9. EVALUATION OF ALTERNATIVES

9.1 Introduction

"There 's small choice in rotten apples."

- from The Taming of the Shrew. Act i. Sc. 1.

by William Shakespeare

The nature of project planning – a detailed assessment of complex project alternatives in several technical aspects – risks an overabundance of information that loses its usefulness in decision-making. The evaluation of alternatives is a critical part of alternatives analysis, and of a Draft Environmental Impact Statement (DEIS), in which the information is sifted and organized, and key differences between the alternatives are highlighted.

This chapter outlines a framework for this evaluation that attempts to structure the information in a way that can be understood by the many non-technical readers of the alternatives analysis and/or DEIS. It must be noted that the framework suggested here simply provides a skeleton on which the evaluation is built. The goals, objectives, evaluation criteria, and discussions that make up the evaluation are necessarily determined by local officials, project staff, and the general public to focus on the local decisions that must be made.

9.2 Framework

There are several possible approaches that might be considered in the evaluation of major transit alternatives. They range form a free-form discussion of the options to a very structured and elaborate analysis complete with weighting and scoring of project attributes. A review of the evaluation efforts in previous alternatives analyses suggests two conclusions:

1. the lack of some basic structure for the evaluation risks a rambling, unfocused discussion that more often repeats rather than interprets the data; and

2. complex "weighting and rating" schemes tend to confuse rather than illuminate the issues and are often only tenuously related to the realities of decision-making.

As a result, some combination of the of structured analysis and informed judgment of local project staff and Technical Advisory Committees is advantageous to focus the evaluation on the key issues.

One suggested approach is to identify and display the key measures against which each alternative is evaluated in a small, one or two-page table. The evaluation measures should be quantitative rather than qualitative if at all possible. The goals and objectives of most transportation projects typically call for five classes of evaluation measures in a desirable project:

1. Effectiveness – the extent to which the project solves the stated transportation problems in the corridor;

2. Impacts – the extent to which the project supports economic development, environmental or local policy goals;

3. Cost-effectiveness (or cost-benefit analysis) – that the costs of the project, both capital and operating, be commensurate with its benefits;

4. Financial feasibility – that funds for the construction and operation of the alternative be readily available in the sense that they do not place undue burdens on the sources of those funds; and

5. Equity – that the costs and benefits be distributed fairly across different population groups.

The evaluation framework must be focused on the transportation problems identified during system planning, which guide the alternatives analysis. The evaluation method should begin with the statement of goals and objectives for transportation improvements. Where existing statements are available, they should be organized into the structure that will be used for the evaluation. Where new or revised statements of goals and objectives are prepared, the perspectives provide a useful starting point for identifying and organizing local concerns.

It is useful to recognize that the evaluation phase of project planning – and of any assessment of complex options – is not restricted to the final phase of the analysis. Rather, it is a continuous and comprehensive process within which the technical work proceeds. The process is continuous in that there is a series of decisions that must be made through the analysis – alignment variations, design standards, operating policies, etc. – that together shape the nature and performance of each alternative. It is comprehensive in that the final evaluation of an alternative considers a broad range of criteria – transportation, environment, costs, finances, etc. – that require a broad perspective in the assessment of design decisions. Clearly, the ongoing decision-making should be carried out with regard to its ultimate impact on the evaluation of each alternative.

It is also important to reemphasize that the evaluation is primarily focused on local decision-making. While this should be obvious, particularly for projects that are not subject to FTA's New Starts evaluation and rating process, there have been cases in which the entire evaluation has focused on "qualifying" for Federal funding rather than on identifying transportation needs and solutions. Emphasis on the Federal decision is not consistent with the intent or nature of FTA's New Starts program. The FTA Final Rule for Major Capital Investments recognizes that legitimate differences often exist between the local and Federal views of major transit projects. It specifically identifies the Federal interest in transit and outlines the standards against which funding proposals will be measured. The intention is that local officials examine the transit alternatives against their own objectives, so that an agreement can be reached on the aspects of a project that are consistent with Federal goals (and attractive for Federal investment) and those that are primarily local objectives that should be funded locally. Therefore, the evaluation process should consider all perspectives from which the alternatives will be examined.

9.3 Understanding the Problem

The evaluation measures chosen to evaluate the relative merits of transportation alternatives spring directly from the local problems the alternatives analysis is designed to solve. While many transportation projects have similar objectives, such as improved mobility and accessibility and economic development, local conditions should drive the development and evaluation of alternatives.

Local conditions may focus the evaluation on environmental concerns, capacity constraints, congestion relief, social policy goals, mobility of transit dependent populations, land use impacts, or any other local concern. The decision to select a project as the locally preferred alternative should spring from local needs and concerns rather than the evaluation criteria used for the federal funding decision.

However, the conduct of the alternatives analysis where a fixed guideway transit investment could become the locally preferred alternative should produce the inputs required for the federal rating and evaluation process to avoid the possibility that significant new work would be required before entering PE. The measures used in the federal evaluation for New Starts projects is found in *Reporting Instructions for the Section 5309 New Starts Criteria*, published every year by the Federal Transit Administration.

9.4 Identifying Measures

The measures selected to guide the evaluation of the alternatives should be focused on solving the specific problems in the corridor. Most of the commonly used measures are discussed in the following sections and fall under the general categories of transportation effectiveness, impacts, cost-effectiveness, financial feasibility and equity.

There are several considerations in the selection of evaluation measures related to the assessment of alternative investments:

1) *The measures should be developed early in the analysis with appropriate input from local decision-makers.*

The review is an obvious step to ensure the relevance and usefulness of the information. The evaluation methodology should be a high priority item in the early stages of the analysis. Development of a written explanation of the evaluation process is often the catalyst for local officials to come to grips with the specific measures that are of importance for local decision-making.

2) *The measures should be comprehensive in that they address all of the stated objectives, but they should be structured to avoid simple restatements of the same benefits.*

Many potential effectiveness and impact measures are interrelated. In some cases, there is good reason to include measures of the same impact that portray the impact from different perspectives. For example, the increased development potential of an area may be due primarily to the improvement in transit accessibility to that site. While including both measures of accessibility and measures of development potential double-counts some benefits, both may be of sufficient interest to warrant their use in the analysis. This is in contrast to the subsequent cost-effectiveness analysis where double-counting the same benefits would be an error. In other cases, two candidate measures can be purely redundant. For example, it is unnecessary to include both “total transit trips” and “transit trips diverted from autos” since the second measure is a direct mathematical derivation from the first.

