrease in the number of HOT passenger trips due to the alternative considered	From G-1 (33) 0	(5)	From G-1 (34) 0	(6)
Expected increase/decrease in the number of Bus passenger trips due to the alternative considered	0	(7)	0	(8)
Expected increase/decrease in the number of LRT passenger trips due to the alternative considered	0	(9)	0	(10)
Expected increase/decrease in the number of CRT passenger trips due to the alternative considered	0	(11)	0	(12)
Expected increase/decrease in the number of Bike passenger trips due to the alternative considered	0	(13)	0	(14)
Expected increase/decrease in the number of Pedestrian passenger trips due to the alt. considered	0	(15)	0	(16)

FUTURE TRAVEL CONDITIONS FOR EXISTING MODES FOR SEGMENT #1

(Trips for analysis period under the alternative scenario conditions)

SOV	= (	From D (9) 6756 Trips A-B Dir.	+	From G-1 (35) 0 Change in veh. trips	) =	**A-B Direction** 6756 Analysis SOV Volume	(17)	= (	From D (10) 10135 Trips B-A Dir.	+	From G-1 (36) 0 Change in veh. trips	) =	**B-A Direction** 10134.6 Analysis SOV Volume (18)
HOV	= (	From D (11) 0 Trips A-B Dir.	+	From G-1 (37) 0 Change in veh. trips	) =	**A-B Direction** 0 Analysis HOV Volume	(19)	= (	From D (12) 0 Trips B-A Dir.	+	From G-1 (38) 0 Change in veh. trips	) =	**B-A Direction** 0 Analysis HOV Volume (20)
HOT	= (	From D (13) 0 Trips A-B Dir.	+	From G-1 (39) 0 Change in veh. trips	) =	**A-B Direction** 0 Analysis HOT Volume	(21)	= (	From D (14) 0 Trips B-A Dir.	+	From G-1 (40) 0 Change in veh. trips	) =	**B-A Direction** 0 Analysis HOT Volume (22)
BUS	= (	From D (15) 0 Trips A-B Dir.	+	From (7) 0 Change in pass. trips	) =	**A-B Direction** 0 Bus Analysis Volume	(23)	= (	From D (16) 0 Trips B-A Dir.	+	From (8) 0 Change in pass. trips	) =	**B-A Direction** 0 Bus Analysis Volume (24)
LRT	= (	From D (17) 0 Trips A-B Dir.	+	From (9) 0 Change in pass. trips	) =	**A-B Direction** 0 LRT Analysis Volume	(25)	= (	From D (18) 0 Trips B-A Dir.	+	From (10) 0 Change in pass. trips	) =	**B-A Direction** 0 LRT Analysis Volume (26)
CRT	= (	From D (19) 0 Trips A-B Dir.	+	From (11) 0 Change in pass. trips	) =	**A-B Direction** 0 CRT Analysis Volume	(27)	= (	From D (20) 0 Trips B-A Dir.	+	From (12) 0 Change in pass. trips	) =	**B-A Direction** 0 CRT Analysis Volume (28)
BIKE	= (	From D (21) 0 Trips A-B Dir.	+	From (13) 0 Change in pass. trips	) =	**A-B Direction** 0 Bike Analysis Volume	(29)	= (	From D (22) 0 Trips B-A Dir.	+	From (14) 0 Change in pass. trips	) =	**B-A Direction** 0 Bike Analysis Volume (30)
PED	= (	From D (23) 0 Trips A-B Dir.	+	From (15) 0 Change in pass. trips	) =	**A-B Direction** 0 Ped Analysis Volume	(31)	= (	From D (24) 0 Trips B-A Dir.	+	From (16) 0 Change in pass. trips	) =	**B-A Direction** 0 Ped Analysis Volume (32)

FORM H-a1 SOV

MOEs for Segment #1 under the Alternative Scenario for Pass. Cars (Part 1)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

LENGTH OF SEGMENT From B-a1(1) 11.2 (Miles) (1)

TYPE OF LANES SOV (2)
(Indicate lane type: SOV, HOV, or HOT)

NUMBER OF LANES 3 DIR A-B (3) 3 DIR B-A (4)

CAPACITY PER LANE (Veh / Hr) 2000 (5)
See Reference Table R-11

VEHICLE CAPACITY PER DIRECTION

(From (3) 3 N. of Lanes * From (5) 2000 Cap. per Lane * From A (1) 2 N. of Hours) = DIR A-B 12000 Capacity in Vehicles per analysis period (6)

(From (4) 3 N. of Lanes * From (5) 2000 Cap. per Lane * From A (1) 2 N. of Hours) = DIR B-A 12000 Capacity in Vehicles per analysis period (7)

FREE-FLOW SPEED 70 (Mi / Hr) (8)
(Posted speed + 5)

Free-Flow Travel Time = (From (1) 11.2 Length of Segment / From (8) 70 FF Speed) = 0.16 FFTT (hrs) (9)

Parameters for the Highway Travel Time Function Alpha = 0.84 (10) Beta = 5.5 (11)
(Values recommended for multilane freeways are 0.84 for Alpha and 5.5 for Beta respectively. See Table R11)

V/C Ratio A-B = (From G-2 (17) 6756.4 A-B Volume / From (6) 12000 Capacity) = 0.56 V/C Ratio A-B (12)

V/C Ratio B-A = (From G-2 (18) 10134.6 B-A Volume / From (7) 12000 Capacity) = 0.84 V/C Ratio B-A (13)

(References G(17) and G(18) are for SOV. For HOV and HOT these will be G(19), G(20) and G(21), G(22), respectively)

Travel Time = (From (9) 0.160 FFTT (hrs) * (1+ From (10) 0.84 Alpha * (From (12) 0.56 V/C Ratio A-B) ^ From (11) 5.5 Beta)) = **Dir. A-B** 0.166 Travel Time (14)

Travel Time = (From (9) 0.160 FFTT (hrs) * (1+ From (10) 0.84 Alpha * (From (13) 0.84 V/C Ratio B-A) ^ From (11) 5.5 Beta)) = **Dir. B-A** 0.213 Travel Time (15)

FORM H-a2 SOV
MOEs for Segment #1 under the Alternative Scenario for Pass. Cars (Part 2)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

		From H-a1(1)		From H-a1(14)		**Dir. A-B**	
Speed	= (	11.2	/	0.166	) =	67.6	**(1)**
		Segm Length		Travel Time		(Miles / Hour)	
		From H-a1(1)		From H-a1(15)		**Dir. B-A**	
Speed	= (	11.2	/	0.213	) =	52.6	**(2)**
		Segm Length		Travel Time		(Miles / Hour)	

(References G(17) and G(18) are for SOV. For HOV and HOT these will be G(19), G(20) and G(21), G(22), respectively)

		From G-2 (17)		From H-a1(14)					
VHT Direction A-B	= (	6756.4	*	0.166			) =	1119.6	**(3)**
		Analysis Volume A-B		Travel Time				VHT Dir. A-B	
		From G-2 (18)		From H-a1(15)					
VHT Direction B-A	= (	10134.6	*	0.213			) =	2159.4	**(4)**
		Analysis Volume B-A		Travel Time				VHT Dir. B-A	
		From G-2 (17)		From H-a1(1)					
VMT Direction A-B	= (	6756.4	*	11.2			) =	75671.7	**(5)**
		Analysis Volume A-B		Segm. Length				VMT Dir. A-B	
		From G-2 (18)		From H-a1(1)					
VMT Direction B-A	= (	10134.6	*	11.2			) =	113507.5	**(6)**
		Analysis Volume B-A		Segm. Length				VMT Dir. B-A	
		From (5)		From B-a1(16)					
PMT Direction A-B	= (	75671.7	*	1.2			) =	90806.0	**(7)**
		VMT Dir. A-B		Pass. / Vehicle				PMT Dir. A-B	
		From (6)		From B-a1(16)					
PMT Direction B-A	= (	113507.5	*	1.2			) =	136209.0	**(8)**
		VMT Dir. B-A		Pass. / Vehicle				PMT Dir. B-A	
		From (5)		From (6)					
Total VMT	= (	75671.68	+	113507.52			) =	189179.2	**(9)**
(Both Directions)		VMT Dir. A-B		VMT Dir. B-A				Total VMT	
		From (9)							
Annual VMT	= (	189179.2	/	0.14	*	365	) =	493217200	**(10)**
(Both Directions)		Total VMT		Total Volume as a % of AADT		Days per year		Annual VMT	

