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FAA AIRPORT BENEFIT-COST ANALYSIS GUIDANCE

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Section 1: INTRODUCTION

1.1 Purpose of Guidance: The purpose of this document is to provide clear and thorough guidance to airport sponsors on the conduct of project-level benefit-cost analysis (BCA) for capacity-related airport projects. It will facilitate the production of consistent, thorough, and comparable analyses that can be used by the Federal Aviation Administration (FAA) in its consideration of airport projects for discretionary funding under the Airport Improvement Program (AIP). Airport sponsors should conform to the general requirements of this guidance for all BCAs submitted to FAA. However, airport sponsors are encouraged to make use of innovative methods for quantifying benefits and costs where these methods can be shown to yield superior measures of project merit.

1.2 Background: On October 31, 1994, FAA simultaneously published "Policy Regarding Revision of Selection Criteria for Discretionary Airport Improvement Program Grant Awards" and "Policy for Letter of Intent Approvals Under The Airport Improvement Program" in the Federal Register. These policies establish the requirement for BCA to demonstrate the merit of capacity projects for which airport sponsors are seeking AIP discretionary funds. In practice, FAA interprets capacity projects to include those involving new construction or reconstruction of airport infrastructure intended to accommodate or facilitate airport traffic. The FAA policy requiring BCA does not apply to projects undertaken solely, or principally, for the objectives of safety, security, conformance with FAA standards, or environmental mitigation. The selection criteria policy for discretionary grants was issued in final form in October 1994 and modified on June 24, 1997, in the Federal Register Notice "Policy and Guidance Regarding Benefit Cost Analysis for Airport Capacity Projects Requesting Discretionary Airport Improvement Program Grant Awards and Letters of Intent." This modification established dollar thresholds above which BCA was required, transferred the responsibility for accomplishing the BCA from the FAA to the airport sponsor, issued BCA guidance, and requested comments on the thresholds, the guidance, and FAA forecasts of operations and enplanements. The final policy on the application of BCA to Letter of Intent (LOI) applications was issued on December 15, 1999.

Airport capacity projects meeting a dollar threshold of $5 million or more in AIP discretionary grants over the life of the project and all airport capacity projects requesting LOIs must be shown to have total discounted benefits that exceed total discounted costs. Projects for reconstruction or rehabilitation of critical airfield structures may be exempt from BCA requirements on a case-by-case basis. Airport sponsors requesting an exemption must apply to the FAA which will consider the essential need of the project, its timing, and whether the estimated cost is reasonable and typical.

1.3 Application: When possible, airport sponsors should conduct BCA as specified in this guidance as a standard practice in the development of the airport master plan. At the master plan level, airport sponsors should apply BCA to all capacity projects for which the sponsor anticipates the need for $5 million or more in Airport Improvement Program (AIP) discretionary grants and for all airport capacity projects requesting LOIs.

While inclusion in a master plan appears to be the best time for BCA, other appropriate occasions are in conjunction with environmental studies, or during project formulation. Where it is not feasible to include BCA in these activities, the BCA should be conducted on a supplemental basis and submitted to FAA when requesting funds.

FAA retains the option to review BCAs conducted by airport sponsors, request further documentation or analysis by the sponsor, and/or conduct an independent BCA.

1.4 Limitations of Guidance: FAA has attempted to present this guidance in a manner that covers both theoretical and practical issues of the application of BCA to airport projects. Where possible, a "how to" approach is provided for identifying and quantifying project benefits and costs. However, it is impossible to define a mechanistic blueprint for BCA that would cover all possible situations. Competent professional judgment is indispensable for the preparation of a high-quality analysis.

Airport sponsors and others wishing to employ BCA and evaluation techniques not covered by this guidance should consult with the FAA Office of Aviation Policy and Plans, Systems and Policy Analysis Division, at (202) 267-3308.

Section 2: ROLE OF BCA

BCA seeks to determine whether or not a certain output shall be produced and, if so, how best to produce it. BCA requires the examination of all costs related to the production and consumption of an output, whether the costs are borne by the producer, the consumer, or a third party. Similarly, the methods used in BCA require an examination of all benefits resulting from the production and consumption of the output, regardless of who realizes the benefits.

2.1 General Objectives of BCA: Benefit-cost analyses submitted to FAA should provide information that allows FAA to determine if:

- There is adequate information indicating the need for, and consequences of, the proposed project or action;
- Potential benefits to society (usually defined by FAA as the aviation public) justify potential costs (recognizing that not all benefits and costs can be described in monetary or even in quantitative terms);
- The proposed project or action will maximize net benefits to society; and
- Data used in the BCA are the best reasonably obtainable technical, economic, and other information.

Analysis of benefits, costs, and uncertainty associated with a project or action must by guided by the principle of full disclosure. Data, models, inferences, and assumptions should be identified and evaluated explicitly, together with adequate justifications for choices made, and assessments of the effects of these choices on the analysis.

2.2 Distinction Between BCA and Financial Analysis: BCA as discussed in this guidance applies to airport infrastructure investments made in whole or in part using public funds. In particular, AIP funds are paid from the Airport and Airway Trust Fund, which historically has received its revenue from taxes imposed on aviation system users for the improvement and operation of the airport and airway system. As such, all benefits and costs affecting the aviation public or directly attributable to aviation must be considered and evaluated in the BCA. Such benefits may include benefits realized in the form of monetary gains (e.g., lower operating costs), reductions in non-monetary resources (e.g., personal travel time), or mitigation of environmental impacts. A detailed listing of typical benefits and costs for inclusion in BCA studies is provided in Sections 10 and 11 of this guidance.

Airport investments to be made by a quasi-private or private entity from investment funds will generally be evaluated through a more restrictive form of investment evaluation known as financial analysis. Financial analysis considers only the cash benefits and costs accruing to the corporation making the investment. In the case of a privately-owned airport, or a privately-owned component of a public airport, these cash benefits would principally include higher user fees (e.g., landing fees, service charges, rents, etc.) raised by the corporation from users of the airport to cover the cost of the investment.

It is sometimes assumed that financial analysis should be applied to publicly financed airport projects. However, financial analysis is not appropriate because it does not measure full costs and benefits of projects to the aviation public. The following factors may cause public benefits to vary from those captured by the project builder and operator:

- Producers sometimes create benefits for other members of the economy but are unable to obtain payment for these benefits, or alternatively may cause losses to others without having to pay the full costs. These events are called externalities. A frequently cited negative externality to airport operations is aircraft noise. In the case of externalities, the measure of net benefits to the producer will not be the same as the net benefits to the public.
- Public costs and benefits may not be fully captured in market transactions due to imperfect information. The full value of saved passenger time or improved air safety attributable to an investment may not be understood by passengers and thus may be difficult to recover through higher air fares and airport fees.
- Some airports are de facto monopoly providers of regional airport services to certain classes of aircraft. Users of such an airport do not have reasonable alternatives to the airport should it increase its fees to cover a project's cost, although the project may or may not have benefits equivalent to the rate increase. (Thus, the ability of an airport to cover a project's costs by a rate increase does not necessarily mean that the project has economic merit from the public's standpoint.)
- A project at an airport may have important benefits, but if some users are in a position to block the project (e.g., by refusing to pay higher landing fees), the worthwhile project could be blocked. For instance, a dominant airline might oppose the addition of new capacity that would disproportionately benefit its competitors, or, due to short-term financial problems, may reject any project with future benefits that would increase current costs.

Consequently, it is appropriate that a full and objective accounting of aviation system user benefits should be conducted through the BCA quantification methods described in this guidance.

2.3 Treatment of Macro-Economic Impacts Associated with Airport Projects: A general caveat to the inclusion of benefits and costs in an airport project BCA applies to certain macroeconomic impacts such as regional employment generation, improved business environment, and other non-aviation benefits that may be generated by the project.

Macroeconomic impacts accruing to a community as a result of an airport project are difficult to quantify and frequently represent transfers from other regions. Moreover, these benefits are largely external to the national airport system, whereas the taxes that fund the AIP are collected from aviation system users to operate, maintain, and/or improve the nation's aviation system. In addition, Section 6(b)(3) of OMB Circular A-94 generally rules out consideration in BCAs of employment or output multipliers that purport to measure the secondary effects of government expenditures in measured social benefits and costs.

However, FAA acknowledges the contributions of airports to regional economic objectives and will consider important macroeconomic impacts separately from the BCA. A brief discussion of macroeconomic impacts and how they may be quantified and presented is provided in Section 10.6 of this guidance.

Section 3: OVERVIEW OF BCA PROCESS

The BCA process consists of the following steps:

- Define project objectives
- Specify assumptions about future airport conditions
- Identify the base case (no investment scenario)
- Identify and screen all reasonable alternatives to meet objectives
- Determine appropriate evaluation period
- Establish reasonable level of effort for analysis
- Identify, quantify, and evaluate benefits and costs of alternatives relative to base case
- Measure impact of alternatives on airport usage
- Compare benefits and costs of alternatives
- Evaluate variability of benefit-cost estimates
- Perform distributional assessment when warranted; and
- Make recommendation of best course of action

The following is a summary of the analytical considerations involved in each of these steps. A more comprehensive discussion is provided in the remaining sections of this guidance.

3.1 Define Project Objectives: The BCA cannot proceed until the exact objectives of the project under consideration are precisely stated. Any project undertaken without a clear understanding of the desired outcome is likely to be inefficient and, perhaps, unnecessary.

3.2 Specify Assumptions: A set of assumptions about the most likely future of the airport must be explicitly stated at the outset of an analysis. These assumptions will serve as a framework for the consideration of all potential investments at the airport, and should include realistic assessments of future traffic, traffic management improvements, constraints on future capacity, etc. These assumptions should be fully explained and documented.

3.3 Identify the Base Case: The base case represents the best course of action that would be pursued in the absence of a major initiative to obtain the specified objectives. The base case is critical to BCA because it represents the reference point against which the incremental benefits and costs of various possible investment alternatives will be measured.

3.4 Identify and Screen Reasonable Investment Alternatives: This step is one of the most difficult yet important parts of a BCA. It involves the identification of all reasonable ways to achieve the desired objective(s). This step is critical because only those alternatives that are identified will be evaluated in the BCA. By definition, any alternative not identified and evaluated cannot be selected as the most efficient method to achieve the objective.