3) *To the extent possible, the measures should quantify the impacts rather than express subjective judgments on the nature of the impact.*

Many of the important objectives of an improvement can be difficult to quantify and the consequent temptation is to use subjective evaluation measures: significant or not significant, desirable or not desirable, and so forth. However, it is usually more useful to provide measurements rather than judgments to local officials and the public. There is an adage to the effect that the relocation of a single residence for a major project is not “significant” unless it is your residence. Useful quantified measures can usually be identified for most objectives. For example, the impacts of street closings on neighborhoods can be addressed with such measures as the number of local streets closed to traffic and the number of residences and business.

4) *The measures should provide the proper perspective on the magnitude of the impacts.*

Many of the impacts of a transportation improvement occur in terms of numbers that are large in an absolute sense but are relatively small when placed in perspective. For example, travel time savings of 1,000 hours a day represents 3 minutes per trip when spread over 20,000 transit trips. However, 1,000 hours is only 14 seconds per trip if spread over 250,000 drivers, which is not likely to be noticed. Also, the relocation of one million square feet of new office space to station areas may appear quite significant when presented by itself, but is more meaningful when also shown as the percentage (say three percent) of total development expected in the corridor over the study period. Similarly, pollutant reductions expressed in terms of thousands of pounds per day is misleading in terms of region-wide air quality impacts if the reduction constitutes a tiny fraction of total emissions in the region.

5) *Finally, discussion of the measures should reflect the magnitude of differences in the measures compared to the likely error levels they may contain.*

Varying degrees of uncertainty exist in all information used in project planning. The presentation of evaluation measures should be accompanied by a well-written discussion that both highlights the major differences between alternatives and indicates where the differences are small given the levels of uncertainty. Minor differences in transit ridership, for example, are usually within the error of the estimates.

Within these general guidelines, the identification of specific measures depends only on the locally identified goals and objectives, together with the judgment of local analysts and officials on the most useful ways of portraying the relative merits and trade-offs involved with each alternative. The following sections describe the range of evaluation measures commonly used to evaluate alternatives.

9.4.1 Effectiveness

Goals and objectives related to effectiveness both establish the reasons for which major transit improvements are being considered, and identify ancillary concerns that constrain the options. Transportation concerns – congestion, mobility, etc. – are usually the primary basis for consideration of a major action in the corridor.

Effectiveness measures may include, but are not limited to:

- travel costs/user benefits;

- transportation system capacity;
- accidents and incidents;
- level of service/volumes/trips on key facilities;
- accessibility measures (number of jobs or households within specific travel times to destinations by mode);
- system redundancy (travel reliability measures); and
- any other quantifiable transportation system impact.

These effectiveness measures, with the exception of accidents and incidents, are generally the direct result of the travel demand forecasting process. Most of these measures are an output of the regional travel demand model and their calculation covered in Part I Chapter 6 *Interpretation and Use of Travel Forecast Data* of this guidance.

9.4.2 Impact Measures

Transportation projects create numerous secondary impacts that must typically be evaluated during alternatives analysis. The predominant secondary impacts that are commonly used to evaluate transportation alternatives are environmental considerations and economic development impacts. In some cases, these impacts are the focus of the locally defined evaluation if they respond directly to the primary problem in the corridor.

The menu of impact measures generally includes, but is not limited to:

- Regional economic impacts:
    - jobs added;
    - tax base;
    - redevelopment of distressed areas;
    - national competitive standing; and
    - distribution of economic impacts across jurisdictions.
- Effects on the human environment:
    - residential/business/farm property takings;
    - impacts on nearby residences/businesses/farms;
    - community impacts of facilities, disruption or barriers;
    - parks and recreation areas - number, acreage or proximity effects; and
    - historic and archeological sites – number, acreage, or proximity effects.
- Effect on the natural environment:

  - streams, wetland, floodplains – number, nature, likely impacts, implications for approvals;
  - water quality;
  - aquifers;
  - rare, threatened or endangered species and related habitat;
  - forests; and
  - air quality.

- Consistency with local or state plans and policies:
  - comprehensive plans;
  - proximity and impact on priority development areas; and
  - land use and zoning policies.

9.4.3 Comparison of Benefits and Costs

Two common methods are used to evaluate the benefits of transportation improvements in the context of their relative costs. These are cost-effectiveness and cost-benefit analysis. These measures help identify the most efficient use of public resources to achieve the projected transportation benefits or other impacts.

Three primary issues arise in any attempt to fashion cost-benefit measures or measures of cost-effectiveness:

- the overall structure of the analysis and resulting measures;
- the baseline against which the alternatives are compared; and
- the measures used to quantify costs and benefits.

FTA has identified an approach used to support Federal decision-making. Local officials may choose a different approach, so long as it is technically sound and can accurately measure project merit relative to the purpose and need for the project. The results of both approaches may be presented in the environmental document produced by the study.

9.4.3.1 Structure of the Evaluation of Benefits and Costs

A major question in evaluation is the way in which the trade-off between costs and benefits is portrayed. One option is the standard cost-effectiveness approach in which a required performance level is stated and alternatives are evaluated for the least cost option that achieves this performance. This approach is very useful where the performance requirements are easily stated and measured. Unfortunately for transportation planning, the objectives for urban transportation investments are usually so many, so varied, and perhaps so unclearly defined that they defy statement in terms of specific performance levels.

The conventional approach to comparing the costs and benefits of transportation investments is to estimate resource cost savings resulting from a proposed project relative to a baseline scenario. For instance, an investment in a new light rail transit system will create benefits for existing transit riders who take advantage of the new system and to those who switch from auto or HOV to the new rail line. These user benefits (costs) are generally:

- time-savings;
- out-of-pocket cost savings (parking, tolls, fares);
- vehicle operating cost savings (fuel, oil, tires, insurance, depreciation); and
- safety benefits (reduced accidents, injuries and fatalities).

In addition to user benefits (costs), there are a several categories of benefits (costs) that accrue to society at large rather than to users of the transportation system. These so-called non-user benefits (costs) include, but are not limited to:

- environmental benefits (costs); and
- resource savings for transportation operations and maintenance (infrastructure unit costs).

These benefits and costs are driven primarily by changes in travel demand and the generalized cost of travel caused by the project. Each of the benefit measures can usually be related in some way to changes in travel demand and the relative costs of each unit of that demand.