FORM H-AQ
Air Quality MOEs for Segment #1 under the ____________ Alternative per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

Emissions for SOV mode	= (	From H-a2(10) 493217200 SOV Annual VMT	*	3.87 Emissions rate (grams / SOV VMT)	/	907,200 grams/Ton	) = 2104.00 Tons of pollutants per year (1)
Emissions for HOV mode	= (	From H-a2(10) 0 HOV Annual VMT	*	3.87 Emissions rate (grams / HOV VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (2)
Emissions for HOT mode	= (	From H-a2(10) 0 HOT Annual VMT	*	3.87 Emissions rate (grams / HOT VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (3)
Emissions for Bus mode	= (	From H-b(14) 0 Bus Annual VMT	*	24.9 Emissions rate (grams / Bus VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (4)
Emissions for LRT mode	= (	From H-c(14) 0 LRT Annual VMT	*	0 Emissions rate (grams / LRT VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (5)
Emissions for CRT mode	= (	From H-d(14) 0 CRT Annual VMT	*	316.5 Emissions rate (grams / CRT VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (6)
Emissions for Bike mode	= (	From H-e(10) 0 Bike Annual VMT	*	0 Emissions rate (grams / Bike VMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (7)
Emissions for Ped mode	= (	From H-f(10) 0 CRT Annual PMT	*	0 Emissions rate (grams / Ped PMT)	/	907,200 grams/Ton	) = 0.00 Tons of pollutants per year (8)

Emission rates per mode are given in Table R5 in grams per mile. These are:
3.87 for SOV, HOV, and HOT modes.
24.9 for Bus.
0.0 for LRT, Bike, and Pedestrian modes.
316.5 for CRT with one diesel locomotive.

FORM H-S
Safety MOEs for Segment #1 under the ____________ Alternative per mode

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

Crashes for SOV mode	= (	From H-a2(10) 493217200 SOV Annual VMT	*	0.00000146 Crash rate for SOV (crashes per VMT)	) =	720.1 Crashes per year	(1)
Crashes for HOV mode	= (	From H-a2(10) 0 HOV Annual VMT	*	0 Crash rate for HOV (crashes per VMT)	) =	0.0 Crashes per year	(2)
Crashes for HOT mode	= (	From H-a2(10) 0 HOT Annual VMT	*	0 Crash rate for HOT (crashes per VMT)	) =	0.0 Crashes per year	(3)
Crashes for Bus mode	= (	From H-b(14) 0 Bus Annual VMT	*	0.0000248 Crash rate for Bus (crashes per VMT)	) =	0.0 Crashes per year	(4)
Crashes for LRT mode	= (	From H-c(14) 0 LRT Annual VMT	*	0.00002924 Crash rate for LRT (crashes per VMT)	) =	0.0 Crashes per year	(5)
Crashes for CRT mode	= (	From H-d(14) 0 CRT Annual VMT	*	0.00000918 Crash rate for CRT (crashes per VMT)	) =	0.0 Crashes per year	(6)
Crashes for Bike mode	= (	From H-e(10) 0 Bike Annual VMT	*	0 Crash rate for Bike (crashes per VMT)	) =	0.0 Crashes per year	(7)
Crashes for Ped mode	= (	From H-f(10) 0 Ped Annual PMT	*	0 Crash rate for Ped (crashes per PMT)	) =	0.0 Crashes per year	(8)

Fatalities for SOV mode	= (	From H-a2(10) 493217200 SOV Annual VMT	*	1.13E-08 Fatality rate for SOV (fatalities per VMT)	) =	5.57 Fatalities per year	(9)
Fatalities for HOV mode	= (	From H-a2(10) 0 HOV Annual VMT	*	0 Fatality rate for HOV (fatalities per VMT)	) =	0.00 Fatalities per year	(10)
Fatalities for HOT mode	= (	From H-a2(10) 0 HOT Annual VMT	*	0 Fatality rate for HOT (fatalities per VMT)	) =	0.00 Fatalities per year	(11)
Fatalities for Bus mode	= (	From H-b(14) 0 Bus Annual VMT	*	0.000000043 Fatality rate for Bus (fatalities per VMT)	) =	0.00 Fatalities per year	(12)
Fatalities for LRT mode	= (	From H-c(14) 0 LRT Annual VMT	*	0.000000235 Fatality rate for LRT (fatalities per VMT)	) =	0.00 Fatalities per year	(13)
Fatalities for CRT mode	= (	From H-d(14) 0 CRT Annual VMT	*	0.000000312 Fatality rate for CRT (fatalities per VMT)	) =	0.00 Fatalities per year	(14)
Fatalities for Bike mode	= (	From H-e(10) 0 Bike Annual VMT	*	0 Fatality rate for Bike (fatalities per VMT)	) =	0.00 Fatalities per year	(15)
Fatalities for Ped mode	= (	From H-f(10) 0 Ped Annual PMT	*	0 Crash rate for Ped (crashes per PMT)	) =	0.00 Fatalities per year	(16)

Crashes and fatality rates per million miles traveled per mode are given in Tables R1 and S1. Crash rates are as follows:
0.00000124 and 0.00000271 for Rural and Urban highways, respectively.
0.0000248 incidents per Annual VMT for Bus.
0.00002924 incidents per Annual VMT for LRT.
0.00000918 incidents per Annual VMT for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

Fatality rates are as follows:
0.0000000261 and 0.0000000116 for Rural and Urban highways, respectively.
0.000000043 incidents per Annual VMT for Bus.
0.000000235 incidents per Annual VMT for LRT.
0.000000312 incidents per Annual VMT miles for CRT.
No rates available for Bike and Pedestrian modes. Use 0.00.

FORM I

Summary of Travel Conditions under The ______________ Alternative Scenario Segment #1