3.5 Determine Appropriate Evaluation Period: An unbiased comparison of investment alternatives requires that they be analyzed over equivalent evaluation periods or time frames. Large infrastructure projects will have useful lives of 20 years or more, although for some investments, shorter time frames may be preferable.

3.6 Establish Reasonable Level of Effort: The amount of work and expense required to conduct a BCA can vary widely depending on:

- The importance and complexity of the project;
- The number of alternatives being considered;
- The availability of information on benefits and costs;
- The sensitivity of net benefits to changing assumptions; and
- The consequences of an incorrect decision.

The correct level of effort is a matter of judgement based on a careful assessment of these and other factors.

3.7 Identify, Quantify, and Evaluate Benefits and Costs: This step requires that the value in dollars of all quantifiable benefits and costs be estimated for each year of the project life span. With respect to benefits, it is necessary to identify the types, amounts, and values of benefits the project can be expected to yield. Typical benefits include reduced delay, use of more efficient aircraft, safer and more secure air travel, and reduced environmental impacts. For costs, the physical resources consumed by the project must be determined and their associated costs estimated. Typical efforts generating costs include planning, construction, and operation and maintenance. Guidelines for formulating benefit estimates are presented in Section 10. Procedures for cost estimation are contained in Section 11.

Not all benefits and costs can be quantified and stated in terms of dollar values. A natural follow-on to valuation of quantifiable benefits and costs is the identification and description of those benefits and costs which cannot be evaluated in dollar terms--referred to in this guidance as "hard-to-quantify". "Hard-to-quantify" considerations should be listed and described for the decision-maker. If possible, a range in which a dollar value could be reasonably expected to fall should be reported. Hard-to-quantify benefits and costs should not be neglected and can be very important to the outcome of the analysis. These items are discussed in appropriate subsections of Sections 10 and 11.

3.8 Measure Impact of Alternatives on Airport Usage: The benefits generated by an investment for pre-existing airport users may induce some new users to come to the airport who will also benefit from the project. However, these new users will impose demands on the airport's capacity that should be factored into the BCA. Appendix C of this guidance addresses the issue of induced demand caused by airport improvements. Because of the uncertainty associated with the data used in an analysis of induced demand, it is left to the option of the airport sponsor whether or not to include this analysis in the BCA.

3.9 Compare Benefits and Costs of Alternatives: Most airport investments involve the expenditure of large blocks of resources at the outset of the project in return for an annual flow of benefits to be realized in the future. Because benefits are not realized simultaneously with costs, the analyst must compare total benefits and costs in a manner that recognizes that the present value decreases with the length of time that will occur before they are incurred. This procedure establishes whether or not benefits exceed costs for any or all of the alternatives (thus indicating whether or not the objectives should be undertaken) and which alternative has the greatest net present value. Criteria for making this comparison are enumerated in Section 12.

3.10 Perform Sensitivity Analysis: Because uncertainties are always present in the benefit and cost estimates used in the comparison of alternatives, a complete understanding of the investment decision can be developed only if key assumptions are allowed to vary. When this is done, it is possible to examine how the ranking of the alternatives under consideration holds up to a change in a relevant assumption and under what conditions the project is or is not worth doing. Methodology for conducting sensitivity analysis is presented in Section 13.

3.11 Make Recommendations: The final outcome of the economic analysis process is a recommendation concerning the proposed objective. Under a BCA there are two parts to this recommendation: should the activity be undertaken, and if so, which alternative should be selected to achieve it. The recommendation of the appropriate alternative will depend on measured benefits and costs, consideration of hard-to-quantify benefits and costs, and sensitivity of results to changes in assumptions.

Section 4: OBJECTIVES

4.1 Statement of Objectives: It is essential to be clear when stating the objective(s) of a potential project or action. The objective should be stated in the context of an identified problem or need at the airport. For instance, runway congestion may be causing unacceptable levels of aircraft delay at an airport. Accordingly, the objective of the project should be stated in terms of mitigating runway congestion to reduce aircraft delays.

The analyst should be careful not to state the project objective in a manner that prejudges the means to obtain the objective. A runway may have reached a severe state of deterioration such that delays may soon be incurred due to frequent maintenance and/or closure of the runway. In this case, reconstruction of the runway may appear to be the obvious course of action. However, the objective of potential action should not be to "rebuild the runway to preclude the development of delay." Rather, the objective of the project should be to "undertake actions to preclude the development or worsening of airside delay." Rebuilding the runway might be only one of several alternatives to meet this objective.

4.2 Range of Possible Objectives: Possible objectives for an airport infrastructure project include (but are not limited to) the following:

- Reduce delay associated with airport congestion;
- Improve efficiency of airport operations;
- Increase the number of aircraft and passengers the airport can serve;
- Permit new service by accommodating larger and more efficient aircraft at the airport;
- Improve (maintain) airport safety and security;
- Mitigate environmental impacts of the airport on the surrounding community;
- Improve passenger comfort and convenience; and
- Lower airport operating costs.

4.3 Treatment of Multiple Objectives: It is likely that the project sponsor may have two (or more) objectives and that a particular project may be able to address both. The sponsor may, for instance, wish to reduce delay and mitigate aircraft noise--objectives that might be met by a new runway that directs traffic over less noise-sensitive areas. However, the analyst should be careful not to assume that a given set of objectives must be collectively solved by one large project. It may be more efficient to target the various objectives with independent projects. In the above example, it may prove more cost-beneficial to build a runway that does not significantly redistribute noise but which lowers congestion, and undertake a separate noise mitigation project (e.g., noise insulation) to address the noise problem.

The sponsor should be especially careful not to merge separate projects designed to meet different objectives into megaprojects. This practice may occur when a diverse collection of recommended projects (perhaps developed in an earlier master plan exercise) are presented as a single airport development package. For instance, reconstruction and extension of a given runway may be marketed as one project, but in reality these are two separate projects with different objectives and benefit streams. Failure to treat separate projects with different objectives independently could lead to incorrect decisions. The runway reconstruction may prove cost-beneficial whereas the runway extension may not. If the projects were combined, they would either both fail or both pass--in which case a desirable project would go unbuilt or an unnecessary project would be constructed.

4.4 Designation of Principal Objective: Finally, a project undertaken for multiple objectives must, for the purposes of AIP funding, be presented as falling principally under one objective. Thus, a project meeting both capacity and noise mitigation objectives must be classified as one or the other. Project classification should conform to the principal objective of the project, which should also conform to the principal source of benefits stemming from the project.

Selection of the key project objective is clearly not a matter of indifference from the standpoint of this guidance. The requirement for BCA applies only to capacity-related projects funded with discretionary grants or LOI approvals. Due to the importance of the correct designation of the key objective, the airport sponsor should consult with FAA at the project conception stage concerning the specification of the key objective for any project that has any capacity-related benefits.

Section 5: ASSUMPTIONS

5.1 Future Airport Environment: Formulating intelligent alternative courses of action to attain desired aviation objectives depends on the clear and realistic statement of assumptions about the future operating environment of the airport. Assumptions that should be specified and documented at the outset of most investment studies include:

- Projected growth in demand for airport services;
- Future changes in airport facilities and capacity that are likely to occur independently of the investment being considered;
- Binding constraints on airport capacity that would not be affected by the potential investment; and
- Improvements in regional air traffic management procedures.

These and other assumptions are typically developed in the normal course of preparing an airport master plan.

5.2 Projected Growth in Airport Activity: Timely provision of appropriate airport infrastructure is based on airport activity growth projections. Incorrect forecasts can lead to improper timing of airport investments. Overly optimistic forecasts can lead to a facility being in place far in advance of when its needed, causing scarce AIP funds to be tied up in idle facilities. Alternatively, forecasts that fail to anticipate growth may lead to unnecessary delay and inconvenience to airport users due to inadequate infrastructure. Unfortunately, realistic forecasts are difficult to make.

Chapter 5 of AC 150/5070-6A (Airport Master Plans, June 1985) provides detailed guidance on the development of projections of the levels of growth in airside operations and enplanements at an airport. Activity forecasts are generally developed for 5, 10 and 20 year time horizons. Table 5.1 summarizes the aviation demand elements that must be developed to support airport master planning and BCA.

Throughout this guidance, each enplanement is assumed to equal two passengers (a departure and an arrival) in the case of origin and destination (O&D) airports. At hub airports, some passengers on continuing flights neither enplane nor deplane. A factor of 2.1 passengers per enplanement may be used at hub airports to capture through passengers.

Given the critical importance of correct forecasts on BCA results, a summary (with some augmentation relevant to BCA) of the six step forecasting process described in AC 150/5070-6A is provided below:

TABLE 5.1: TRAFFIC GROWTH ASSUMPTIONS

MUST BE SPECIFIED	SPECIFIED WHERE APPROPRIATE
Number of Aircraft Operations (Landings and Takeoffs)	
Itinerant Operations	
Air Carrier Commuter and Air Taxi General Aviation Military	Domestic vs. International Operations Annual Instrument Approaches IFR Operations Helicopter Operations
Local Operations	
General Aviation Military	Touch and Go Operations
Peak Hour Operations by Aircraft Type	
Number of Passenger Enplanements	
Air Carrier Commuter and Air Taxi	Domestic vs. International Enplanements General Aviation Enplanements Helicopter Enplanements
Number of Air Cargo Operations by Aircraft Type	
Number of Based Aircraft by Aircraft Type	

1) Obtain existing FAA and other related forecasts for the area served by the airport being studied--FAA produces Terminal Area Forecasts (TAF) each year for the more than 3,300 airports in the National Plan of Integrated Airport Systems. The TAF traffic projections are based on, and controlled in aggregate by, the national FAA Aviation Forecast. These forecasts (which are driven by projected enplanement growth) provide enplanement and aircraft operation estimates over a future time frame for most of the categories described in Table 5.1. State and regional aviation activity forecasts are also important sources of data, as they reflect local conditions and policy considerations. The Air Transport Association should also be consulted concerning the reasonableness of forecasts.