A cost-benefit analysis requires each of these impacts to be monetized to compare the value of the project to its costs. Monetizing these benefits is very difficult and occasionally controversial since this step requires assigning a value to, for instance, a ton of a particular pollutant or greenhouse gas and valuing a person's life and time.

A cost-benefit analysis begins with forecasts of total monetized benefits and annual capital and operating and maintenance costs for the evaluation period which is typically 20 years, but can be longer due to the long useful life of most transportation investments. These streams of benefits and costs are discounted to reflect the time value of money and summed to reflect the total present value of the stream of costs and benefits. The discount factor is $1/(1+i)^n$ where i is the discount rate and n is the year of analysis. Traditionally the discount rate is between 7% and 10%.

The most common cost-benefit measures are

1. Net Present Value (NPV) = [PV of Benefits ($) – PV of Costs ($)]
2. Internal Rate of Return (IRR) = Discount rate at which NPV=0

3. Benefit/Cost ratio (B/C) = PV of Benefits ($)/PV of Costs ($)

Assuming all benefits and costs are counted, the project with the highest (positive) NPV is the preferred project. The alternative with the highest Internal Rate of Return is the most economically efficient project, but may not be preferred if it does not adequately solve the transportation problem. The B/C ratio expresses the dollars of benefit per dollar of cost and will result in the same ranking as the NPV measure. A B/C ratio over 1.0 implies that benefits exceed costs.

Unfortunately, all of the benefits and costs cannot be counted so the highest NPV may not be the preferred project. There are numerous impacts of transportation project alternatives that are very difficult or impossible to measure and the process of attaching monetary values to several of the known impacts is uncertain at best. Transportation projects long term effect on land use; transit service reducing auto-ownership rates; and the value of transit service as a back-up mode, among others have been suggested as benefits or costs of transportation investments that are very difficult or impossible to measure let alone value.

Other even more vexing factors might be the distribution of benefits and costs to low-income or mobility-constrained communities, access to jobs and welfare to work initiatives, and economic development benefits. These types of benefits represent a transportation investment's contribution to social policy goals as opposed to transportation user benefits. There is no clear way to monetarily value these benefits.

Another option is to select a measure of benefits that captures, both directly and indirectly, as large a share of the expected benefits as possible without trying to express the benefits in monetary terms. A ratio between this measure and a measure of costs then provides an index of the cost-effectiveness of an alternative. For example, an index expressed in terms of cost-per-unit-of-benefit can be computed as:

Cost-Effectiveness Index = Cost measure ($)/Benefit measure

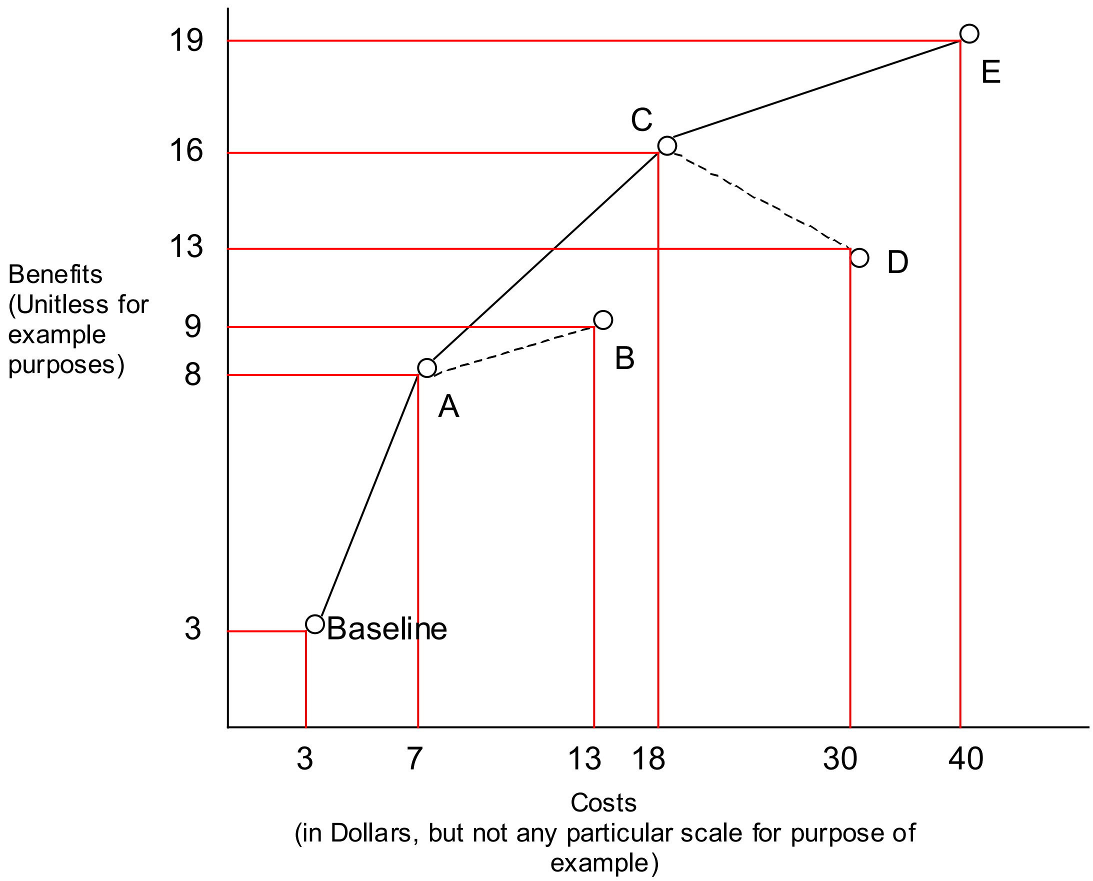
where the benefit measure is not expressed in terms of dollars. Since many benefits and costs of transit and highway projects are unknown and unknowable, it is possible to calculate cost-benefit measures that indicate negative net benefits, even though the alternatives may be beneficial. Cost-effectiveness measures are not expressed in terms of absolute economic benefit, but in the cost per unit of the benefit being measured. The alternative with the lowest cost per unit of benefit is most cost-effective **at providing that benefit**. The most cost-effective project is not necessarily the preferred option. For instance, a very cost-effective project may be identified that does not come close to solving the primary transportation problem in a given corridor and should not be the preferred alternative.

Since cost-effectiveness explicitly focuses on single benefit categories, the analysis should be explicit about what the cost-effectiveness index is measuring. Options may include measures like: cost-effectiveness at reducing travel time; cost-effectiveness at increasing transit ridership; cost-effectiveness at increasing accessibility; cost-effectiveness at concentrating economic development in a corridor; or cost-effectiveness at reducing harmful emissions.