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

MOEs **PER ANALYSIS PERIOD**	**SOV**	**HOV**	**HOT**	**BUS**	**LRT**	**CRT**	**BIKE**	**PEDS**
MOBILITY								
	From G (17)	From G (19)	From G (21)	From G (23)	From G (25)	From G (27)	From G (29)	From G (31)
Total Trips Segm 1 A-B	6756	0	0	0	0	0	0	0
	From G (18)	From G (20)	From G (22)	From G (24)	From G (26)	From G (28)	From G (30)	From G (32)
Total Trips Segm 1 B-A	10135	0	0	0	0	0	0	0
	From H-a1(14)	From H-a1(14)	From H-a1(14)	From H-b(6)	From H-c(6)	From H-d(6)	From H-e(3)	From H-f(3)
Travel Time Segm 1 A-B (hrs)	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	From H-a1(15)	From H-a1(15)	From H-a1(15)	From H-b(6)	From H-c(6)	From H-d(6)	From H-e(3)	From H-f(3)
Travel Time Segm 1 B-A (hrs)	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	From H-a2(3)	From H-a2(3)	From H-a2(3)	From H-b(10)	From H-c(10)	From H-d(10)	From H-e(4)	From H-f(4)
Veh. Hours Traveled Segm 1 A-B	1120	0	0	0	0	0	0	0
	From H-a2(4)	From H-a2(4)	From H-a2(4)	From H-b(10)	From H-c(10)	From H-d(10)	From H-e(5)	From H-f(5)
Veh. Hours Traveled Segm 1 B-A	2159	0	0	0	0	0	0	0
	From H-a2(5)	From H-a2(5)	From H-a2(5)	From H-b(11)	From H-c(11)	From H-d(11)	From H-e(6)	
Veh. Miles Traveled Segm 1 A-B	75672	0	0	0	0	0	0	
	From H-a2(6)	From H-a2(6)	From H-a2(6)	From H-b(11)	From H-c(11)	From H-d(11)	From H-e(7)	
Veh. Miles Traveled Segm 1 B-A	113508	0	0	0	0	0	0	
	From H-a2(1)	From H-a2(1)	From H-a2(1)	From H-b(4)	From H-c(4)	From H-d(4)	From H-e(2)	From H-f(2)
Average Speed Segm 1 A-B (mi/hr)	67.6	0	0	0	0	0	0	0
	From H-a2(2)	From H-a2(2)	From H-a2(2)	From H-b(4)	From H-c(4)	From H-d(4)	From H-e(2)	From H-f(2)
Average Speed Segm 1 B-A (mi/hr)	52.6	0	0	0	0	0	0	0
	From H-a1(12)	From H-a1(12)	From H-a1(12)	From H-b(7)	From H-c(7)	From H-d(7)		
Average Capacity Utilization Segm 1 A-B	0.56	0.00	0.00	0.00	0.00	0.00		
	From H-a1(13)	From H-a1(13)	From H-a1(13)	From H-b(8)	From H-c(8)	From H-d(8)		
Average Capacity Utilization Segm 1 B-A	0.84	0.00	0.00	0.00	0.00	0.00		
	From H-a2(7)	From H-a2(7)	From H-a2(7)	From H-b(12)	From H-c(12)	From H-d(12)	From H-e(6)	From H-f(6)
Pass. Miles Trav. Segm 1 A-B	90806	0	0	0	0	0	0	0
	From H-a2(8)	From H-a2(8)	From H-a2(8)	From H-b(12)	From H-c(12)	From H-d(12)	From H-e(7)	From H-f(7)
Pass. Miles Trav. Segm 1 B-A	136209	0	0	0	0	0	0	0
AIR QUALITY								
	From H-AQ(1)	From H-AQ(2)	From H-AQ(3)	From H-AQ(4)	From H-AQ(5)	From H-AQ(6)	From H-AQ(7)	From H-AQ(8)
Emissions Segm 1 (tons of pollutant/yr)	2104.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SAFETY								
	From H-S(1)	From H-S(2)	From H-S(3)	From H-S(4)	From H-S(5)	From H-S(6)	From H-S(7)	From H-S(8)
Crashes Segm 1 (Per Year)	720	0	0	0	0	0	0	0
	From H-S(9)	From H-S(10)	From H-S(11)	From H-S(12)	From H-S(13)	From H-S(14)	From H-S(15)	From H-S(16)
Fatalities Segm 1 (Per Year)	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FORM J-1
Corridor Capital Costs for the Alternative Scenario

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
Corridor Length affected by alternative	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8
Number of Additional Lanes/Tracks	2							
Unit Cost per Lane/Track (Table R-\2)	$8,000,000							
Number of Components/Equipment 1								
Number of Components/Equipment 2								
Unit Cost Per Component/Equipment 1 (Table R2)								
Unit Cost Per Component/Equipment 2 (Table R2)								
Subtotal	684800000	0	0	0	0	0	0	0
Preliminary Engineering % (Table R8)	17%	17%	17%	17%	17%	17%	17%	17%
Construction Engineering % (Table R8)	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%
ROW% (Table R8)	7%	7%	7%	7%	7%	7%	7%	7%
Total / mode (in Millions $)	929.27	0	0	0	0	0.00	0	0
ALTERNATIVE CAPITAL TOTAL (in Millions $)	929.27							
Number of Years to Construct/Purchase	5							
Annual Construction/Purchase Costs (Millions $)	185.85							

FORM J-2
Corridor Annual Maintenance & Operation Costs under the ____________ Alternative Scenario

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR 2020

	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
Corridor Length affected by alternative	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8
Number of Additional Lanes/Tracks	2	0	0	0	0	0	0	0
M&O Unit Cost per Lane/Track (Table R8)	$60,000							
Subtotal	5136000	0	0	0	0	0	0	0
Administration/Overhead (%)	10%	10%	10%	10%	10%	10%	10%	10%
Total (per mode)	5649600	0	0	0	0	0	0	0
ALTERNATIVE M&O TOTAL (Annual)	5649600							
Service Delivery Components (%) (Table R10)	0%	0%	5%	75%	72%	72%	0%	0%
Service Delivery Components	0	0	0	0	0	0	0	0

FORM K-1
Summary Table for Corridor Mobility Conditions for All Segments Each Direction

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990 **ANALYSIS YEAR** 2020

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs for BASELINE conditions								
Avg. Number of Passenger Trips A-B	3508.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avg. Number of Passenger Trips B-A	3930.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time A-B (hrs)	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time B-A (hrs)	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Veh. Hours Traveled A-B	1632	0	0	0	0	0	0	0
Veh. Hours Traveled B-A	1849	0	0	0	0	0	0	0
Veh. Miles Traveled A-B	125132	0	0	0	0	0	0	0
Veh. Miles Traveled B-A	140203	0	0	0	0	0	0	0
Weighted Mean Speed A-B (mi/hr)	76.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weighted Mean Speed B-A (mi/hr)	76.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Miles Trav. A-B	150158	0	0	0	0	0	0	0
Passenger Miles Trav. B-A	168244	0	0	0	0	0	0	0
Capacity Utilization A-B	0.37	0.00	0.00	0.00	0.00	0.00		
Capacity Utilization B-A	0.41	0.00	0.00	0.00	0.00	0.00		
Max. Theor. Cap. per ln/track (Table R17)	9600							

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs for No-Build scenario								
Avg. Number of Passenger Trips A-B	7123.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avg. Number of Passenger Trips B-A	8310.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time A-B (hrs)	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time B-A (hrs)	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Veh. Hours Traveled A-B	4104	0	0	0	0	0	0	0
Veh. Hours Traveled B-A	9238	0	0	0	0	0	0	0
Veh. Miles Traveled A-B	254061	0	0	0	0	0	0	0
Veh. Miles Traveled B-A	296395	0	0	0	0	0	0	0
Weighted Mean Speed A-B (mi/hr)	64.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weighted Mean Speed B-A (mi/hr)	56.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Miles Trav. A-B	304873	0	0	0	0	0	0	0
Passenger Miles Trav. B-A	355674	0	0	0	0	0	0	0
Capacity Utilization A-B	0.74	0.00	0.00	0.00	0.00	0.00		
Capacity Utilization B-A	0.87	0.00	0.00	0.00	0.00	0.00		
Max. Theor. Cap. per ln/track (Table R17)	9600	0	0	0	0	0		

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs under Alternative scenario								
Avg. Number of Passenger Trips A-B	7123.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avg. Number of Passenger Trips B-A	8310.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time A-B (hrs)	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Travel Time B-A (hrs)	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Veh. Hours Traveled A-B	3396	0	0	0	0	0	0	0
Veh. Hours Traveled B-A	4481	0	0	0	0	0	0	0
Veh. Miles Traveled A-B	254061	0	0	0	0	0	0	0
Veh. Miles Traveled B-A	296395	0	0	0	0	0	0	0
Weighted Mean Speed A-B (mi/hr)	75.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weighted Mean Speed B-A (mi/hr)	71.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Miles Trav. A-B	304873	0	0	0	0	0	0	0
Passenger Miles Trav. B-A	355674	0	0	0	0	0	0	0
Capacity Utilization A-B	0.49	0.00	0.00	0.00	0.00	0.00		
Capacity Utilization B-A	0.58	0.00	0.00	0.00	0.00	0.00		
Max. Theor. Cap. per ln/track (Table R17)	9600	0	0	0	0	0		

FORM K-2
Summary Table for Corridor Mobility Conditions for All Segments Both Directions

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990 **ANALYSIS YEAR** 2020

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs for BASELINE conditions (both directions)								
Total # of Pass.Trips both Directions	7439	0	0	0	0	0	0	0
Corridor Avg. Travel Time per Direction	0.56							
Total Veh. Hours Traveled	3481	0	0	0	0	0	0	0
Total Veh. Miles Traveled	265335	0	0	0	0	0	0	0
Weighted Mean Speed (mi/hr)	76.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Passenger Miles Traveled	318402	0	0	0	0	0	0	0
Avg. Capacity Utilization	0.39							
Weighted Mean Speed for all Available Modes both Directions (mi/hr) =				76.8				