2) Determine if there are significant local conditions or changes in forecast factors--FAA and other forecasts may need to be adjusted to consider local conditions not accounted for in existing forecasts. For instance, income and population levels may be growing at different levels than assumed in making the forecast. In addition, planned removal of a constraint (other than one to be addressed by the proposed investment itself) that was specifically factored into the existing forecast (such as night time landing restrictions) may lead to increased demand.

3) Make and document any adjustments to the aviation activity forecast to account for such conditions or factors--AC 150/5070-6A describes forecast adjustment mechanisms based on extrapolation, analysis, and judgment. All underlying assumptions, deductions, and methods used to adjust TAF forecasts must be well-documented to facilitate FAA review.

Traffic growth estimates exceeding those in the FAA Terminal Area Forecast must be explained or approved by FAA. Early and periodic discussions with FAA airports and forecasting staffs are encouraged.

It is critical that the basic activity forecast does not reflect any improvements associated with the infrastructure projects being analyzed. Methods for quantifying and evaluating induced activity impacts are provided in Appendix C.

4) Consider the effects of changes in uncertain factors affecting demand for the airport services--Major components of airport demand may be driven by the continued existence of a particular hub service or fixed base operator (FBO). Clearly, if there is a reasonable possibility that the hub operation will be discontinued or the FBO will close down, the impact of this event on the forecast should be quantified. Contingencies such as this must be specifically addressed in BCA sensitivity analysis (see Section 13).

5) Evaluate the potential for peak loads within the overall forecasts of aviation activity--It is important that design hour forecasts (peak hour in average month) be subjected to rigorous testing of their sensitivity to the factors underlying their prediction. This is particularly so if the design hour possesses abnormal peaking characteristics relative to that of comparable airports. In particular, the analyst should address the likelihood of spreading of peak demand in the event of future congestion (see Section 7.3.3). Failure to allow for adjustments to lessen peak demand in future years can lead to an over-estimation of future infrastructure needs.

6) Monitor actual activity levels over time to determine if adjustments are necessary in the forecast--Forecasts made in prior years should be monitored continuously for accuracy. Where actual traffic varies from forecast traffic, the analyst should endeavor to understand why this is so and make appropriate adjustments to the forecast by modifying the data base used to generate the forecast and/or the forecasting method. Use of a forecast made in a prior year that conflicts with recent traffic data and/or forecasts will obviously undermine the credibility of a BCA based on it.

The above six-step process focuses on growth in airside activity, but has direct applications to airport terminal building (ATB) and landside projects. In particular, airside passenger forecasts can be used to forecast passenger demand for ATB and landside facilities.

5.3 Future Changes in Airport Facilities and Capacity: The analyst must carefully outline the expected changes in airport conditions and capacity that are scheduled to occur independently from the project being evaluated in the BCA. The inventory of current airport

plant, land use, ground access, and environmental conditions required by the master plan process (AC 150/5070-6A, Chapter 4) represents a good starting point to discuss likely changes. Development of land outside the airport's boundaries should also be addressed. Future residential development near an airport may greatly restrict the usefulness of a runway project due to noise problems.

A project intended to reduce runway congestion may become superfluous at some time in the future due to other expected development at the airport (e.g., the relocation of the airport or planned construction of a new runway that will lead to the closure or reduced use of the current project). Similarly, a series of small-scale projects already approved at an airport may negate or capture benefits being attributed to the project under consideration in the BCA. All such future developments should be listed, thoroughly discussed, and factored into the base case (see Section 6).

5.4 Binding Constraints on Airport Capacity: It is rarely the case that only a single constraint is potentially binding on the ability of an airport to accommodate traffic growth. Therefore, a project designed to alleviate a currently binding constraint may yield benefits only to the point that some other constraint not addressed by the project becomes limiting.

Correct specification of potential constraints is essential to defining useful alternatives for BCA consideration. Realization of benefits from a new runway may be contingent on simultaneous investments in terminal or ground access capacity. The proper identification of an alternative designed to capture the full potential benefit of the runway would therefore need to consider the cost of upgrading terminal or ground access capacity.

5.5 Regional Air Traffic Management: Scheduled improvements in air traffic equipment and procedures may accomplish the same objectives that a particular infrastructure project is intended to accomplish. Such improvements may include the accommodation of higher approach speeds, reduced separation of aircraft, redesign of airspace, and applications of new technologies (e.g., GPS).

Alternatively, a precision runway monitor (PRM) may permit the implementation of independent parallel approaches on runways too closely spaced for independent operations using Airport Surveillance Radar (ASR) systems. Whereas the current separation requirement without PRM is 4,300 feet, it is 3,400 feet with PRM and may eventually be lowered to 2,500 feet. AC 150/5070-6A (Chapter 6) discusses the issue of technology and operational improvements. FAA air traffic personnel should be consulted in the development and documentation of assumptions concerning the future air traffic control environment.

5.6 Environmental Considerations: The analysis should clearly address any environmental constraints that the airport will operate under. For instance, if the airport has an agreement with the local community not to operate aircraft over certain areas for noise mitigation purposes, these agreements should be explained. It would not be appropriate to attribute improved traffic patterns to an investment when a long-term agreement precludes such traffic patterns.

On the other hand, current restraints on airport operations attributable to noise could be relaxed in the future due to the conversion of the national aircraft fleet to Stage 3 aircraft. This may permit improvements in the utilization of current airport infrastructure and mitigate the need for the investment in question.

5.7 Need for New or Adjusted Assumptions: Specification of assumptions often cannot be done exhaustively at the initial stage of a BCA. Sufficient data may not be available to make some assumptions up front. Other assumptions must be changed as the project proceeds and more information is obtained or information gaps appear that can be filled only by new assumptions.

The need for revisions may become especially apparent once capacity simulation modeling begins. For instance, should simulation modeling reveal that the baseline traffic forecast would lead to average airside, terminal, or landside delays of more than 20 minutes per operation or passenger, the rate of growth in the baseline forecast would need to be adjusted downward. This revision is necessary because approximately 20 minutes represents the highest level of average delay realized in actual practice, even at highly congested airports. A method for making such adjustments to the basic forecast is provided in Section 10.4.1.2 of this guidance.

5.8 Economic Values: Certain economic values, also often referred to as "critical values," are used in the conduct of BCA of investments, including capacity projects funded by AIP. These values have been collected in the document, "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs," FAA-APO-98-8, dated June 1998.

FAA can revise some of these values, such as aircraft capacity and utilization factors, aircraft operating costs, and unit replacement and restoration costs of damaged aircraft. Some of these values are items which the Office of the Secretary of Transportation (OST) has reserved to itself the right to revise, namely the value of passenger time in air travel, and the values of life and injury in economic analysis. The discount rate is also a most critical value in BCA. The Office of Management and Budget (OMB) has reserved to itself the right to revise the discount rate.

Section 6: IDENTIFICATION OF THE BASE CASE

The benefits and costs of one or more initiatives designed to accomplish specified objectives must be measured against a reference point, also called the base case. Ideally, the reference point should be the optimal course of action compatible with the specified project objectives that would be pursued in the absence of a major initiative. However, in most instances, the base case will not fully meet the objectives specified for the potential project.

6.1 Need for Correct Identification: The importance of correct identification of the base case cannot be overemphasized. If the base case is poorly designed, it will lead to incorrect estimation of the benefits and costs of the investment alternatives being considered.

It is especially important that the base case not be defined as a "do nothing" course of action where the current airport configuration and management are held static. BCA based on this static base case will typically overstate the deterioration in delay, efficiency, safety, and other benefit measures as traffic grows. In reality, airport managers, airport users, and air traffic managers may make a variety of operational and procedural changes to mitigate delay and related problems as congestion builds beyond certain thresholds.

6.2 Base Case Specification Requirements: The base case must assume optimal use of existing and planned airport infrastructure and incorporate all improvements to airport infrastructure currently underway and/or funded. It must also incorporate reasonable expectations of corrective actions by airport managers, users, and air traffic managers in response to build-ups in delay and other problems as airport traffic grows.

Adjustments by airport managers to accommodate congestion could include establishing voluntary arrangements with users to spread demand outside of peak periods or offer general aviation users incentives to use reliever facilities. Aircraft operators may make use of larger aircraft, modify schedules to take advantage of less congested periods, cancel marginal flights, etc. Reasonable assumptions about overall improvements in air traffic management should also be factored into the base case (see Section 5.5). All assumptions used to define the base case should be stated and explained.

Section 7: SPECIFICATION OF ALTERNATIVES

Alternatives represent the broad range of possible actions that could be undertaken to achieve the objectives identified by the sponsor. A valid BCA must have at least one alternative identified for each possible course of action. Each alternative must be a reasonable, well-founded, and self-contained investment option.

7.1 Importance of Complete Specification: It may not be possible to determine an optimal course of action if a full range of alternatives is not identified. In particular, any alternative not identified and evaluated cannot, by definition, be selected as the most efficient method to achieve the objective. Therefore, an analyst should not exclude any potential alternative merely because of a predisposition in favor of others. Such predispositions might be due to past practice, prestige (desire to have a new or larger facility), or external constraints such as budget or personnel ceilings.

7.2 Self-Contained Alternatives: Each alternative should be defined so that any incremental benefits and costs identified for it (relative to the base case) are unambiguously and solely attributable to it. When the realization of benefits for an alternative requires additional investment in related infrastructure, the building (and cost) of this related infrastructure should be included in the alternative (see Section 5.4). Only in the case where the additional infrastructure will be economically justified and built for reasons other than to accommodate the objectives of the alternative could the cost of this infrastructure be excluded from the alternative.

7.3 Range of Alternatives: At a minimum, the following alternatives should be identified and discussed for any airport infrastructure project:

- Investments in new facilities, both major and minor, on and off the airport
- Refurbishment, replacement, and enhancements of existing facilities
- Demand management strategies, including provision of improved information; and
- Redistribution of responsibility

7.3.1 Investments in New Facilities: One possible means to accomplish specified objectives is to build new facilities. When considering the addition of new infrastructure, a full range of greater and lesser investments should be addressed. For instance, a new runway could be sized to handle all aircraft classes, or it could be sized to handle a particular class such as commuter aircraft. Similarly, a runway extension should be considered over a range of potential lengths. Each of the length alternatives would then be analyzed.