Regardless of the specific method used, it is clear that the approach should examine the incremental costs and benefits of alternatives. One illuminating approach is to array alternatives graphically in terms of their costs and benefits. Figure 9-1 reveals three types of alternatives. First, alternatives A, C, and E define the cost-benefit frontier with increasing levels of investment. It represents the best possible return for each level of investment with decreasing returns as costs rise. Alternative B is not on the frontier, but provides additional benefits compared to alternative A. If budget realities preclude implementing alternative C, alternative B may be a viable fallback option. Alternative D is clearly a poor option since it provides fewer benefits than C at higher cost.

This graphical analysis suggests a method for computing measures of incremental cost-effectiveness. Each alternative is compared to the next lower cost option that lies on the frontier as summarized in the table below Figure 9-1.

Figure 9-1: Graphical Analysis of Incremental Costs and Benefits



Alternative	Compared to	Cost-Effectiveness ΔCosts/ΔBenefits
A	Baseline	4/5 = $.80
B	A	6/1 = $6.00
C	A	11/8 = $1.37
D	C	**NA** since D cost more than c and has fewer benefits.
E	C	22/3 = $7.33

The measure for incremental cost effectiveness for alternative n, where alternative m is the next lower cost alternative on the frontier, is as follows:

$$Cost\_Effectiveness_n = \frac{\Delta Incremental\_Costs_{n-m}}{\Delta Incremental\_Benefits_{n-m}}$$

Arraying alternatives according to their next lower cost alternative allows the analyst to construct a cost-effectiveness frontier and clearly see how the rate of benefits per unit of cost tends to decline as costs increase. This is the principle of diminishing returns. The TSM alternative should be the most cost-effective alternative relative to the no-build. If the TSM alternative is not the most cost-effective alternative relative to the no-build, the TSM alternative is poorly specified and needs to be re-defined to be a cost-effective alternative.

The build alternatives can then be evaluated against a baseline alternative, which allows each build alternative to be ranked according to their cost-effectiveness. The preferred alternative is not necessarily the alternative with the lowest cost per unit of benefit. If this were the case, the TSM would always be the preferred alternative by its definition.

Cost-effectiveness must be balanced with effectiveness and impact measures as well as financial and equity considerations. Cost-effectiveness is one piece of information that decision-makers must weight to determine the locally preferred alternative.

One way to think of cost-effectiveness measures is as an investment rate of return. An investor may be confronted with a range of investments that can be ranked according to their expected rate of return with each added increment of cost likely providing diminishing returns. However, the wise investor does not stop investing at the level that produces the highest rate if the next level of investment also produces an attractive rate. Investors generally have a "hurdle" rate of return and should continue investing until any additional investment fails to reach the "hurdle", subject to the availability of funds.

Just like an investor, local decision-makers should have some idea about what they are willing to pay to achieve a unit of transportation benefits. The cost-effectiveness analysis should identify the set of alternatives that provide an attractive rate of return on the funds dedicated to build operating and maintain the project. Cost-effectiveness is not the factor that determines the choice of a locally preferred alternative.

9.4.3.2 Choice of a Baseline Alternative

All comparisons of costs and benefits necessarily begin with some baseline alternative that provides a starting point for the analysis. There are two candidates for use as a baseline: the No-Build and TSM alternatives. Much discussion has occurred on the merits of each option as the baseline. This section discusses the advantages of each and presents a recommendation.

Three advantages can be cited for using the No-Build alternative. First, it has intuitive appeal as a baseline since the alternative is usually defined as an extrapolation of current operating policies and improvement programs. Thus, it is a logical baseline on which all improvements will be based. Second, its use as the baseline makes clearer that the TSM alternative is real option for solving problems and is not simply an artificial construct invented to serve as a baseline. The TSM alternative therefore would be a more competitive alternative for consideration by local officials. Third, an evaluation that uses the No-Build as the baseline can detect proposed TSM alternatives that are not cost effective. Thus, errors in development of the TSM alternative can be identified and corrected so that the final definition of that option in fact represents an attractive, low-cost alternative.

The advantage of using the TSM alternative as the baseline is that it better isolates the benefits and costs of the major investment alternatives. In many cases, the TSM alternative presents an opportunity to identify improvements that are desirable **today**. Therefore, potentially large benefits are available from making changes in a No-Build alternative that is largely based on today's situation. Since these benefits are independent of any major investment, they should not be attributed to the guideway options. This problem is avoided if the TSM alternative serves as the baseline since the benefits produced by the TSM actions are not attributed to the Build alternative.

In FTA's view, the careful accounting of benefits possible with the TSM baseline is crucial in assessing cost-effectiveness or conducting a cost benefit analysis. While the TSM baseline is preferred, this conclusion is clearly a difficult choice between two reasonable options. Recognizing the arguments for using a No-Build baseline, it is important to treat the TSM alternative in a way that emphasizes its role as a real option, and that detects TSM alternatives that are not competitive. Two steps can be taken towards this end. First, the TSM alternative should be described simply as a viable, low-cost option. References to its role as a baseline should be made only where it is necessary in the cost-effectiveness analysis. Second, the TSM baseline should be treated only as another alternative that has both costs and benefits compared to the No-Build alternative.

Local decision-makers and project staff should understand that the purpose of the federal grant decision-making process is different from the local decision-making process. The federal process for providing New Starts mandates a particular set of evaluation criteria and a specific definition for a baseline alternative that focus on the federal interest in transit funding. The local issues and problems that the alternatives are designed to address may be very different from the federal interest and may demand different measures of project worth.

9.4.3.3 Quantification of Costs and Benefits

Given a structure and baseline for the assessment of cost-effectiveness or cost-benefit analysis, all that remains to be selected are the specific measures of costs and benefits. Calculations on the cost side are reasonably simple in that all measure s are expressed in a common unit – the dollar – and basic techniques of engineering economics are available to put one-time capital costs and recurring operating and maintenance cost on a common annual basis.

This section outlines a direct method for translating capital costs into their uniform annual equivalent. This annualized cost can then be summed with the operating cost estimated for the forecast year to represent the total annual cost of the alternative. Present value calculations used in cost-benefit analysis are also summarized.

The evaluation of the cost-effectiveness of each alternative requires that all evaluation measures (capital costs, operating costs, non-Federal funding, and user benefits) be expressed in annual terms. Since the capital cost estimate is expressed as a total expenditure of constant (base year) dollars or inflated year of expenditure dollars, it is necessary to compute an annual payment that would be equivalent to what is in reality a one-time expenditure of capital funds.