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs for No-Build scenario (both directions)								
Total # of Pass.Trips both Directions	15433	0	0	0	0	0	0	0
Corridor Avg. Travel Time per Direction	0.91							
Total Veh. Hours Traveled	13342	0	0	0	0	0	0	0
Total Veh. Miles Traveled	550456	0	0	0	0	0	0	0
Weighted Mean Speed (mi/hr)	60.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Passenger Miles Traveled	660547	0	0	0	0	0	0	0
Avg. Capacity Utilization	0.81							
Weighted Mean Speed for all Available Modes both Directions (mi/hr) =				60.2				

MOEs PER ANALYSIS PERIOD	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS
MOBILITY MOEs under Alternative scenario (both directions)								
Total # of Pass.Trips both Directions	15433	0	0	0	0	0	0	0
Corridor Avg. Travel Time per Direction	0.59							
Total Veh. Hours Traveled	7877	0	0	0	0	0	0	0
Total Veh. Miles Traveled	550456	0	0	0	0	0	0	0
Weighted Mean Speed (mi/hr)	73.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Passenger Miles Traveled	660547	0	0	0	0	0	0	0
Avg. Capacity Utilization	0.54							
Corridor Average Speed Limit	72.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weighted Mean Speed for all Available Modes both Directions (mi/hr) =				73.7				

FORM L
ANNUAL USER COSTS *

CORRIDOR IDENTIFICATION: Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR: 2020

BASELINE CONDITIONS	Unit	SOV		HOV		HOT		Unit	BUS		Unit	LRT		Unit	CRT		Unit	BIKE		Unit	PEDS	
	Cost	Units	Cost	Units	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost
Auto Gasoline (Unit=VMT) (Table R8)	0.062	1.3E+08	8225385	0	0	0	0															
Auto Parking (Unit=Auto Trips)	1.00	3099708	3099708	0.00	0	0.00	0															
Auto Tolls (Unit=Auto Trips)		3099708	0	0.00	0	0.00	0															
Transit Fares (Unit=Passenger Trips)									0	0		0	0		0	0						
VARIABLE COSTS (per mode)			1.1E+07		0		0			0			0			0						
Capital (Table R2)	0.267	1E+08	3.5E+07	0	0	0	0															
Insurance (Table R8)	0.056	1E+08	7429380	0	0	0	0															
Maintenance (Table R8)	0.082	1E+08	1.1E+07	0	0	0	0															
Registration/Taxes (Table R8)	0.002	1E+08	265335	0	0	0	0															
PERIODIC COSTS (per mode)			5.4E+07		0		0												0			
	TOTAL Variable Costs (Mill $)						11.33	TOTAL Periodic Costs (Mill $)					54									
TOTAL ANNUAL USER COSTS (in Millions $)	65.321																					

NO-BUILD SCENARIO	Unit	SOV		HOV		HOT		Unit	BUS		Unit	LRT		Unit	CRT		Unit	BIKE		Unit	PEDS	
	Cost	Units	Cost	Units	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost
Auto Gasoline (Unit=VMT) (Table 8)	0.062	2.8E+08	1.7E+07	0	0	0	0															
Auto Parking (Unit=Auto Trips)	1.00	6430563	6430563	0	0	0	0															
Auto Tolls (Unit=Auto Trips)		6430563	0	0	0	0	0															
Transit Fares (Unit=Passenger Trips)									0	0		0	0	9	0	0						
VARIABLE COSTS (per mode)			2.3E+07		0		0			0			0			0						
Capital (Table R2)	0.267	3E+08	7.3E+07	0	0	0	0															
Insurance (Table R8)	0.056	3E+08	1.5E+07	0	0	0	0															
Maintenance (Table R8)	0.082	3E+08	2.3E+07	0	0	0	0															
Registration/Taxes (Table R8)	0.002	3E+08	550456	0	0	0	0															
PERIODIC COSTS (per mode)			1.1E+08		0		0												0			
	TOTAL Variable Costs (Mill $)						23.4947	TOTAL Periodic Costs (Mill $)					112.018									
TOTAL ANNUAL USER COSTS (in Millions $)	135.51																					

ALTERNATIVE SCENARIO	Unit	SOV		HOV		HOT		Unit	BUS		Unit	LRT		Unit	CRT		Unit	BIKE		Unit	PEDS	
	Cost	Units	Cost	Units	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost	Cost	Units	Cost
Auto Gasoline (Unit=VMT) (Table R8)	0.062	3E+08	1.7E+07	0	0	0	0															
Auto Parking (Unit=Auto Trips)	1.00	6E+06	6430563	0	0	0	0															
Auto Tolls (Unit=Auto Trips)		6E+06	0	0	0	0	0															
Transit Fares (Unit=Passenger Trips)									0	0		0	0		0	0						
VARIABLE COSTS (per mode)			2.3E+07		0		0			0			0			0						
Capital (Table R2)	0.267	3E+08	7.3E+07	0	0	0	0															
Insurance (Table R8)	0.056	3E+08	1.5E+07	0	0	0	0															
Maintenance (Table R8)	0.082	3E+08	2.3E+07	0	0	0	0															
Registration/Taxes (Table R8)	0.002	3E+08	550456	0	0	0	0															
PERIODIC COSTS (per mode)			1.1E+08		0		0												0			
	TOTAL Variable Costs (Mill $)						23.49	TOTAL Periodic Costs (Mill $)					112									
TOTAL ANNUAL USER COSTS (in Millions $)	135.51																					

** Annual user costs are calculated using number of trips under congested (peak period) conditions only.*

FORM M
Summary Table for Corridor Annual MOEs (All Segments Both Directions)

CORRIDOR IDENTIFICATION Lincoln Avenue-Academy Blvd corridor

BASELINE YEAR 1990 **ANALYSIS YEAR** 2020

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs for BASELINE conditions (both directions)									
MOBILITY									
Annual Number of Pass. Trips	19395315	0	0	0	0	0	0	0	19395315
Annual # of Pass Pk-per Trips*	3719650	0	0	0	0	0	0	0	3719650
Vehicle Miles Traveled	691766250	0	0	0	0	0	0		691766250
VMT (Peak period)*	132667500	0	0	0	0	0	0		132667500
Passenger Miles Traveled	830119500	0	0	0	0	0	0	0	830119500
PMT (Peak Period)*	159201000	0	0	0	0	0	0	0	159201000
AIR QUALITY									
Emissions (tons of pollutants)	2951	0	0	0	0	0	0	0	2951
SAFETY									
Number of Crashes	1010	0	0	0	0	0	0	0	1010
Fatalities	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8
USER COSTS									
Variable User Cost	11.33	0.00	0.00	0.00	0.00	0.00			11.33
Periodic User Cost	54.00	0.00	0.00				0.00		54.00

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs for No-Build scenario (both directions)									
MOBILITY									
Annual Number of Pass. Trips	40236952	0	0	0	0	0	0	0	40236952
Annual # of Pass Pk-per Trips*	7716676	0	0	0	0	0	0	0	7716676
Vehicle Miles Traveled	1435117950	0	0	0	0	0	0		1435117950
VMT (Peak period)*	275228100	0	0	0	0	0	0		275228100
Passenger Miles Traveled	1722141540	0	0	0	0	0	0	0	1722141540
PMT (Peak Period)*	330273720	0	0	0	0	0	0	0	330273720
AIR QUALITY									
Emissions (tons of pollutants)	6122	0	0	0	0	0	0	0	6122
SAFETY									
Number of Crashes	2095	0	0	0	0	0	0	0	2095
Fatalities	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2
USER COSTS									
Variable User Cost	23.49	0.00	0.00	0.00	0.00	0.00			23.49
Periodic User Cost	112.02	0.00	0.00				0.00		112.02