Although AC 150/5070-6A states that an airport must be designed to standards that will accommodate the most demanding airplane (critical aircraft), the implementation of the BCA requirement for large scale projects requires that size alternatives that fall short of the designated critical aircraft also be considered. This requirement is particularly important when a facility is being expanded to accommodate a large size class of critical aircraft from what it served previously. The BCA may reveal that the alternative sized to the new critical aircraft would

yield substantially lower net benefits than would one sized to the existing class of critical aircraft. In this instance, FAA, in its award of grant funds, could take the position that the smaller alternative is the preferred one even though it may not accommodate certain critical aircraft.

In some cases, it may be logical to consider the addition of new infrastructure at a site other than the airport itself. If general aviation (GA) traffic is contributing to congestion at a primary airport, construction of a new or longer GA runway at a nearby reliever airport may be a more cost-beneficial means of reducing congestion than would be the construction of a new runway at the congested airport.

7.3.2 Reconstruction of Existing Facilities: An obvious course of action when delay or other costs are caused by facilities in an advanced states of disrepair, obsolete equipment, or inefficient design is to replace the facilities or equipment. However, there may be a wide range of alternatives to meet this course of action. Replacement can be done in place or may involve moving the facility to another location at the airport. Reconstruction in place may range in magnitude from partial reconstruction (e.g., removal and replacement of a layer of a runway's pavement) to full depth reconstruction (including replacement of the subgrade of the runway). In addition, it is appropriate to propose a range of potential enhancements that will improve on the performance of the original. Enhancements may include strengthening (to accommodate heavier aircraft), improved materials (e.g., Portland concrete rather than asphalt concrete), better signage and lighting, etc.

7.3.3 Demand Management Strategies: FAA has generally discouraged the building of new capacity to meet infrequent and short-lived peaks in airport traffic. One alternative for consideration would be to encourage users of a facility to spread peak usage over a longer period or to move usage to off-peak hours. Such inducements might include voluntary modifications to arrival and departure schedules, improvement of service at alternative airports (e.g., reliever airports), or price incentives (e.g., lower landing fees at off-peak hours). A critical role of the airport sponsor might be to provide information to airport users on the benefits associated with movements of some flights out of the highest peak period--perhaps through a simulation modeling exercise.

Extreme care should be exercised in the specification of any alternative to reallocate traffic by increasing landing fees (congestion pricing) or use restrictions. Attempts to apply demand management strategies at some airports have been complicated by charges that these strategies would result in unjust discrimination against certain classes of users less able to afford higher landing fees. However, some airports (e.g., those operated by the Port Authority of New York and New Jersey) have successfully imposed congestion pricing and aircraft allocation schemes under carefully prescribed circumstances.

FAA does not currently have policy guidance on implementation of fee-based demand management. Until such time that a formal policy is issued by FAA, airport sponsors are advised to consult directly with FAA (Office of Aviation Policy and Plans) prior to considering plans to implement non-voluntary demand management strategies.

7.3.4 Redistribution of Responsibility: FAA encourages airport sponsors to consider the use of private providers of infrastructure and airport services. In some cases, private providers may possess proprietary or innovative solutions to infrastructure shortages, or they may have special management skills. When evaluating alternatives involving private provision of infrastructure, all benefits and costs to airport users should be considered, not only those benefits and costs captured by the private provider. In addition, all AIP grant assurances associated with the airport sponsor must be honored under the terms of the contract with the private provider.

7.4 Screening Alternatives: Although as many reasonable alternatives as possible should be identified initially, not all of these will require detailed analysis. Many technically possible alternatives may be screened out from the beginning as inferior to others also being considered. This may occur in several situations:

- A particular approach may clearly be more costly than others, at least for the scale of activity under consideration;
- A particular approach may not mesh with existing facilities; and
- Major political, legal, or environmental constraints may preclude implementation.

For instance, it may cost no more to replace a facility with an improvement in its design or layout than it would cost to replace the original configuration. In this case, the original configuration option would be quickly eliminated. Such determinations should be well founded and specifically explained in the analysis.

Section 8: SELECTION OF EVALUATION PERIOD

8.1 Types of Evaluation Periods: The evaluation period is the number of years over which the benefits and costs of an investment should be considered. The choice of the evaluation period is dependent on the circumstances of the analysis. Three time periods are of concern in determining the evaluation period: requirement life; physical life; and economic life.

8.1.1 Requirement Life: The requirement life is the period over which the benefits of the good or service to be provided will be greater than the costs of producing it through the most cost-effective means. It can be for a very short period of time such as a requirement to accommodate traffic during the reconstruction of a major airport facility. Alternatively, it may be for a very long period of time such as the provision of a major new runway. From a practical point of view, requirement lives should not exceed 30 years.

8.1.2 Physical Life: The physical life of an asset is that period for which the asset can be expected to last. This period is generally not fixed--it is to a considerable degree under the control of the decision-maker. Alternative facilities with different physical lives resulting from inherent quality differences can be procured or maintenance policies can be varied to alter an asset's physical life after it has been put in service.

8.1.3 Economic Life: The economic life is that period over which the asset itself can be expected to meet the requirements for which it was acquired in a cost-effective manner. By definition, economic life is less than or equal to requirement life. Economic life may equal (but not exceed) physical life, but it is often less. If less, this indicates that it is not efficient to operate the asset as long as possible. Rather, it would be cheaper to replace it beyond some point in time. The need to replace often occurs as the consequence of ever rising maintenance costs, particularly for relatively old items.

8.1.4 Selection of Appropriate Time Period: Investment projects are usually evaluated over their economic lives. Use of the requirement life method may require the assumption that the facilities would be replaced at the end of each economic life period forever. Such an assumption, while not improper, would add little to the analysis. Moreover, it might obscure the fact that technology is likely to improve with time and that better performance, lower cost alternatives may be available in the future. To the extent that physical life exceeds economic life, it is, by definition, not an appropriate time period.

FAA generally uses an economic life span of 20 years beyond the completion of construction for major airport infrastructure projects, although longer life spans may be used if justified.

8.2 Comparable Time Periods For All Alternatives: Regardless of the evaluation period selected, it should extend over the same number of years for each alternative. This equivalence is necessary because benefits and costs are flows that must be measured with respect to time. Clearly, if total net benefits are the basis for selection among two or more projects, net benefits quantified over different periods will yield non-comparable results.

In certain situations, it will not be possible to compare alternatives with the same number of time periods. This situation frequently arises when an existing facility is being compared with replacements. The existing facility will continue to be functional for some period of time, although its remaining physical life probably will not extend beyond the economic life of the new replacement alternatives. In addition, various options being compared may have different economic lives.

When the need to compare projects with different economic lives occurs, the conventional practice is to set the BCA timeframe to the useful life of the most durable (longest-lived) alternative. The shorter-lived alternative should be assumed to be replaced or reconstructed at the end of its useful life so that the combined life span of the shorter-lived alternative will equal or exceed that of the longer-lived one. A residual value would then be assigned to the replacement asset should its life exceed that of the most durable alternative. (Another approach would be to extend the life of the shorter-lived alternative to a common timeframe with that of the longer-lived alternative and include the extension cost is the cost calculations. This eliminates the issue of salvage value, which for a government project is difficult to evaluate.)

8.3 Augmentation Of Evaluation Period To Assist In Project Timing Evaluation: FAA recommends that the selected evaluation period (e.g., 20 years) be augmented by at least 5 years to accommodate the need to evaluate optimal timing of investment alternatives. Inclusion of the extra 5 years will permit BCA to be completed for the specified evaluation period (20 years) beginning in year X and in year X+5. In some cases, particularly those where major benefits develop late in the project's life, this process will reveal that net benefits would be maximized by waiting to undertake an investment rather than beginning right away. A further discussion of project timing is provided in Section 12.

Section 9: LEVEL OF EFFORT

9.1 Appropriate Level of Effort: The performance of a full-fledged BCA, covering a wide range of alternatives, can be expensive and time-consuming. In certain cases that require complex modeling and extensive passenger surveys, studies have required one or more years to complete with costs in the millions of dollars. Clearly, efforts of this magnitude would neither be practical nor economically justified for projects expected to cost $20 to $30 million, although they may well be justified for projects expected to cost several hundred million dollars or more.

There is no exact formula for determining an appropriate or optimal level of effort. Generally speaking, the amount of work for an evaluation should be tailored to such things as:

- Magnitude of the project--Projects that involve major resource expenditures will generally require more extensive analytical efforts than will smaller, less expensive projects;
- Complexity of the project--Projects that have complex interactions with other airport and groundside infrastructure may require a more extensive evaluation of total benefits and costs;
- Number of practical alternatives--Projects involving only a limited number of reasonable alternatives will require less work than those with numerous alternatives;
- Dominance of one alternative--Level of effort can be reduced to the extent that one option shows a clear advantage as analysis proceeds;
- Materiality of benefits and costs--Minimal effort should be spent refining estimates of benefits and costs that do not vary significantly among options (base case and alternatives) or which represent a small share of the overall project benefits or cost;
- Sensitivity of benefits and costs to assumptions--Projects with important benefit and cost streams that vary greatly depending on uncertain assumptions (e.g., traffic growth) require more extensive refinements of assumptions;
- Availability of data--Projects with important benefits or costs that are inherently difficult to quantify (e.g., time savings associated with reduced congestion) will require more effort than those with more straightforward benefits and costs (e.g., time savings associated with shorter taxiing distances); and
- Controversy--Projects that are subject to large amounts of public controversy (e.g., due to environmental impacts) often must be investigated more thoroughly than non-controversial projects.

9.2 Justification: The BCA summary report should address how and why the specific level of effort was selected with reference to each of the above criteria. Other considerations that may be appropriate are the availability of time and budget to conduct the BCA. However, while lack of budget or time may constrain the scope of a BCA, they cannot be used to justify an inadequate analysis where circumstances clearly indicate a need for more information.