Direct Annualization of Capital Costs

The conversion of capital costs into an equivalent annual payment is easily accomplished with basic techniques of engineering economics. The approach requires only the estimated cost in constant dollars and the lifetime of each line item in the cost estimate, plus a discount rate that reflects the time-value of money. For each capital cost item, the annualized equivalent is computed through application of an annualization factor computed as:

Equation 9-1: $$AF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where

n = economic life;

i = discount rate.

The annualized cost of the line item is simply the total capital cost of that line item multiplied by its annualization factor. The summation of all annualized line item costs gives the overall annualized cost for the alternative.

For the evaluation of any project advanced for Federal funding, the traditional discount rate is 10 percent. Since this rate is used with costs expressed in constant dollars, it represents a rate of return net of inflation. A 10 percent return in this setting may appear somewhat higher than that commonly used in the private sector. This is done purposely provide a margin of safety in computing the cost-effectiveness of publicly funded projects whose merits are based on forecasts of such difficult-to-predict measures as transit ridership, time savings, and operating costs.

Table 9-1 summarizes values of the annualization factor for various economic lives. One indication from the table is that there is little variation in the annualization factor for economic lives exceeding 25 years. For example, the annualized value of a $100 million item over 25 years would be $11.0 million. The same item annualized over 40 years would have an equivalent annual cost of $10.2 million, a change of about 7 percent. This suggests that precise identification of economic lifetimes of various capital items is not critical to the evaluation. Therefore, standard assumptions are used for all computations of annualized costs in alternatives analysis.

Table 9-1: Assumptions of Economic Life

Capital Cost Element	Economic Life
Right-of-way	**100 years**
Right-of-way preparation (major grading, etc.)	**100 years**
Structures	**30 years**
Trackwork	**30 years**
Signals, electrification	**20 years**
Pavement, parking lots, grade crossings	**25 years**
Rail vehicles	**25 years**
Buses	**12 years**
Contingencies	**item-specific**
Engineering, construction management	**allocated**

The last two items are typically included as add-ons in the estimation of capital costs. In computing annualized costs, contingencies are easily dealt with since they are available on a line-item basis. However, add-ons for engineering and construction management are available only on a project-wide basis and mist be allocated to individual line items. As a simplifying assumption, the same factor used to compute the project-wide allowance for these costs is applied to each line item, giving it a share of the project's engineering and a management costs equal to its share to total capital costs. Table 9-2 depicts the annualization of capital costs for a sample alternative.

Figure 9-2: Annualization Factors

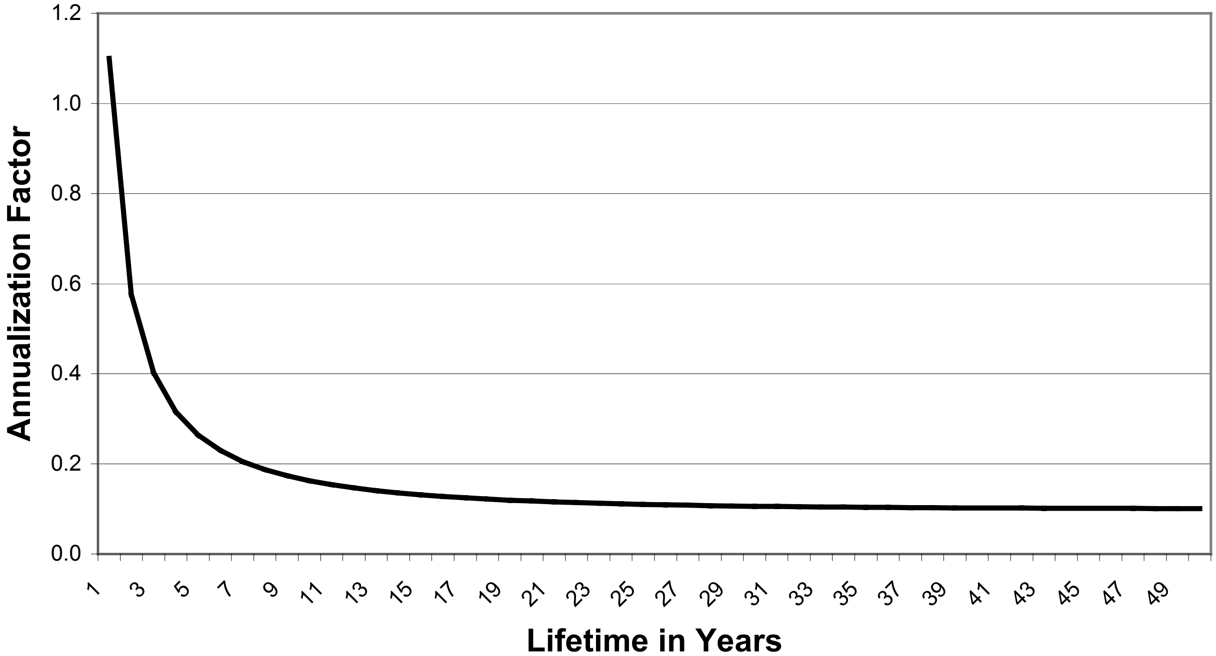


Table 9-2: Example: Annualization of Capital Costs

Corridor:	**Southwest**			
Alternative:	**10 Mile LRT, Subway**			
Discount Rate:	**10%**			
Item	**Cost**	**Lifetime**	**Annualization Factor**	**Annualized Cost**
Right-of-Way	$ 65,000	100	0.100	$ 6,500
Structures	$ 225,000	30	0.106	$ 23,868
Trackwork	$ 90,000	30	0.106	$ 9,547
Signals/Electrification	$ 75,000	30	0.106	$ 7,956
Vehicles				
Rail	$ 40,000	25	0.110	$ 4,407
Bus	$ 15,000	12	0.147	$ 2,201
Total	**$ 510,000**			**$ 54,480**

Present Value Calculations

The approach outlined above is different from what might be termed the classical approach to computing an annualized capital cost, an approach that was used in most alternatives analysis prior to 1984 and still used when preparing a cost-benefit analysis. The classical approach starts with a time stream of capital costs over a predefined analysis period – up to 50 years for major construction projects. Within this time stream, capital costs are assigned to specific years, both during the construction period and for any replacement costs in later years. The cost in each year is then converted to its present value with a present value factor computed as:

Equation 9-2: $$PV = \frac{1}{(1+i)^n}$$

where n and i are the project life and discount rate, respectively.