MOEs PER YEAR	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL
MOEs under Alternative scenario (both directions)									
MOBILITY									
Annual Number of Pass. Trips	40236952	0	0	0	0	0	0	0	40236952
Annual # of Pass Pk-per Trips*	7716676	0	0	0	0	0	0	0	7716676
Vehicle Miles Traveled	1435117950	0	0	0	0	0	0		1435117950
VMT (Peak period)*	275228100	0	0	0	0	0	0		275228100
Passenger Miles Traveled	1722141540	0	0	0	0	0	0	0	1722141540
PMT (Peak Period)*	330273720	0	0	0	0	0	0	0	330273720
AIR QUALITY									
Emissions (tons of pollutants)	6122	0	0	0	0	0	0	0	6122
SAFETY									
Number of Crashes	2095	0	0	0	0	0	0	0	2095
Fatalities	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2
USER COSTS in millions $									
Variable User Cost	23.49	0.00	0.00	0.00	0.00	0.00			23.49
Periodic User Cost	112.02	0.00	0.00				0.00		112.02
AGENCY COST in millions $									
Alternative Capital Total **	929.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	929.27
Alternative M&O Total	5.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.65
Service Delivery Component				0.00	0.00	0.00			0.00

* *Only considers trips made under congested (peak period) conditions and 250 workdays in a year.*

** *Total Agency Cost is not annualized, but reflects project's total cost.*

FORM N
MOE Index for the ______________________ Alternative Scenario

CORRIDOR IDENTIFICATION: Lincoln Avenue-Academy Blvd corridor

ANALYSIS YEAR: 2020

MEASURES FOR EVALUATION	SOV	HOV	HOT	BUS	LRT	CRT	BIKE	PEDS	TOTAL	
	From M	From M	From M	From M	From M	From M	From M	From M		
Fatalities per year	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	(M1)
	From M	From M	From M	From M	From M	From M	From M	From M		
Tons of pollutants per year	6122	0	0	0	0	0	0	0	6122	(M2)
	From J-1	From J-1	From J-1	From J-1	From J-1	From J-1	From J-1	From J-1		
Agency cost ($ in millions)	929.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	929.3	(M3)
									From K-2	
Weighted Mean Speed for all Modes for all Directions (mi/hr) =									73.7	(M4)

Weight for Fatalities measure (Wf)= 0.35 (1)

Weight for Cost measure (W$) = 0.25 (3)

Weight for Air Quality measure (Wp)= 0.20 (2)

Weight for Speed measure (Ws)= 0.20 (4)

Note: The summation of all weights must add to 1.0

	From (M1)		From (1)			
1/M1^Wf =	0.061664	^	0.35	=	0.38	(5)
	From (M2)		From (2)			
1/M2^Wp =	0.000163	^	0.20	=	0.17	(6)
	From (M3)		From (3)			
1/M3^W$ =	0.001076	^	0.25	=	0.18	(7)
	From (M4)		From (4)			
M4 ^ Ws =	73.7	^	0.20	=	2.36	(8)

	From (5)		From (6)		From (7)		From (8)		
MOE Index =	0.38	*	0.17	*	0.18	*	2.36	=	0.02822

FORM AA, Air Quality Benefits Worksheet

Project/Alternative Name Lincoln Avenue-Academy Blvd corridor

A1. Enter Analysis year and decision-making year from Form UI or MOE Form D.

Analysis Year 2020 **Decision-Making Year** 1998

A2. Enter total emissions in tons per year for each applicable mode under no-build and the alternative from Form M.

	No-Build		Alternative	
Total Emissions (tons. of pollutants)	6122.0	(1)	6122.0	(2)

A3. Enter total vehicle miles traveled (VMT) by all modes under no-build and alternative from Form M.

	No-Build		Alternative	
Total VMT per year (all modes)	275228100	(3)	275228100	(4)

A4. Enter total passenger miles traveled (PMT) by all modes under no-build and alternative from Form M.

	No-Build		Alternative	
PMT per year	330273720	(5)	330273720	(6)

A5. Calculate Air Quality Measures of Effectiveness (MOEs) for no-build and the alternative.

MOE	No-Build	Alternative
Emissions/VMT (Tons/VMT)	0.00002224 (1)/(3)	0.00002224 (2)/(4)
Emissions/PMT (Tons/PMT)	0.00001854 (1)/(5)	0.00001854 (1)/(6)

A6. Enter ratio of average annual concentration (ug/m3) to emissions (tons/year) for the county from Reference Table R6. In case of multiple county alternativs, see instructions in Table R6.

County Name El Paso + Douglas (7)

Ratio 0.001583 (8)

A7. Calculate change in annual emissions (tons/year) due to the alternative.

0.00 (9)
(1)-(2)

A8. Calculate change in average annual concentration of emissions (ug/m3) due to the alternative. 0.00000 (10)
(8)*(9)

A9. Human Health Damages default value in dollars per ug/m3 per person per day (1992$)

$0.1052 (11)

A10. Update human health damages value to decision-making year using consumer price index (1992 CPI=140.3)

Decision-making year CPI 162.2 (12)

Updated Human Health Damages Value 0.1216 (13)
(11)*(12)/140.3

A11. Enter population of county or counties impacted by emissions from Table R6. The population figures in Table R6 are for 2005. These figures may be used as a default for years up to 2010, for future analysis years, projections from the State Demographer should be used . State Demographer projections may also be used for all analysis years. 593008 (14)

A12. Calculate annual air quality benefit of the alternative (dollars). A negative value means the alternative harms air quality. $0 (15)
(10)*(13)*(14)*365

A13. Transfer annual air quality benefits to Form EE <u>Part 2</u>, the NSB Table. Round to Millions.

FORM BB1 Part 1. User Benefit Worksheet for Project with New Mode.

Project/Alternative Name: Lincoln Avenue-Academy Blvd corridor

New Mode Type: SOV

Benefits of New Mode for Segment # 1 and Direction A-B

B1. Enter analysis year and decision-making year from Form UI.
Analysis Year 2020 Decision Making Year 1998

B2. Enter value for elasticity with its minus sign for new mode from Form UI.
-0.7 (1)

B3. Percentage (in decimals) of new mode daily trips that occur during the analysis period. 0.20

B4. Number of annual peak-period new mode passenger trips from Form I. (Multiply number of trips by 365 days/year and divide by the % of new mode daily trips that occur during the analysis period) 0 (2)

B5. Enter the travel time per trip (in hrs) for new mode from Form I.
0.00 (3)

B6. Enter the fare or toll per trip, or enter 0 if no fare or toll from Form UI.
$3.00 (4)

B7. Enter the value of time from Form UI. $7.07 (5)

B8. Calculate the user benefit (consumer surplus) of the new mode and place in Form BB-S, (Summation of User Benefits Form).
$ - (6)
-0.5[[(5)*(3)+(4)]/(1)]*(2)

FORM BB1 Part 2. User Benefits Worksheet for Project with New Mode.

Project/Alternative Name. Lincoln Avenue-Academy Blvd corridor

New Mode's Impact on Other Existing Modes for Segment # 1 and Direction A-B

Existing Mode Type: SOV

B9. Speed for Segment # 1 (direction A-B) under the No-Build scenario from Form F. 52.6

If speed under the No-Build scenario is greater than or equal to the speed limit, then skip B10 - B22 and enter $0 in B23.