Should FAA review a BCA study and conclude that the level of effort was inadequate, FAA could require the study be redone and/or augmented. For this reason, it is highly recommended

that an airport sponsor consult with FAA on appropriate levels of effort before beginning full-scale analysis.

Section 10: MEASUREMENT OF BENEFITS

10.1 Benefits of Capacity Projects: The benefits that result from capacity-related airport projects and other initiatives will largely consist of cost savings to current and future airport users associated with reduced time spent in the airport system. Reduced time in system may take the form of reduced delay, more efficient processing, or reduced idle time. In addition, time and cost savings can result from the ability of a facility to accommodate more efficient aircraft. Capacity-related projects may also contribute to the ability to process more operations and passengers, greater safety and security, reduced environmental impacts, greater comfort for travelers, and other benefits.

Measurement of benefits can be a formidable task and in some cases can only be done in a qualitative sense. However, a careful and methodical approach to benefit measurement will often reveal that more benefits can be quantified and/or understood than was initially thought possible.

10.2 Identification and Measurement of Benefits: Estimation of the total monetary value of benefits attributable to a project can be accomplished through a three-step identification and measurement process. The first step is to identify what effects will occur and who will be affected as a consequence of undertaking an activity. The second step is to measure these effects in physical or time-based units. Finally, the physical or time-based units must be valued in dollars.

Once this three-step process is completed, the analyst can calculate the total monetary benefits to users attributable to a project at different future traffic levels, and then determine which of these traffic and benefit levels corresponds most closely to final market equilibrium levels (see Section 12).

10.3 Step 1--Identification of Benefits: Table 10.1 and the following text identify and describe the types of benefits which are often associated with various types of airside, terminal, and landside capacity-related projects. Benefits are specified with regard to whether the particular benefit occurs to aircraft operators, passengers, or cargo shippers.

Please note that projects intended primarily to meet objectives of safety, security, design standards, and environmental objectives are not subject to BCA requirements but are listed in Table 10.1 for the sake of completeness.

10.3.1 New Airside Capacity Projects: Airside capacity projects are intended principally to reduce airside delay, improve aircraft processing efficiency, improve predictability of landing

and take-off schedules, and/or to accommodate larger, heavier, longer-range aircraft at the airport. Other benefits of airfield capacity projects may include noise mitigation, reduced aircraft emissions, and compliance with FAA standards for airport safety, security, and design.

TABLE 10.1: BENEFITS OF AIRPORT PROJECTS

PROJECT TYPE	TYPICAL BENEFIT TYPE
AIRSIDE	
Airside Capacity Projects	
• New or extended runway, taxiway, apron, or hold pad	• Reduced aircraft, passenger, and cargo delay during normal airport operations • Reduced aircraft, passenger, and cargo delay during reconstruction of other airport facilities • Greater schedule predictability: - Aircraft operator able to make more efficient use of equipment and personnel - Passenger able to take later flight and arrive at destination on time • Improved efficiency of traffic flows (reduced vectoring and taxiing distances) • Reduced aircraft operating costs and passenger travel times due to airport's ability to accommodate faster, larger, and/or more efficient aircraft • Bringing pre-existing infrastructure into compliance with FAA safety and security standards • Safety improvements • Noise abatement • Reduction of aircraft emissions
• Reconstruction of runway, taxiway, apron, or hold pad	• Lower facility maintenance costs • Avoided loss of capacity benefits associated with facility failure
• Acquisition of airside equipment to support capacity objectives (navigational aids, snow removal and maintenance equipment)	• Reduced aircraft, passenger, and cargo delay during normal airport operations • Greater schedule predictability • Improved safety • Lower facility maintenance costs
Airside Safety, Security, and Design Standards Projects	
• Installation of signage and lighting • Expansion of runway safety areas • Removal of obstructions from existing approaches • Fencing • Acquisition of rescue and fire-fighting equipment	• Compliance with FAR and Advisory Circular safety, security, and design standards is mandatory and not subject to BCA. Compliance must be done in most cost-effective manner acceptable to FAA.
Airside Environmental Projects	
• Noise mitigation for pre-existing infrastructure (noise insulation, structure removal) • Fuel and chemical containment for pre-existing infrastructure	• Compliance with FAA environmental order is mandatory and not subject to BCA. Compliance must be done in most cost-effective manner acceptable to FAA.

AIRPORT TERMINAL BUILDING (ATB)	
ATB Capacity Projects	
• Reconstruction, expansion, and/or modernization of ATBs (excluding concession areas which are not eligible for AIP funding)	• Reduced aircraft, passenger, cargo, and meeter/greeter delay (attributable to more gates and faster passenger transfers to connecting flights) • Improved passenger schedule predictability (ability to allow less time for potential delays at ATB) • More efficient traffic flows (shortened pedestrian traffic distances) • Improved passenger comfort • Lower ATB operating and maintenance costs
• Baggage Handling Systems	• Reduced passenger and cargo delay • More efficient baggage distribution • Lower operating and maintenance costs
ATB Security Projects	
• Passenger, baggage, and freight security systems	• Compliance with FAA standards--not subject to BCA if primary objective of project
• Security fencing and gates	• Compliance with FAA standards--not subject to BCA if primary objective of project
Inter-Terminal Transportation	
• Fixed rail • Bus	• Reduced aircraft, passenger, and cargo delay (attributable to faster passenger transfers to connecting flights) • Improved passenger comfort • Lower operating and maintenance costs
LANDSIDE	
Landside Access Projects	
• Airport access roads • Passenger pick-up/drop-off areas • Transit areas	• Reduced passenger, cargo, and airport and airline employee delay in getting to airport • Improved schedule predictability (ability to leave later for airport and arrive on time for check in) • Lower operating and maintenance costs • Improved safety • Reduced automobile emissions

10.3.1.1 Delay Benefits. "Delay" is the added trip time attributable to congestion at the study airport, where congestion constitutes any impediment to the free flow of aircraft and/or people through the system. The costs of delay are incurred by aircraft operators (chiefly through incurring more aircraft operating hours), passengers (longer travel times in delayed aircraft),

cargo shippers, and (to a limited extent) persons at the airport for purposes other than their own air transportation needs.

Projects intended primarily to reduce airside delay include new or expanded runways, taxiways, aprons, and hold pads. These projects enable the airport to handle current or projected aircraft volumes with less congestion, allowing larger numbers of aircraft to land, taxi, hold, and take-off in a given time period or under particular weather conditions. Aircraft flights are less likely to be delayed (or in extreme cases, diverted or canceled), saving aircraft operators the added expense of fuel, maintenance, and crew costs associated with delays and/or repositioning aircraft. Passengers on-board the aircraft save personal or work-related time, as may persons waiting to meet or escort the passengers at the airport. Shippers benefit from more expedient delivery of air cargo.

In some cases, an airfield capacity project may yield only marginal delay benefits during routine airport operations, but may be critical to the airport's efficient operation during the reconstruction and temporary closure of some other component of the airport's capacity. For instance, a second runway can become especially important for handling traffic if the airport's primary runway must be closed for a prolonged period for major reconstruction.

10.3.1.2 Improved Schedule Predictability. Aircraft operators, passengers, and shippers may tie-up resources and/or pad schedules to accommodate possible delays in air travel. This risk-minimizing behavior (which effectively incorporates a delay event into a schedule whether it is realized or not) may be particularly pronounced at airports known to have chronic or highly variable delays associated with airside, ATB, or landside operations.

As an example, a passenger may add half an hour to a reasonable trip time to reach an airport from his or her residence (due to past experience of congestion on airport roads or at airport parking facilities). The passenger may then add another 15 minutes to a reasonable time for check in and boarding at the ATB (due to possible expected congestion). The passenger might also take a flight scheduled to arrive at the destination one hour earlier than necessary (due to the likelihood of airside departure delays and subsequent missed connections). In total, the passenger might add an hour and 45 minutes to his or her trip even if no delays are actually encountered.

A capacity project can lead to delay reductions that are substantial enough to cause aircraft operators, passengers, and shippers to place more confidence in flight and travel schedules (particularly if the project curtails the numbers of operations experiencing extreme delay events). After the project is completed, aircraft operators may reduce the amount of resources (aircraft and personnel) allocated to accommodate potential delays. Passengers travelling to time-sensitive events can take later flights and arrive at terminals closer to flight times--allowing better use of their time and terminal space.

Although the benefits of schedule predictability are potentially significant, it represents a relatively new category of benefit to FAA and lacks a well-tried methodology for its

quantification. Consequently, FAA will treat large claimed benefits from improved predictability with caution. However, if sufficiently large and well documented, this benefit can lend major support to an argument that a project is economically merited.

10.3.1.3 More Efficient Traffic Flows. Certain airfield improvements, including the positioning of new runways and additions of taxiways and crossovers, may permit aircraft to land, taxi, hold, and depart from an airport with reduced processing time. Reduced processing time may result from reduced time spent in airborne vectoring to an open runway within the terminal airspace and shorter taxiing distances to open runways or hold areas. These benefits would generally result in uncongested as well as congested conditions.

10.3.1.4 Use of Faster, Larger, and/or More Efficient Aircraft. Some capacity projects are intended primarily to accommodate faster, larger, and/or more efficient aircraft at an airport. These projects include new runways that exceed existing airport runway dimensions, and extensions to and/or strengthening of existing runways. Larger aircraft types, or current aircraft types carrying heavier fuel loads, can then fly directly to more distant locations (reducing route circuits) or carry more people at lower cost on existing routes. In the case of a capacity project that allows an airport to accommodate jet service for the first time, passengers will also experience shorter flight times to those direct destinations to be served by jet aircraft.

10.3.1.5 Compliance with FAA Safety, Security, and Design Standards. Airport capacity projects must conform to Federal Aviation Regulation (FAR) safety and security standards, including FAR Part 77, "Objects Affecting Navigable Airspace," Part 107, "Airport Security," and (if applicable) Part 139, "Certification and Operations: Land Airports Serving Certain Air Carriers." FAA also publishes airport design and performance standards in Advisory Circular (AC) guidance, including AC 150/5300-13, "Airport Design," and AC 150/5370-10, "Standards for Specifying Construction of Airports." From FAA's perspective, these standards establish the basic safety and security requirements for airport facilities, and the costs of complying with these standards are inherent to the minimum cost of any capacity project. No safety or security benefit can be claimed for the potential project's conformance to FAR safety, security, and design standards. In particular, it would be inappropriate to count as a benefit the correction of a safety, security, or design problem that would not exist if the project were not built.