For cost-benefit analysis, the summation of the present values over the entire analysis period is, therefore, the present value of the project's capital and operating costs over its lifetime. This present value of costs is compared to the present value of benefits over the entire analysis period.

The present value calculation is the correct method for constructing the cost portion of the cost-benefit measures: NPV, Internal Rate of Return, and B/C ratio. This method is correct for cost-benefit analysis because both costs and benefits are expressed in present value dollars.

For cost-effectiveness, the cost measure is less clear. The annualized cost of the project could be calculated with an annualization factor computed with Equation 9-1, using the assumed 50-year project lifetime and expressed as a present value using Equation 9-2. This approach accurately reflects the lower annualized cost that results from construction costs over a construction period of several years. Expenditures that occur later in the period have a lower present value than these occurring in the first year and therefore contribute less to the annualized costs. As a result, the classical approach gives a more accurate portrayal of equivalent annual costs.

The problem with using this method to construct cost-effectiveness measures is that, while it correctly recognizes the scheduling of capital costs over time, it has usually been used in an analysis that ignores the scheduling of benefits. Typically, the capital cost stream has been discounted back to a present value, while benefits (ridership, time savings, user benefits…etc.) are fixed at their value in the forecast year. The error biases the analysis towards alternatives with longer construction periods since it discounts their out-year costs quite heavily but does not discount the delayed benefits. The error also invites game-playing with construction schedules, since stretching or delaying the construction period makes the project appear less expensive with no attendant decrease in benefits.

Two alternative approaches are available to correct this problem for cost-effectiveness calculations. The first, and "best," is to construct time streams of all items (costs, patronage, time savings) and discount everything to a present value. The second is to ignore the scheduling of capital costs, just as the scheduling of benefits have been ignored.

The "best" approach is superior in the sense that it provides the most accurate accounting of costs and benefits, and yields an evaluation closest to the true trade-off between the investment and its transportation returns. This approach recognizes that benefits from any project begin to accrue only after the construction period is completed. It also specifically examines the growth rates over time for such benefit measures as transit patronage, travel time savings, consumer surplus, and operating cost savings. Unfortunately, the results of this approach are highly dependent on assumptions (guesses) made for the out-years of the time streams of costs, ridership and time savings. Even with the heavy discounting of these out-year values, they are able to influence the indices significantly, particularly for projects that have relatively small benefits.

The local study team is free to choose the method that works best for their own application. The method that FTA uses to support the federal grant decision essentially ignores timing on both sides – costs as well as benefits. The need for FTA to fairly evaluate different projects around the country with very different schedules drives the selection of the cost annualization method. FTA does not want projects to "appear" preferable to potentially better projects simply based on their construction schedule or level of project development.

The FTA New Starts evaluation approach implicitly assumes that capital costs and benefits occur at the same time. Since the benefits always occur after the construction costs, there remains some understating of the relative costs of projects with long construction periods. This approach yields evaluation results that are somewhere between the old method and the "best" method.

Measuring Benefits

Calculations on the benefits side are made difficult by the wide range of benefits associated with major transit projects – congestion relief, improved travel times, fewer accidents/injuries/fatalities, energy conservation, pollutant reductions, economic development, and so forth. No single measure of benefits is readily apparent.

Since the major purpose of transit investments in improved mobility, it is clear that the most useful proxy measures will be travel related. There are several measures of travel impacts that might be considered for use as an overall indicator of benefits. Changes in total transit ridership, travel times, ridesharing, highway congestion, and so forth are all possible candidates. The challenge is to select a measure that represents, either directly or indirectly, the wide range of benefits and that avoids a systematic bias towards or against any particular kind of alternative.

Transportation System User Benefits. One potentially useful measure can be termed "user benefits", though it is more commonly called "consumer surplus" in microeconomic theory. It is computed simply as the aggregate difference in "user costs" between a pair of alternatives, summed over all existing and new users of the transportation system. User costs are defined in terms of a generalized price of transit, including both out-of-pocket costs – fares, parking fees at park/ride lots – and time costs – walking, waiting, riding, and transferring. Thus, this generalized price is a measure of the level of mobility provided by the transportation system to individual users, and total user benefits indicate the overall improvement in regional mobility provided by an alternative. Happily, an excellent measure of transit price is used routinely in the mode choice analysis done as part of travel demand forecasting. Thus, the evaluation can proceed using data already developed in the study. FTA's *Reporting Instructions for the Section 5309 New Starts Criteria* outlines the calculation of a measure of user benefits in terms of hours of travel time.

User Benefits as Proxy Measure. Obvious questions arise on the extent to which a single measure, no matter how broadly defined, can capture the wide variety of benefits resulting from a major transportation investment. To the extent that user benefits do not include all the benefits of a particular alternative, some may question whether user benefits is a sound basis for gauging cost effectiveness or for developing cost-benefit measures.

The potential problem with using user benefits as a proxy for total benefits of an alternative is minimal if the alternatives analysis is only concerned with transit alternatives. The direct benefits of a transit improvement are improvements in travel times and increases in transit ridership, and the indirect benefits are consequences of these mobility and ridership changes. For example, where significantly improved transit service attracts substantial numbers of new riders, there will be associated benefits – economic development impacts, lower energy consumption and pollutant emissions, and so forth – whose magnitude depends directly on the magnitude of the ridership gain and associated user benefits. Further, the analysis of user benefits accruing to different travel markets within a region can provide excellent indicators of improved mobility for the transit dependent and increased accessibility to employment locations. Therefore, when an alternatives analysis includes only transit alternatives, there is every reason to believe that the ranking of projects based on cost-effectiveness or cost-benefit measures would be exactly the same even if all benefits were incorporated into the cost-benefit or cost-effectiveness analysis.

Even such an indirect impact as economic development is related to changes in user benefits. The likelihood that a transit project will have significant impacts on development patterns is largely determined by its ability to provide significant increases in accessibility and ridership. As a result, a project with little or no service and ridership impacts will likely have similarly modest development impacts. Thus, the proxy measure does reflect, at least in a general sense, differences between alternatives in terms of their overall impacts on development. Development impacts at individual sites, of course, require site-specific analysis of changes in accessibility and other incentives for development.