B10. Number of days per year when congestion is present from Form UI. 250

B11. Number of analysis periods per day from Form UI. 2

B12. Average highway occupancy per car from Form UI. 1.2

B13. Enter value for elasticity with its minus sign for existing mode from Form UI. -0.5 (1)

B14. Annual number of peak-period passenger trips for existing mode under the No-Build scenario from Form F. (Multiply number of trips by 250 days/year by 2 peak-periods/day by the average occupancy per vehicle) 4053840 (2)

B15. Enter travel time per trip for existing mode under No-Build from Form F. 0.21 (3)

B16. Calculate the price per trip for existing mode under No-Build. Use value of time from B6 (entry 5) in Part 1, times (3) on this form. $1.51 (4)

B17. Calculate the slope of the trip demand curve. -7.4319E-07 (5)

[(4)/(2)]/(1)

B18. Number of Annual Peak-period passenger trips for existing mode under the Alternative scenario from Form I. (Multiply number of trips by 250 days/year by 2 peak-periods/day by the average occupancy per vehicle) 4053840 (6)

B19. Speed for Segment 1 (direction A-B) under the Alternative scenario from Form I. 67.6

If the speed with the new mode is greater than the speed limit, calculate values for B20 and B21 with the Speed Limit Constrained Worksheet below. Enter the values and continue with B22.

B20. Enter the travel time per passenger trip for the existing mode under the Alternative scenario from Form I or Form BB1(3). 0.17 (7)

B21. Calculate the price per trip for existing mode under the Alternative scenario. Use value of time from B6 (entry 5) in Page 1, times (7) on this form. $1.22 (8)

B22. Calculate the intercept for the trip demand curve with the new mode built. 4.23 (9)

(8)-(5)*(6)

B23. Calculate the total benefit for the existing mode under the Alternative scenario and place it in Form BB-S (Summation of User Benefits Form). $1,112,366 (10)

(0.5*(9-8)*6)-(0.5*(9-4)*((4-9)/5)

SPEED LIMIT CONSTRAINED WORKSHEET

A. Segment speed limit for existing mode under the No-Build scenario from Form E-a1. 65.0 (1)

B. Enter the length of Segment # 1 in miles from Form UI. 11.2 (2)

B20. Travel time (in hrs) per existing mode trip at the speed limit under the Alternative scenario. 0.172 (3)

(2)/(1)

B21. Time price per trip at the speed limit under the Alternative scenario. $1.22 (4)

(3) * [(5) in Form BB1 Part 1]

Enter the values form B20 and B21 in this worksheet in B20 and B21 on the worksheet for the New Mode's Impact on Exisiting Modes, Form BB1 Part 2 above.

FORM BB2. User Benefit Worksheet for Projects that Increase Highway Capacity.

Project/Alternative Name: Lincoln Avenue-Academy Blvd corridoı

User Benefits due to Increased Highway Capacity for Segment # 1 and Direction A-E

B201. Speed for Segment # 1 (direction A-B) under the No-Build scenario from Form F. 52.6

If average speed for the No-Build is greater than or equal to the speed limit,
then skip B202 - B215 and enter $0 in B216.

B202. Enter analysis year and decision-making year from Form UI.
Analysis Year 2020 Decision-Making Year 1998

B203. Number of days per year when congestion is present from Form UI. 250

B204. Number of analysis periods per day from Form UI. 2

B205. Average highway occupancy per car from Form UI. 1.2

B206. Annual number of peak-period passenger trips for existing mode under the No-Builc scenario from Form F. (Multiply number of trips by the number of days/year when congestion occurs by the number of analysis periods per day, and by the average highway occupancy per vehicle) 4053840 (1)

B207. Enter travel time (hrs.) per trip for existing mode under No-Build from Form F. 0.21 (2)

B208. Enter the value of time from Form UI. $7.07 (3)

B209. Time price per trip for existing mode under No-Build conditions. $1.51 (4)
(2)*(3)

B210. Speed for Segment 1 (direction A-B) under the Alternative scenario from Form I. 67.6

If the avg. speed under the Alternative scenario is greater than the speed limit, then calculate the values for B211 and B212 with the Speed Limit Constrained Worksheet below.

B211. Enter the travel time per passenger trip for the existing mode under the Alternative scenario from Form I or from the speed-limit constrained worksheet below. 0.17 (5)

B212. Calculate the time price per trip with the additional highway capacity. $1.22 (6)
(3)*(5)

B213. Number of Annual Peak-period passenger trips for existing mode under the Alternative scenario from Form I. (Multiply number of trips by the number of days/yeaı when congestion occurs by the number of analysis periods per day, and by the average highway occupancy per vehicle) 4053840 (7)

B214. Calculate the benefits of travel time savings. $1,168,238 (8)
[(4)-(6)]*(1)

B215. Calculate the additional consumer surplus benefit. $0 (9)
[(4)-(6)]*[(7)-(1)]*0.5

B216. Calculate total user benefits due to additional highway capacity and place in Form BB-S (Summation of User benefits Form). $1,168,238 (10)
(8)+(9)

SPEED LIMIT CONSTRAINED WORKSHEET

A. Segment speed limit for existing mode under the No-Build scenario. 65.0 (1)

B. Enter the length of Segment # 1 in miles from Form UI. 11.2 (2)

B211. Calculate the travel time per highway trip at the speed limit under the Alternative scenario. 0.172 (3)
(2)/(1)

B212. Time price per trip at the speed limit under the Alternative scenario. $1.22 (4)
(3) * [(3) in Form BB2 Part 1]

Enter the values form B211 and B212 in this worksheet in B211 and B212 on the worksheet for the Benefit of Increased Highway Capacity, Form BB2 Part 1 above.

FORM BB-S. User Benefits for Projects that Increase Highway Capacity.

Project/Alternative Name: Lincoln Avenue-Academy Blvd corridor

Analysis Year: 2020

Does the Project Alternative Increases the Highway Capacity (Yes/No)? yes

User Benefits due to Increased Highway Capacity

Benefits for Segment # 1 Direction A-B	[From (10) in Form BB2]	*$1,168,238*	(1)
Benefits for Segment # 1 Direction B-A	[From (10) in Form BB2]	*$18,937,185*	(2)
Benefits for Segment # 2 Direction A-B	[From (10) in Form BB2]	*$0*	(3)
Benefits for Segment # 2 Direction B-A	[From (10) in Form BB2]	*$550,376*	(4)
Benefits for Segment # 3 Direction A-B	[From (10) in Form BB2]	*$1,280,569*	(5)
Benefits for Segment # 3 Direction B-A	[From (10) in Form BB2]	*$197,805*	(6)
Benefits for Segment # 4 Direction A-B	[From (10) in Form BB2]	*$0*	(7)
Benefits for Segment # 4 Direction B-A	[From (10) in Form BB2]	*$0*	(8)
Benefits for Segment # 5 Direction A-B	[From (10) in Form BB2]	*$0*	(9)
Benefits for Segment # 5 Direction B-A	[From (10) in Form BB2]	*$0*	(10)
	Total (1) to (10)	*$22,134,174*	(11)

Enter Total in millions in Form BB (User Benefits Summary Table).

FORM CC. Safety Benefits Worksheet

Project/Alternative Name Lincoln Avenue-Academy Blvd corridor

C1. Enter analysis year and decision-making year from UI.

Analysis Year 2020 **Decision-Making Year** 1998

C2. # of fatalities per year under the No-Build and Alternative scenarios from Form M.

	No-Build		Alternative	
Total fatalities/year	16.2	(1)	16.2	(2)

C3. Calculate change in fatalities due to Alternative. 0.0 (3)

(1)-(2)

C4. Fatalitiy risk default value. (March 1998) $4,200,000 (4)

C5. Update fatality risk value to decision-making year using consumer price index. (March 1998 CPI = 162.2). See Table R3.

Decision-making year CPI 162.2 (5)

Updated fatality risk value $4,200,000 (6)

(4)*(5)/162.2

C6. Calculate annual safety benefits of the alternative - in millions $. (A negative value means the alternative harms safety by its increase in fatalities

0.00

(6)*(3)

C7. Transfer annual safety benefit to Form EE Part 2, Net Social Benefits Table.