Particular care should be assigned to the designation of the aircraft which will serve as the critical (most demanding) aircraft to which the airport design must conform. FAA AC guidance does not mandate that a capacity and/or standards investment must be made (and funded) if a particular critical aircraft that will serve the airport will require it. Rather, the guidance simply presents the safety and design guidance to which the airport must conform to be served by the critical aircraft. Consequently, the benefits associated with the airport's ability to accommodate the critical aircraft must be sufficiently large to cover the costs of expanding the airport in conformance with FAA standards.

A benefit for compliance with FAR and AC standards compliance may be taken when a new capacity project precludes the need to undertake remedial standards projects on pre-existing

infrastructure elsewhere on the airfield. For instance, a facility which was built before the issuance of current FAA standards may be used by aircraft too large to use it under the current standards. A new, additional facility built to FAR and AC standards and able to accommodate the larger aircraft (which would then be excluded from the original facility) would eliminate the need for a special project to modify the original facility.

10.3.1.6 Safety Benefits of Capacity Projects. A limited number of airfield projects intended to improve airport capacity may have a benefit of increasing the safety of airports that already operate in full conformance with FAA safety and design standards. This safety improvement is generally a consequence of implementation or improvement of precision and/or reduced-obstacle approaches and applies only to airports experiencing an overall upgrade in precision. Moreover, given the already very safe airport environment that results from compliance with FAR and AC standards, safety benefits attributable to capacity projects will be relatively minor.

10.3.1.7 Environmental Benefits of Capacity Projects. Environmental requirements of airport capacity and other projects are specified in FAA Order 5050.4A, "Airport Environmental Handbook." The cost added to a project for compliance with this guidance must be treated as an integral component of the cost of the new project. In general, no benefit may be attributed to the project for compliance with the requirements of FAA Order 5050.4A because the need for compliance would not have resulted were the project not built.

However, a capacity project may have positive environmental impacts that can be factored into the BCA. For instance, a new runway may permit an airport to redistribute air traffic from highly noise-impacted areas to less noise-impacted areas. In this case, environmental benefits may be claimed for the noise reduction to the formerly impact area.

By reducing the time an aircraft must spend waiting in queue for take-off, an airfield capacity project will also reduce the production of air pollutants by jet engines. In areas not in attainment of Clean Air Act standards, this reduction can be treated as a project benefit.

10.3.2 Rehabilitation of Airside Facilities: Airside facilities must be periodically rebuilt or replaced due to age, obsolescence, or premature structural failure. The critical benefit stream associated with rehabilitation will reflect the impact on the airport if the facility were allowed to fail. Thus, for a runway, it would be appropriate to determine the impact of the runway's loss on airfield delay, schedule predictability, ability to accommodate aircraft, compliance with FAA standards, and environmental conditions.

FAA expects that there will be relatively few situations where it will be cost-beneficial to allow a major airside facility to fail. The more interesting problem associated with decisions on rehabilitation concern development of the most cost-effective method to accomplish it--complete reconstruction, partial depth reconstruction, overlay, or intensive maintenance designed to defer the replacement decision further into the future. It may also be appropriate to relocate the runway. Determination of replacement strategies is essentially a study of comparative costs, and the focus of Section 11.4.

10.3.3 Acquisition of Airside Equipment Supporting Capacity: FAA is responsible for the economic evaluation, purchase, installation, and operation of landing and navigation aids acquired through its airways facilities and equipment (F&E) program. In the future, AIP funds may be used to acquire some such systems. FAA would retain BCA responsibility for AIP-financed systems but would conduct these analyses in close cooperation with the airport sponsor.

Acquisition of snow removal, maintenance, and other miscellaneous airfield equipment is not subject to Order 7031.2C or other FAA orders requiring BCA. Moreover, the cost of any one purchase of this equipment will seldom cost enough to require the application of the BCA procedure described in this guidance. In the event that a BCA must be performed, benefits would include reduced delay (stemming from the ability to keep capacity open in inclement weather) and improved productivity of airport personnel (lower operating and maintenance costs).

10.3.4 Airfield Safety, Security, and Design Standards Projects: FAA does not require that investments or actions intended solely or principally to improve an airport's compliance with safety, security, and design standards be subjected to BCA requirements (described in Section 10.3.1.5). The principal economic requirement applying to safety, security, and design investments and/or actions is that they be undertaken in the most cost-effective manner possible that is also acceptable to FAA.[1] However, were benefits of safety, security, and design standards projects to be measured directly in a BCA, they would include reduced fatalities, reduced injuries, and reduced property loss or damage.

[1]In some cases, FAA will have already conducted program-level BCA analyses on particular safety and security requirements, and in such cases the investment can be assumed to be cost-effective.

10.3.5 Environmental Projects: FAA does not require that investments or actions intended primarily to alleviate environmental problems associated with pre-existing facilities at the airport be subjected to BCA. Rather, compliance with the requirements specified in FAA Order 5050.4A must be accomplished in the most cost-effective manner possible acceptable to FAA. Were benefits of environmental (especially noise) projects to be measured directly in a BCA, they could include willingness to pay to avoid environmental degradation and avoided moving costs.

10.3.6 Air Terminal Building Capacity Projects: Air terminal building (ATB) capacity projects include new, reconstructed, or expanded ATBs, consisting of passenger halls, counter space, gates, baggage handling systems and areas, and passenger arrival and departure areas. Benefits of these projects chiefly take the form of reduced passenger and passenger meeter/greeter delay due to alleviation of ATB congestion, improved and/or shortened pedestrian traffic flows, and quicker unloading of passenger baggage.

Sufficient delay savings may induce some passengers to arrive at the ATB closer to actual flight times (rather than early to allow for potential delay), thus saving passenger time and reducing ATB congestion.

ATB delay benefits may extend to aircraft operations through the availability of more gates and the ability to transfer passengers more expeditiously between connecting flights. Other benefits of these projects are expedited air cargo handling, lower ATB operating and maintenance costs, and improved passenger comfort and convenience.[2]

10.3.7 ATB Security Projects: FAA does not require that ATB investments or actions undertaken to comply with FAA security regulations and requirements be subjected to BCA by the airport sponsor. As in the case of airfield projects, FAA's principal economic requirement is that the initiative represent the most cost-effective means that is also acceptable to FAA for conforming to the regulations.

10.3.8 Inter-Terminal Transportation: Larger airports with more than one ATB may undertake projects to expedite the movement of persons between the ATBs. Benefits of these projects principally include reduced delay for passengers, passenger meeter/greeters, and airport employees. Aircraft operators may also experience cost savings due to more efficient movement of crew members to gates and the ability to allow less time between connecting flights due to shorter inter-terminal passenger transit times.

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[2]Concession area projects are not eligible for AIP funding. To the extent possible, benefits (e.g., concession rents) and costs of concession projects should be removed from projects submitted for AIP funding.

10.3.9 Landside Access Projects: Efficient access to airports is vital to the perceived utility of air transportation. Access projects, including access roads on airport property, passenger pick-up and drop-off areas, parking areas, taxi/bus marshalling areas, and acquisition of road maintenance equipment, may yield important benefits. These benefits might be reduced landside delay for passengers, meeter/greeters, cargo shippers, and airport employees attempting to get to and from the airport by automobile, bus, taxi, or rail.

Passengers, meeter/greeters, and cargo shippers using automobile or trucks will benefit from reduced transit and vehicle hours due to less time spent in congested conditions and/or more efficient routing. Passengers, meeter/greeters, cargo shippers, and airport and airline employees may also be able to schedule travel time more efficiently because they will no longer have to allow time in their schedules for potential airport road or parking congestion. Landside congestion may also be alleviated if persons formerly arriving early for flights are now able to arrive closer to departure times.

Other potential benefits include reduced automobile emissions (due to fewer automobiles and trucks tied up in congested conditions), improved safety (for persons in vehicles and airport pedestrians), and lower operating and maintenance costs (due to less employee time spent in congestion while travelling on the airport grounds).

10.4 Step 2--Measurement of Benefits: Once the analyst has determined which benefits apply to a particular project, he or she must attempt to measure them in physical or time-based units. Measurement begins with the identification of material units of output associated with the benefit in question. Table 10.2 summarizes the material units associated with each benefit.

TABLE 10.2: MEASURES OF AIRPORT PROJECT BENEFITS

BENEFIT TYPE	MEASUREMENT UNIT
Reduced Delay	
• Reduced aircraft delay	• Reduced aircraft delay hours by airborne, taxi, or gate status for each aircraft class (air carrier, commuter, GA, military)
• Reduced passenger delay	• Reduced passenger delay hours by airside, ATB, and landside status • Reduced passenger vehicle delay hours in landside access
• Reduced cargo delay	• Reduced units of express cargo arriving at/departing from airport after time required to make guaranteed delivery time • Reduced air freight ton delay hours by airside, ATB, and landside status • Reduced truck delay hours in landside access
Improved Schedule Predictability	
• Aircraft operator ability to make more efficient use of equipment and personnel due to more predictable schedules	• Reduced numbers of aircraft and crew required to accommodate posted schedules
• Passenger confidence to take later flight with expectation of arriving at destination on time • Passenger confidence to arrive at ATB closer to flight time with expectation of making flight • Passenger confidence to leave residence or business later for airport with expectation of arrival at ATB in time for check in	• Reduced hours of passenger travel time scheduled to accommodate potential delay by airside, ATB, and landside components (less the amount of reduced delay associated with the project)
More Efficient Traffic Flows	
• Reduced aircraft vectoring and taxiing	• Reduced aircraft and passenger hours due to more efficient layout of runways, taxiways, hold pads, and aprons
• Shortened pedestrian traffic distances	• Reduced passenger time required to walk or travel within ATB (not attributable to reduced ATB congestion)