The second key is that in most cases, the purpose of the evaluation is to rank alternatives against each other. This task requires only the ordering of projects according to their relative merits rather than calculation of their absolute merits. Since the transportation benefits of an alternative are proportional to overall benefits, the ordering of alternatives based on transportation benefits alone is very likely to be the same ordering that would result if the secondary benefits were measured as well. Consequently, the indirect measurement of secondary benefits is quite adequate for the purposes of the evaluation. Direct measurement of the secondary benefits would become critical only if the evaluation were designed to judge the absolute merits of each alternative – whether its total benefits exceed its costs.

Multimodal Considerations. The evaluation of multimodal alternatives adds a new wrinkle to the analysis since the secondary impacts of investments in different modes can be offsetting rather than complimentary. Many transportation planners presume that new freeways result in higher emissions while transit projects reduce them, added freeway capacity results in different development patterns than transit investments, travel via automobile results in higher accident/injury/fatality rates while transit is a relatively safer mode, and so on. For this reason, the analysis may not be able to rank the alternatives using user benefits as a proxy for total benefits when alternatives of different modes are compared to each other. Multimodal alternatives require an approach that considers multiple measures of project merit to allow decision-makers to weigh the broad impacts of each alternative.

In FTA's view, user benefits are superior to other candidate measure of the overall benefits of an alternative. This measure can be defined broadly so that it captures directly a large share of likely transportation benefits. It is also a good proxy measure of a wide range of indirect benefits, since many of the secondary impacts of a transportation improvement are directly dependent on the degree to which it increases mobility. Regarding the specific definition of the user benefits measure, FTA's view is that it should be defined as broadly as necessary to capture all expected travel benefits.

9.4.4 Summary of the Recommended Approach to Cost-Effectiveness Calculation

Cost-effectiveness can be adequately addressed with two measures that are based on a simple ratio between the costs of building and operating an alternative, and the user benefits accruing from that alternative. These measures are computed with the aid of a graphical representation of the costs and benefits of the alternatives, illustrated in Figure 9-1. The calculations use the TSM alternative as a baseline for the assessment.

The first measure is incremental in that it examines the cost-effectiveness of each alternative in comparison with the next less costly option:

$$\text{Incremental Cost-Effectiveness Measure} = \frac{\Delta\ \$CAP + \Delta\ \$O\&M}{\Delta\ \text{USER BENEFITS}}$$

Where the Δ's represent incremental costs and benefits between the pair of alternatives considered, and where:

$CAP	is total capital costs, annualized over the life of the project;
$O&M	is annual operating and maintenance costs; and
USER BENEFITS	is annual benefits, expressed in terms of hours of travel time, for all users of the transportation system.

This incremental measure can be expressed in terms of $/hour of user benefits. The second measure examines the cost-effectiveness of a build alternative relative to the TSM alternative, reflecting the total cost-effectiveness of alternative rather than the last increment only.

FTA's *Reporting Instructions for the Section 5309 New Starts Criteria* provides additional guidance on the calculation of project cost effectiveness.

9.5 Financial Feasibility

Part II Chapter 8 *Financial Planning for Transit* of this guidance outlines the financial analysis appropriate to this stage of project planning. The financial analysis establishes 1) the funding requirements for both the capital and operating costs of each alternative, 2) the projected revenues from existing sources of funds used to support transit, 3) the potential revenues from other possible funding sources in cases where existing resources are not sufficient, and 4) assesses of the feasibility of the alternative funding packages.

The task remaining for the evaluation of the alternatives is to use the measures of financial feasibility to examine the likelihood that sufficient existing and, where necessary, additional funding sources would be available to cover the capital and operating costs of each alternative. The selected measures should be a relatively few key indicators of financial impacts. Three kinds of indicators can be used in this analysis.

1. For existing sources that are dedicated entirely to transit, the surplus or deficit of projected funds compared to projected needs is likely the best indicator of financial capability.

2. For new sources, discussion of the steps necessary to develop the source is a primary concern. This discussion would identify the necessary major actions – referenda, local legislation, State legislation, etc. – and, to the extent possible, the likelihood of success given past experience with similar efforts. Levels of risk can be defined and assigned to each source as an indicator of its feasibility.

3. For new sources or for existing sources that are not dedicated entirely to transit, ratios can be constructed to illustrate the size of the transit requirement in comparison with various measures of financial capability. For example, where transit is currently funded as a budget line item of local government, a useful measure is the current and projected percentage of the total budget necessary for transit. This measure reflects the need for transit assistance, the total resources available to the local government, and the needs of other local governmental functions. A second example would be measures of the financial feasibility of value capture mechanisms that indicate the fractional change in profitability of development within a value capture district.

In sum, the evaluation of financial feasibility presents measures of the impact of projected transit assistance needs on existing and potential sources of funds. While the measures themselves are rarely conclusive indicators of financial feasibility, they help to define for local and federal decision-makers the financial context in which the selection of an alternative is made.

9.6 Equity

Equity issues (sometimes called environmental justice) are those concerned with the distribution of the costs and benefits of an alternative across the various subgroups in the region. Equity considerations generally fall within three classes.

1. The extent to which the transit investments improve transit service to various population segments, particularly those that tend to be transit-dependent;

2. The distribution of the costs of the project across the population through whatever funding mechanism is used to cover the local contribution to construction and operation; and

3. The incidence of significant environmental impacts.

Each of these classes of impacts should be pursued to the extent that they are identified as areas of concern by study team, local decision-makers or by other groups contacted through the study's public participation process. Where appropriate, there are analytical techniques available to quantify several measures of the distribution of costs and benefits. For the distribution of service improvements, the demographic data and transit network information developed in the travel forecasting work provide a wealth of data on service changes for individual market segments. Finally, the environmental analysis provides an inventory of likely impacts on neighborhoods, residences, and businesses that can be used to quantify the extent to which specific population groups would be adversely affected by any of the alternatives.

9.7 Trade-Off Analysis

Thus far, the evaluation has proceeded sequentially through five perspectives, examining each alternative in turn. The purpose of the trade-off analysis is to pull together the key differences among the alternatives across all of the perspectives. It is designed to take the broadest view possible, highlighting for decision-makers the advantages and disadvantages of each option and pointing out the key trade-offs of costs and benefits that must be made in choosing a course of action.

As in much of the evaluation, the content and approach to the analysis is dependent upon local goals and objectives and the nature of the alternatives. Perhaps the most important component of a successful trade-off analysis is its assignment to an analyst who is able to take a broad perspective on the purpose of the transportation improvement and the merits of the alternatives, and who has strong writing skills. Together with reviews by the Technical Advisory Committee, the analyst's insight and reasoning are indispensable to a result that aids local officials in the choice of an alternative.