Form EE Part 2. Net Social Benefit Table

Project/Alternative Name: Lincoln Avenue-Academy Blvd corridor

Year	Date	User Benefits	Air Quaility Benefits	Safety Benefits	Capital Costs	M&O Costs	Net Social Benefits	Present Value NSB
0	1998	0.00	0.00	0.00	0.00	0.00	$0.00	$0.00
1	1999	0.00	0.00	0.00	0.00	0.00	$0.00	$0.00
2	2000	0.00	0.00	0.00	185.85	0.00	-$185.85	-$166.18
3	2001	0.00	0.00	0.00	185.85	0.00	-$185.85	-$160.10
4	2002	0.00	0.00	0.00	185.85	0.00	-$185.85	-$154.24
5	2003	0.00	0.00	0.00	185.85	0.00	-$185.85	-$148.59
6	2004	0.00	0.00	0.00	185.85	0.00	-$185.85	-$143.15
7	2005	1.34	0.00	0.00	0.00	5.65	-$4.31	-$3.20
8	2006	1.82	0.00	0.00	0.00	5.65	-$3.83	-$2.74
9	2007	2.31	0.00	0.00	0.00	5.65	-$3.34	-$2.30
10	2008	2.79	0.00	0.00	0.00	5.65	-$2.86	-$1.90
11	2009	3.28	0.00	0.00	0.00	5.65	-$2.37	-$1.52
12	2010	3.76	0.00	0.00	0.00	5.65	-$1.89	-$1.16
13	2011	5.60	0.00	0.00		5.65	-$0.05	-$0.03
14	2012	7.43	0.00	0.00		5.65	$1.79	$1.02
15	2013	9.27	0.00	0.00		5.65	$3.62	$1.99
16	2014	11.11	0.00	0.00		5.65	$5.46	$2.90
17	2015	12.95	0.00	0.00		5.65	$7.30	$3.73
18	2016	14.78	0.00	0.00		5.65	$9.13	$4.50
19	2017	16.62	0.00	0.00		5.65	$10.97	$5.20
20	2018	18.46	0.00	0.00		5.65	$12.81	$5.85
21	2019	20.30	0.00	0.00		5.65	$14.65	$6.45
22	2020	22.13	0.00	0.00		5.65	$16.48	$6.99
23	2021	27.79	0.00	0.00		5.65	$22.14	$9.04
24	2022	33.44	0.00	0.00		5.65	$27.79	$10.94
25	2023	39.09	0.00	0.00		5.65	$33.44	$12.68
26	2024	44.75	0.00	0.00		5.65	$39.10	$14.28
27	2025	50.40	0.00	0.00		5.65	$44.75	$15.75
28	2026	56.05	0.00	0.00		5.65	$50.40	$17.09
29	2027	61.71	0.00	0.00		5.65	$56.06	$18.31
30	2028	67.36	0.00	0.00		5.65	$61.71	$19.42
31	2029	73.01	0.00	0.00		5.65	$67.36	$20.42
32	2030	78.67	0.00	0.00		5.65	$73.02	$21.33
33	2031	78.67	0.00	0.00		5.65	$73.02	$20.55
34	2032	78.67	0.00	0.00		5.65	$73.02	$19.79
35	2033	78.67	0.00	0.00		5.65	$73.02	$19.07
36	2034	78.67	0.00	0.00		5.65	$73.02	$18.37
Present Value		$339.9	$0.0	$0.0	$772.3	$77.1	($509.4)	($509.4)
Annual Value		$17.7	$0.0	$0.0	$40.3	$4.0	($26.6)	($26.6)
Perpetuity Value		$466.4	$0.0	$0.0	$1,059.4	$105.8	($698.9)	($698.9)

* Decision-Making Year

** Difference in yearly User Costs between No-Build and Alternative from MOE Form L

Benefits and Cost are in millions $

Present Value is based on the Interest Rate on Form EE-1, as is Perpetuity Value

Annual Value is based on the Interest Rate and Annualization Period on Form EE-1

Appendix

3

Annotated Bibliography

1. Eubanks, Larry S. and Mueller, Michael J. (1998). ‘Safety Benefit-Cost Estimates’, Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study, Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

   Synopsis:
   This technical paper discusses considerations about transportation safety as used in efficiency analysis and provides the basis for a calculation methodology for safety benefits. The concept of the value of fatality risk is explained.

2. Eubanks, Larry S. and Mueller, Michael J. (1998). ‘Transportation Economic Benefits’, Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study. Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

   Synopsis:
   This technical paper explains economic benefits of transportation as used in efficiency analysis and provides the basis for calculating estimates of benefits for projects that involve a new mode or that increase capacity of existing modes. It also discusses benefits in situations involving congestion considerations.

3. Eubanks, Larry S. and Mueller, Michael J. (1997). ‘Notes on the Booz-Allen Mobility Index’, Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study. Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

   Synopsis:
   This paper provides some analysis of the Booz-Allen Mobility Index that helps one understand the potential usefulness of the index with respect to the Common Performance Measures research.

4. Eubanks, Larry S. and Mueller, Michael J. (1998). ‘The Meaning of Efficiency’, Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study.

Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

Synopsis:
This technical paper describes the meaning of efficiency in order to minimize potential misunderstanding of the economic efficiency analysis used in the research, as well as to provide an adequate foundation for understanding the role which efficiency and benefit-cost analysis can play in transportation planning.

5. Khan, S.I. and Welle, M. (1997). 'A Review of Travel Demand Elasticities', Prepared for the Colorado Department of Transportation as supporting document for the Development of Common Performance Measures to Evaluate Transportation Systems Investments Across Modal Lines. Colorado TransLab, Department of Civil Engineering, University of Colorado at Denver.

   Synopsis:
   Projections of future travel demand and the effects of various transportation alternatives on travel patterns are an essential part of this evaluation process. One method to estimate travel demand is to use direct and cross-elasticites available in the literature. This paper reviews transportation elasticities developed through various studies, but these elasticities represent situations unique to a particular study. For instance, some elasticities categorize the response to price changes by trip purpose- others by trip length or travel time. To apply elasticities to forecast travel demand, an understanding of the details involved in the development of the elasticity is necessary. This overview attempts to provide some background information on transportation elasticities.

6. Khan, S.I., Awad, W. and Robles, J. (1998). 'Estimating Crashes and Fatalities', Prepared for the Colorado Department of Transportation as supporting document for the Development of Common Performance Measures to Evaluate Transportation Systems Investments Across Modal Lines. Colorado TransLab, Department of Civil Engineering, University of Colorado at Denver.

   Synopsis:
   This report presents a discussion on the methodology to estimate number of crashes and fatalities for a corridor investment study or a regional transportation plan, for highway and transit modes.

7. Khan, S.I., Eubanks, L.S., Mueller, M., Van Lauwe, E., and Joy, C. (1997). 'Common Performance Measures to Evaluate Transportation System Investments Across Modal Lines for Rural and Small Urban TPRs'. Presented at the 1997 Transportation Research Board Annual Meeting, Washington, D.C.

   Synopsis:
   This paper is a progress report on the Common Performance Measures - Multi-modal Research Study.

8. Khan, S.I., Eubanks, L.S., and Robles J. (1999). 'An MOE Index to Evaluate Multimodal Transportation Alternatives for Corridor Investment Studies'. Submitted for publication to the Transportation Research (part A) journal.

Synopsis:
This report presents a discussion of the methodology to develop a multi-criteria ordinal index to rank alternatives or projects.

9. Mueller, Michael J. and Eubanks, Larry S. (1997). 'Air Pollution Benefit-Cost and MOE Estimates', Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study. Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

   Synopsis:
   The purpose of this technical paper is to explain the role of air polluting emissions in the economic efficiency analysis of transportation plans, and to define a methodology for computing the effect of changes in emissions on the net social benefit of transportation projects at the sketch planning level. It also defines and discusses a measure of effectiveness for air quality considerations.

10. Mueller, Michael J. and Eubanks, Larry S. (1997). 'Efficiency Analysis and Full Cost Mockup', Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study. Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

    Synopsis:
    This technical paper illustrates, through a hypothetical and simple case study, the use of economic efficiency to analyze a multi-modal transportation planning decision-making situation. It also shows a full cost analysis of the same case study and compares the two types of analysis.

11. Mueller, Michael J. and Eubanks, Larry S. (1997). 'Transportation Economic Costs and Discounting in Economic Efficiency Analysis', Prepared for CDOT Research Contract Common Performance Measures - Multi-modal Research Study. Community, Environmental and Economic Development Analysis Program, Center for Community Development and Design, University of Colorado at Colorado Springs.