Use of Larger, Faster and/or More Efficient Aircraft	
• Reduced aircraft operation costs and shorter passenger travel times due to service by larger, faster, and/or more efficient aircraft	• Lower cost/fare per revenue passenger mile • Lower cost/charge per revenue cargo ton mile • Reduced passenger hours associated with new direct flights • Reduced passenger hours associated with new jet flights • Reduced cargo ton hours associated with new direct flights
Safety, Security, and Design Standard Benefits Associated With Capacity Projects	
• New capacity project complies with FAA safety, security, and design standards	• No benefits applicable. All new capacity projects must be built to FAA safety, security, and design standards to qualify for AIP funds.
• New capacity project enables compliance of pre-existing infrastructure within FAA safety, security, and design standards	• Value of most cost-effective alternative means to bring pre-existing infrastructure into compliance with FAA safety, security, and design standards (if new project were not built)
• Increased safety associated with precision approaches	• Number of precision approaches flown with new landing system (will be calculated by FAA)
Environmental Benefits	
• New capacity project complies with Federal environmental requirements	• No benefits applicable. All new projects must be built to Federal environmental requirements
• New capacity project brings pre-existing infrastructure into compliance with Federal environmental requirements	• Value of most cost-effective alternative means to accommodate Federal environmental requirements (if new project were not built)
Airport Operating and Maintenance Benefits	
• Lower operating and maintenance costs	• Reduced employees, power, fuel, and maintenance materials per passenger

Quantification of the physical outputs attributable to airport projects is accomplished through a variety of means, including simulation and analytical modeling, engineering estimates, review of industry data, passenger and air carrier surveys, and study of airport accounting data. In many cases, measurement of one critical output (e.g., reduced aircraft delay) can be used to measure several other outputs (e.g., reduced passenger and cargo delay) based on known aircraft passenger and cargo load factors.

10.4.1 Analysis of Airfield Delay Reductions: Delay reduction benefits of large-scale projects, such as those subject to BCA requirements for AIP grant consideration, should be measured through the use of capacity simulation models. Simpler, analytical models and methods

described in FAA AC 150/5060-5, "Airport Capacity and Delay") should be used only in situations that are well understood and/or uncomplicated.

10.4.1.1 Airfield Simulation Models. Airfield simulation models are queuing models that accept as inputs a series of events (airline and other flight schedules) and measure the flow of these events through a system with defined processing and performance capabilities (i.e., airfield and air traffic capacity). Arrivals and departures are linked in the schedule and are recognized dynamically. The models estimate aircraft operational delay as a function of demand in excess of processing capability.

Airfield simulation models vary in sophistication and computational requirements, depending on the range of factors, detail, and scope of the operating environment considered by the model. Sophisticated airfield models are time-consuming and expensive to operate. In general, the choice of a model should conform to the complexity and cost of the project. Projects with major impacts on regional airspace or which would cost $50 million should be modeled using more sophisticated simulation models (see Section 9 on level of effort).

FAA makes use of three simulation models for its airfield capacity analyses. These models are the FAA Airport and Airspace Simulation Model (SIMMOD), the Airfield Delay Simulation Model (ADSIM), and the Runway Delay Simulation Model (RDSIM). Of these, SIMMOD is the most complex. It considers airspace and airports in a selected geographical area (multi-airport configurations can be studied) and is capable of calculating delay impacts of a variety of operating alternatives, including different runway configurations, air routes, sectorization, and aircraft separation standards. A SIMMOD analysis generally requires several months in order to accomplish data collection, model specification, model runs, and interpretation of results.[3]

ADSIM calculates travel time, delay, and flow rate data to analyze operations at an airport and its adjacent airspace. An ADSIM analysis can generally be completed in two months or less. RDSIM is a sub-component of ADSIM that focuses only on an airport's final approach, runway, and runway exit. Analysis using RDSIM can often be completed in a matter of weeks. Information concerning all three of the above simulation models is available to the public through the FAA Technical Center. In addition, a growing number of proprietary models (many of which would be acceptable to FAA upon prior consultation) are also available and may be used.

10.4.1.2 Capacity Simulation Models. At a minimum, FAA acceptance of capacity simulation results is contingent on the analyst demonstrating that the following objectives were achieved:

- Estimation of realistic values for performance rates at the study airport;
- Analysis and determination of the interaction between arrival and departure rates;
- Measurement of airport performance under different weather conditions;
- Prediction of airport operational capacity; and

[3]See "SIMMOD User Manual," Release 1.2, March 1991.

- Evaluation of optimal airport capacity utilization.

10.4.1.3 Selection of Traffic Levels for Simulation. Delay reductions attributable to improvements in infrastructure are measured by first simulating average delays associated with projected traffic levels for the base case. Traffic levels are input into the model as aircraft operations.

Projections of base case traffic should be taken from the FAA TAF or some other FAA-approved forecast (see Section 5.2) which links the traffic levels with specific future years. At least three traffic levels should be simulated initially--one typical of the beginning of the project's operational life, one from the middle point of the project's operational life, and one from a year at or near the end of project's life. These selected traffic levels generally define the focus years for all project analysis. Intermediate years are generally approximated by interpolation and/or extrapolation.[4]

Simulation runs at each demand level should be conducted for representative weather conditions and runway configurations, and then annualized to yield average delay per operation over the course of a year. After completion of simulation analysis on the base case scenario, the parameters of the simulation model are adjusted to reflect the improvement in capacity associated with the investment alternative and the simulation is run again at the same traffic levels. Average delay per operation associated with the project alternative should be subtracted from delay associated with the base case to determine net delay savings attributable to the alternative being evaluated.

Simulation of Additional Traffic Levels. Simulation analysis of more than three future traffic levels may be required if traffic and/or delay are expected to grow rapidly. Inclusion of a fourth traffic level (usually intermediate to the middle and end levels initially tested) is particularly important if simulation analysis reveals that delay begins to grow exponentially beyond some level of demand which can reasonably be expected to occur.

Average delay estimated by simulation models usually builds gradually over some range of future operations growth and then may begin to mount rapidly as the extreme limits of the airport's capability are approached and exceeded. Plotted average delay curves where airport capacity has been exceeded should conform to the curvilinear trend shown in Figure 10.1. However, approximation of this curve by connecting the average delay estimates for the base case in years A, B, and C yields a poor approximation of the true delay trend. Inclusion of a fourth focus year, D, enables a much better linear approximation of the true curve.

[4]Due to the expense involved in simulation modeling, it is generally not practical to model every year of the project's operating life.

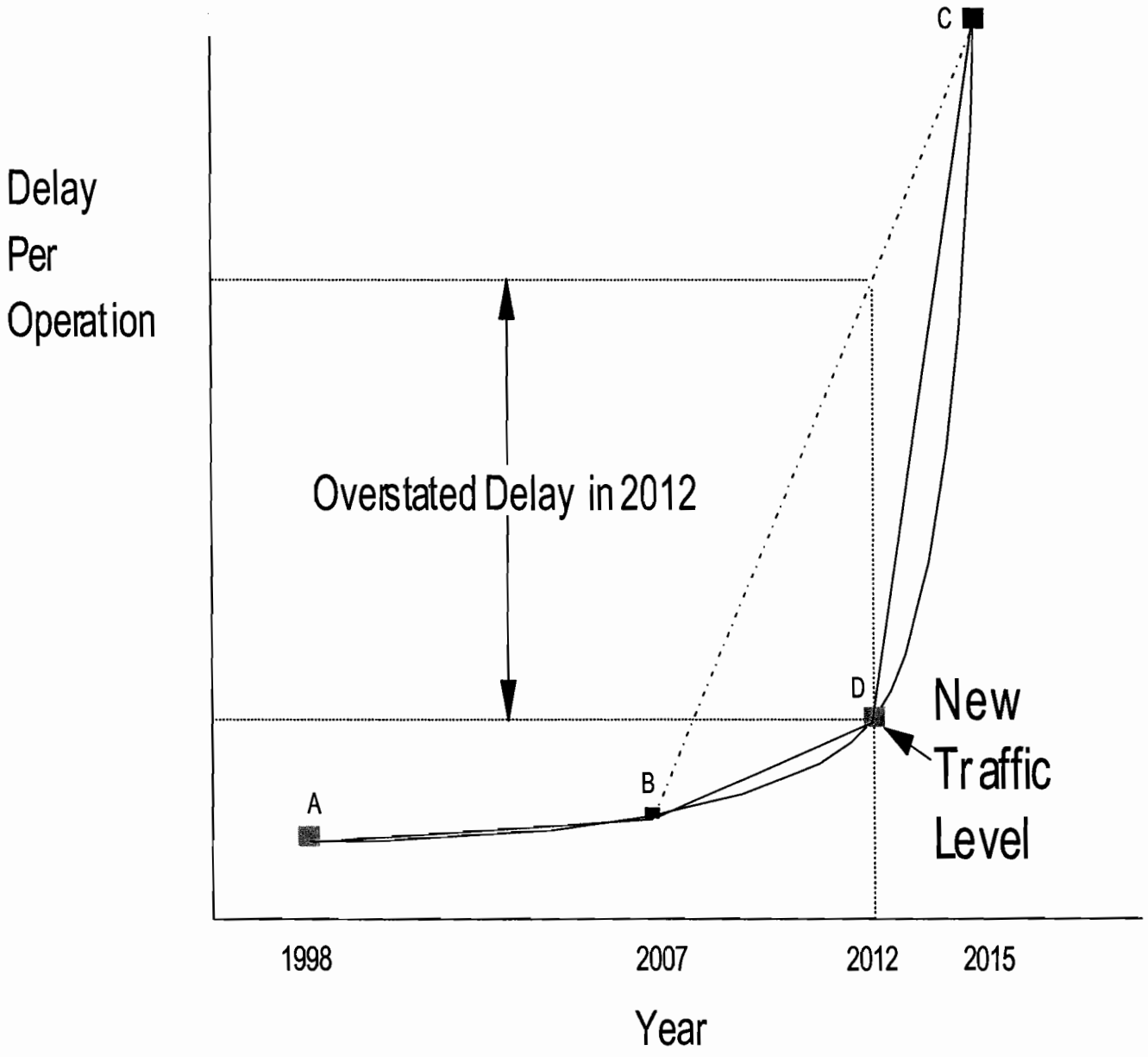

Figure 10.1: Approximation of Exponential Delay Curve

The poor fit of the three-point estimate could have serious repercussions for the BCA if it is used to calculate delays associated with levels of demand intermediate to those simulated. For instance, measurement of delay from the straight-line approximation in the year 2012 would overstate actual base case delay by a significant factor.