Several examples can be used to illustrate the kinds of trade-offs that might be found in a set of alternatives. One frequently-found trade-off is that between effectiveness and cost-effectiveness. One alternative may yield a modest level of transit improvement at a highly cost-effective return on the investment, while a second may yield greater improvements at such a high cost that its overall cost-effectiveness is lower. In this case, the trade-off analysis should point out that the second alternative provides a higher level of benefits, but that the marginal benefits are purchased at a diminishing rate of return.

Another frequent example is the trade-off between effectiveness and financial feasibility. Often, the alternative providing the greatest improvements in transit service is also the most costly and would require a significant increase in the annual investment made by the local area. The trade-off analysis should highlight the additional commitment by the local governments – and possibly the equity implications of the means used to finance this commitment – necessary to implement this alternative.

The major task of the trade-off analysis, then, is to reduce (to the extent possible) the vast amount of information developed during the analysis to those essential differences between the alternatives. Its purpose is to frame the decision on a preferred alternative in terms of the advantages of choosing one option compared to the foregone advantages of the other options.

The recommended approach is to display key characteristics of the alternatives and the evaluation measures in clear tables that allow comparisons among alternatives within the context of their characteristics for each evaluation factor. A summary table that presents the highlights of the evaluation results should be prepared with the goal of presenting a one to two-page table highlighting the main trade-offs among the alternatives.

Some trade-off analyses have used purely qualitative judgments regarding the evaluation measures. Sometimes these are rated in terms of high, medium, and low or use "Harvey Balls" (e.g. comparison charts used by Consumer Reports™) to offer a qualitative assessment of each evaluation measure. FTA cautions against using these qualitative measures in the trade-off analysis since the scope, complexity, and the number of evaluation measures can result in trade-off analyses that are unclear, unfocused, and do not easily expose the most promising alternatives. To provide the most useful information to decision-makers, the measures should be quantitative rather than qualitative if at all possible and be expressed within a context that exposes the relative magnitude of the measures. An example trade-off analysis is provided in Table 9-3.

Table 9-3: Example Trade-Off Analysis Summary

Measure	No Build – Planned expansion of existing service	TSM – Express bus with park and ride lots	LRT Build 1 – 13 mile at grade line, 3 miles street running in CBD	LRT Build 2 – 12.5 mile at grade line, 2.5 mile tunnel in CBD
Project Cost ($YOE)	$45 million	$125 million	$750 million	$950 million
Annual operating and maintenance costs	$2.5 million	$14 million	$ 18 million	$17.5 million
Annualized Cost	$11.5 million	$35 million	$136 million	$153 million
MEASURES OF EFFECTIVENESS				
Daily ridership in study corridor	24,000	32,000	41,000	44,000
Daily system-wide transit ridership (forecast year)	85,000	92,000	103,000	106,000
Annual user benefits (hrs of travel time)				
Vs. No-Build	NA	6,200,000 hrs	13,300,000 hrs	14,000,000 hrs
Vs. TSM	NA	NA	7,100,000 hrs	7,800,000 hrs
Average transit trip time in corridor	37 minutes	31 minutes	24 minutes	20 minutes
Accessibility: Jobs within 30 minutes travel time				
Highway	180,000	195,000	198,000	199,000
Transit	95,000	120,000	130,000	133,000
PROJECT IMPACTS				
Value of added development in corridor over 20 years	$2.2 billion	$2.25 billion	$2.35 billion	$2.5 billion
Property takings	0	45 homes	125 homes	45 homes
		1 commercial	13 commercial	5 commercial
			2 industrial sites	2 industrial sites
Noise and vibration	NA	Localized noise impacts on 58 properties	Localized noise impacts on 40 properties	Localized noise impacts on 25 properties
			10 structures within	8 structures within

			vibration screening distance	vibration screening distance
Pollutant emissions reduction vs. no-build	NA	0.2% reduction	0.3% reduction	0.35% reduction
Consistency with local land-use policies	Not consistent with local plans which recommend fixed guideway transit connection in corridor.	Consistent with local plans to improve transit service in corridor	Supports local plans to improve transit service and concentrate economic development in planned station areas.	Supports local plans to improve transit service and concentrate economic development in planned station areas.
MEASURE OF COST-EFFECTIVENESS				
Cost-effectiveness ($Annual/user benefits)				
vs. No-Build	NA	$5.65	$10.22	$10.93
vs. TSM	NA	NA	$19.15	$19.61
FINANCIAL FEASIBILITY				
Available funds	$ 250 million (local)	$ 250 million (local)	$ 625 million (local plus 50% federal)	$ 725 million (local plus 50% federal)
Additional funding required	NA	NA	$125 million	$225 million
Source of additional funds	NA	NA	Tax referendum	Tax referendum
EQUITY CONSIDERATIONS				
Characteristics of affected communities	Middle/upper income	Middle/upper income	Middle/upper income	Middle/upper income
Travel benefits by income group/location	Lower cost buses serve predominantly lower and middle income passengers	Slightly higher costs to existing lower/middle income riders, additional middle income riders drawn to improved service	Middle/upper income suburban communities benefit most, higher costs for existing riders, improved suburban job access for city residents	Middle/upper income suburban communities benefit most, higher costs for existing riders, improved suburban job access for city residents
Distribution of funding costs between users and non-users	Users pay 25% of costs	Users pay 30% of costs	Users pay 35% of costs	Users pay 35% of costs
	General sales tax – 75%	General sales tax – 70%	General sales tax – 65%	General sales tax – 65%

9.8 Documenting the Evaluation Methodology

The purpose of documenting the evaluation methodology is simply to outline the measures that will be used to quantify the degree to which each alternative meets the stated goals and objectives. The evaluation measures and methodology must be defined at the beginning of alternatives analysis to respond to the problems in the corridor. If the evaluation measures are created after the technical work has been done, they are prone to being manipulated to support a predetermined conclusion. The alternatives analysis should specify at the outset, each objective, identify the measure(s) proposed for each objective, and describes the source of the measure. This step provides a means for local decision-makers and technical staff to agree on a meaningful set of measures, and alert the responsible technical staff of the evaluation data needed from the analysis.

While the evaluation of alternatives in the alternatives analysis does not need to use the same measures required for FTA's New Starts rating and evaluation process, the study should be sure to produce the information required for the federal process. Otherwise, significant additional work may be required if a major capital investment becomes the locally preferred alternative and the project sponsor intends to seek federal funding.