    Synopsis:
    This technical paper discusses the types of economic costs associated with transportation projects in terms of the meaning of costs as used in economic efficiency analysis. It also explains procedures followed in using economic costs, discounting, and discount rates in calculating net social benefits.

12. Robles, J. and Khan, S.I. (1998). 'Mobility and Travel Demand', Prepared for the Colorado Department of Transportation as supporting document for the Development of Common Performance Measures to Evaluate Transportation Systems Investments Across Modal Lines. Colorado TransLab, Department of Civil Engineering, University of Colorado at Denver.

    Synopsis:
    As part of an effort to develop measures to evaluate transportation system investment across modal lines, the CPM team conducted a review aimed at identifying practical, simplified

techniques for travel demand forecasting and assessing their applicability to this research project. The report reviews travel demand modeling techniques and procedures as it pertains to the analysis of demand for corridor investment studies as well as more simplified analyses at the TPR level.

INSTRUCTION FOR ACCESING CPM WORKSHEETS

The attached floppy disk contains three files needed to use the CPM analysis tools—two Excel spreadsheets and a Word file. **It is highly recommended that the user copy all three files onto the user's hard drive and keep the floppy disk as a backup copy.**

The "Userinput.doc" Word file can be used to insert required data to calculate measures of effectiveness and to perform economic efficiency analyses for the corridor to be evaluated. The user may also choose to print the tables in this file to fill the information manually.

The "Manual MOEs.xls" Excel file can be used to print worksheets templates to perform manual analyses. All templates can be sent to the printer in Excel by pulling down the "View" menu and selecting "Print Manager-Print All".

The "Automated_MOEs.zip" file is a compressed Excel file that is used to perform automated analyses as well as sensitivity evaluations. This file will decompress to a 1.8 MB spreadsheet named Automated_MOEs.xls. All required data to perform a corridor analysis can be entered in the first worksheet of this file. This "Data" worksheet requires a more complete data input than the one needed to fill the tables in the "Userinpt.doc" file.

REPORT PUBLICATION LIST
CDOT RESEARCH

99-1 Colorado Rockfall Simulation Program Update
99-2 Effects of Magnesium Chloride on Asphalt Pavements: Quick Study
99-3 Effects of Geometric Characteristics on Interchanges on Truck Safety
99-4 Initial Curing of Portland Cement Concrete Cylinders
99-5 Evaluation of Design/Build Practices in Colorado
99-6 Improving Colorado Transportation through Investigation and Innovation: Status Report on Research Activities
99-7 Common Performance Measures Practitioner's Guidebook
99-8 Cracking in Bridge Decks: Causes and Mitigation

98-1 I-76 Truck Study
98-2 HBP Pilot Void Acceptance Projects in Region 2 in 1997
98-3 1997 Hot Bituminous Pavement QC for Day Pilot Project with Void Acceptance
98-4 Hot Bituminous Pavement QC & QA Project Constructed in 1997 Under QPM2 Specification
98-5 Final Report Evaluation of Iowa Vacuum Tester
98-6 Simulation of 12 High Geosynthetic Reinforced Retaining Walls Under Surcharge Loading by Centrifuge Testing
98-7 Colorado Study on Transfer and Development Length of Prestressing Strand in High Performance Concrete Box Girders
98-8 Particulate Matter from Roadways
98-9 Evaluation of Design Build Practice in Colorado - Construction Report
98-10 Whitetopping Thickness Design in Colorado

97-1 Avalanche Forecasting Methods, Highway 550
97-2 Ground Access Assessment of North American Airport Locations
97-3 Special Polymer Modified Asphalt Cement (Final Report)
97-4 Avalanche Detection Using Atmospheric Infrasound
97-5 Keyway Curb (Final Report)
97-6 IAUAC - (Interim Report)
97-7 Evaluation of Design-Build Practice in Colorado (Pre-Construction Report)
97-8 HBP Pilot Void Acceptance Projects Completed in 1993-1996 (Interim Report)
97-9 QC & QA Projects Constructed in 1996 Under QPM2 Specifications (Fifth Annual Report)
97-10 Loading Test of GRS Bridge Pier and Abutment in Denver, CO

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97-11 Faulted Pavements at Bridge Abutments

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96-3 The Role of Facing Connection Strength in Mechanically Stabilized Backfill Walls
96-4 Revegetation of MSB Slopes
96-5 Roadside Vegetation Management
96-6 Evaluation of Slope Stabilization Methods (US-40 Berthod Pass) (Construction Report)
96-7 SMA (Stone Matrix Asphalt) Colfax Avenue Viaduct
96-8 Determining Asphalt Cement Content Using the NCAT Asphalt Content Oven
96-9 HBP QC & QA Projects Constructed in 1995 Under QPM1 and QPM2 Specifications
96-10 Long-Term Performance of Accelerated Rigid Pavements, Project CXMP 13-006-07
96-11 Determining the Degree of Aggregate Degradation after Using the NCAT Asphalt Content Oven
96-12 Evaluation of Rumble Treatments on Asphalt Shoulders

95-1 SMA (Stone Matrix Asphalt) Flexible Pavement
95-2 PCCP Texturing Methods
95-3 Keyway Curb (Construction Report)
95-4 EPS, Flow Fill and Structure Fill for Bridge Abutment Backfill
95-5 Environmentally Sensitive Sanding and Deicing Practices
95-6 Reference Energy Mean Emission Levels for Noise Prediction in Colorado
95-7 Investigation of the Low Temperature Thermal Cracking in Hot Mix Asphalt
95-8 Factors Which Affect the Inter-Laboratory Repeatability of the Bulk Specific Gravity of Samples Compacted Using the Texas Gyratory Compactor
95-9 Resilient Modulus of Granular Soils with Fine Contents
95-10 High Performance Asphalt Concrete for Intersections
95-11 Dynamic Traffic Modeling of the I-25/HOV Corridor
95-12 Using Ground Tire Rubber in Hot Mix Asphalt Pavements

REPORT PUBLICATION LIST
CDOT RESEARCH

95-13 Research Status Report
95-14 A Documentation of Hot Mix Asphalt Overlays on I-25 in 1994
95-15 EPS, Flowfill, and Structure Fill for Bridge Abutment Backfill
95-16 Concrete Deck Behavior in a Four-Span Prestressed Girder Bridge: Final Report
95-17 Avalanche Hazard Index for Colorado Highways
95-18 Widened Slab Study

94-1 Comparison of the Hamburg Wheel-Tracking Device and the Environmental Conditioning System to Pavements of Known Stripping Performance
1-94 Design and Construction of Simple, Easy, and Low Cost Retaining Walls
94-2 Demonstration of a Volumetric Acceptance Program for Hot Mix Asphalt in Colorado
2-94 The Deep Patch Technique for Landslide Repair
94-3 Comparison of Test Results from Laboratory and Field Compacted Samples
3-94 Independent Facing Panels for Mechanically Stabilized Earth Walls
94-4 Alternative Deicing Chemicals Research
94-5 Large stone Hot Mix Asphalt Pavements
94-6 Implementation of a Fine Aggregate Angularity Test
94-7 Influence of Refining Processes and Crude Oil Sources Used in Colorado on Results from the Hamburg Wheel-Tracking Device
94-8 A Case Study of concrete Deck Behavior in a Four-Span Prestressed Girder Bridge: Correlation of Field Test Numerical Results
94-9 Influence of Compaction Temperature and Anti-Stripping Treatment on the Results from the Hamburg Wheel-Tracking Device
94-10 Denver Metropolitan Area Asphalt Pavement Mix Design Recommendation
94-11 Short-Term Aging of Hot Mix Asphalt
94-12 Dynamic Measurements on Penetrometers for Determination of Foundation Design
94-13 High-Capacity Flexpost Rockfall Fences
94-14 Preliminary Procedure to Predict Bridge Scour in Bedrock (Interim Report)