Demand Adjustment for Exponential Delay Growth. A second area of caution in simulation modeling concerns the finding of very large per operation delay savings attributable to investments. In particular, the analyst should be skeptical of the validity of per operation delay savings of 10 minutes or more resulting from an investment.

Airports experiencing severe delay due to congestion will not be able to accommodate rising demand for air service. Average delay per operation of 10 minutes or more may be considered severe. At 20 minutes average delay (approximately the highest recorded average delay per operation known to FAA at an airport in the U.S.), growth in operations at the airport will largely cease. Prior to reaching these levels, airlines would begin to use larger aircraft, adjust schedules, and cancel or consolidate flights during peak delay periods. Passengers would make use of alternative airports, seek other means of transportation (e.g., automobile or train), or simply avoid making some trips.[5]

Thus, it would be unrealistic to conclude that an investment would be unrealistic to conclude that an investment alternative would save more than 20 minutes of delay per operation relative to the base case. Instead, at some point where delay in the base case begins to increase exponentially beyond 10 to 15 minutes per operation, it would be appropriate to modify the traffic projection developed for the airport in Section 5.2. It would be more realistic to reflect a flat or only slightly escalating rate of growth once delay reaches 20 minutes[6]. Figure 10.2 illustrates the type of adjustment to traffic projections that would be appropriate as delay begins to exceed reasonable levels in the base case. The investment alternatives would also be simulated at the adjusted traffic levels. Capping of traffic growth is clearly an imperfect solution, in that it ignores real costs experienced by aircraft operators who must adjust or constrain schedules or by passengers who must seek other means of transportation due to excessive delays at a preferred airport. However, capping of traffic growth prevents the measurement of excessively high apparent delay savings that ignore the availability to airport users of alternative actions to simply waiting in line.

[5] It should be noted that these are average delay savings per operation, and reflect the averaging of minimal delays in non-peak hours with very long delays at peak hours. Passengers and airlines will react first to the excess delays at peak hours.

[6] Capping delay in excess of 20 minutes should be applied to the base case as well as the alternatives

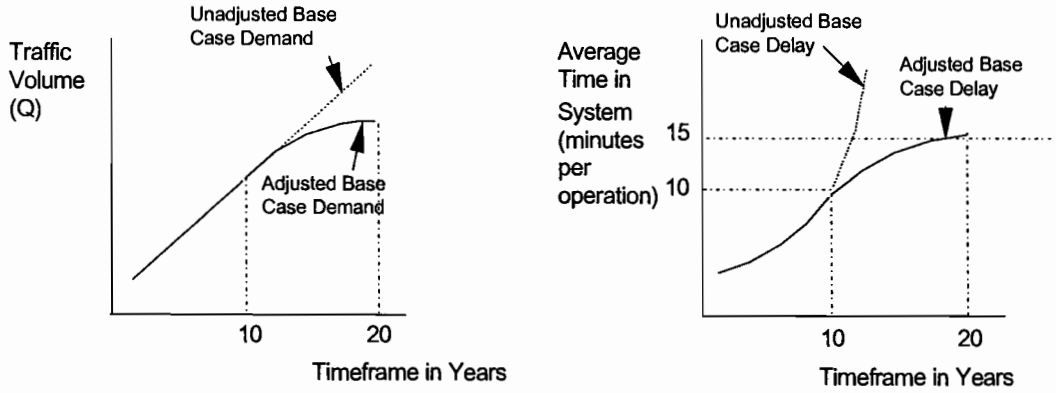

Figure 10.2: Adjustments to Base Case Demand Forecast

Allowance for Induced Demand. It is often the case with transportation projects that an improvement in service attributable to an investment at a facility will induce greater use of the facility than would have occurred without the investment. For instance, an investment that lowers average delay at an airport will induce some potential customers who formerly avoided the airport to use it. However, these additional users will place new demands on the facility and may to some extent erode the per operation delay savings to pre-existing airport users.

Although the phenomenon of "induced demand" is real, due to uncertainty in the data, its analysis is at the airport sponsor's option in the BCA and is the subject of Appendix C of this guidance. However, it is important when doing capacity simulations to anticipate the needs for data for calculating induced demand. Consequently, when preliminary simulation analysis reveals a significant delay saving attributable to an investment alternative, FAA recommends that the level of traffic associated with this delay result be adjusted upwards by small percentage increments and the model re-estimated at the augmented traffic levels. The following general guidance should be followed for deciding when incremental traffic adjustments may be appropriate:

- For projects where delay savings are expected to constitute the majority of project benefits, no adjustments to the simulated traffic level need be made when average delay savings associated with the project are 1 minute per operation or less. Time savings of this magnitude will generally not be sufficient to induce significant numbers of new passengers to use the airport relative to the base case traffic assumption.

- If other benefits besides delay reductions are expected to be prominent project benefits and/or if delay savings are more than one minute per operation, it is advisable to re-simulate the project alternative case assuming 2 percent increments in operations/passengers. As a rule of thumb, one 2 percent increment to base case demand should be simulated for the project case for each 3 minute saving attributable to the project. Thus, in the case of a project saving 6 minutes per operation relative to the base case, demand levels equivalent to the base case demand, the base case demand plus 2 percent, and the base case demand plus 4 percent should be simulated for the project case.

Resulting delays should be recorded and contrasted to the delays of the base case, as shown in the example of Table 10.3. Appendix C presents a detailed methodology for interpreting the data collected in Table 10.3.

10.4.1.4 Collection of Model Input Data. Data used to specify simulation models are taken from various sources. Larger airports can take advantage of FAA's Enhanced Traffic Management System (ETMS), which includes information on arrival (AZ), departure (DZ), and other Z messages. Other data sources include surface observation weather data, data provided by air traffic controllers, and data from airports on runway configurations (log records from some airports).

TABLE 10.3: IMPACT OF INDUCED DEMAND ON BENEFITS

A	B	C	D	E	F	G	H	I
BENEFIT	BASE CASE DEMAND PASSENGERS (PRE-EXISTING)			INDUCED PASSENGERS			TOTAL PASSENGERS	
	Saving Per Pre-Existing Passenger	Total Pre-Existing Passengers	Saving Existing Passengers in Year X Due to Investment (B*C)	Percent Pre-Existing Passenger Saving Applying To Induced Passenger	Total Induced Passengers	Total Benefits Induced Passengers (B*E)	Total Passengers (D+G)	Total Benefit Benefit W/O Correction For Induced Demand
Passenger Time								
Aircraft Operating Cost	$2.00	2,000,000	$4,005,000	50%	-	$0	$4,005,000	$0
Total Benefit	$1.08	2,000,000	$2,160,000	50%	-	$0	$2,160,000	$0
	$3.08	2,000,000	$6,165,000	50%	-	$0	$6,165,000	$0

10.4.1.5 Description of Delay. When possible, delay savings should be presented by class of aircraft and by where the delay would have occurred--in the air, on the ground, or at the gate. Description of delay by aircraft and location is critical to valuing the actual cost savings to the aircraft operator. For instance, a large air carrier jet delayed in the air will involve much greater costs than a small, one-engine aircraft delayed on the ground.

10.4.1.6 Airside Passenger and Cargo Delays. Airside delay affects both the aircraft delayed and the passengers and the cargo on board the delayed aircraft. Although airside simulation modeling provides direct estimates of delay reduction only on a per aircraft operation basis, this information can be readily converted into passenger and cargo units based on known load factors. Conversion to passenger units is particularly easy if, as is the case in FAA TAF forecasts, projections of operations were initially based on projected passenger growth.

Typically, the number of passengers per aircraft flight is equal to enplanements per flight plus passengers already on-board (for non-origin/destination flights) divided by two (because one flight consists of two operations). To the extent practical, it is useful to know the percentages of business and non-business passengers using an airport and to apply these percentages to total estimated passenger delay reductions. This distinction can be important, in that different valuations are generally assigned to the travel time of these two categories. Actual data on the mix of business and non-business passengers at an airport will generally only be available by passenger surveys.

Cargo load factor information is not available through FAA data sources. Where cargo aircraft delay reduction is expected to be significant (e.g., for an air cargo operator with flights during peak airport hours), data on inbound and outbound cargo tonnage and numbers of operations should be collected directly from the air cargo operator(s). In cases where cargo is delivered by conventional air freight carriers, delay hours per cargo ton is the relevant measure. Where cargo is delivered based on guaranteed delivery times (as with integrated express cargo carriers), numbers of cargo items too late for timely delivery could be the relevant measure. Consultation with the cargo carrier may reveal a more appropriate measure, which should be documented (see Section 10.5.5.3).

10.4.2 Analysis of Air Terminal Building Delay Reductions: Queuing models are used to simulate reductions in delays incurred by passengers and cargo moving through airport ATBs. Instead of aircraft movements simulated with airside capacity models, the ATB capacity models simulate passenger flows. Another important distinction from the airside capacity model is the addition of non-passengers who escort the departing passenger or meet the arriving passenger.

FAA does not maintain its own model for ATB delay estimation. However, two examples of available models are the Passenger Flow Simulation Model (Transport Canada) and the Airport Terminal Capacity Assessment Model (IATA).

10.4.2.1 ATB Demand. ATB demand is measured in terms of passenger and non-passenger volumes. Data available to measure this demand are annual passenger volumes and daily

passenger volumes, augmented by a factor (determined through a survey specific to the airport) to reflect non-passengers who accompany passengers. As time savings benefits must be calculated at or close to peak operating conditions, data on passenger and non-passenger volumes by time of day must be assembled.

10.4.2.2 ATB Capacity. ATB capacity and the utilization or strain on that capacity are vital components to establishing proper investment impacts on time-in-ATB. However, determination of capacity is the most difficult aspect of ATB evaluation. While it is relatively easy to measure the processing capacity of each processor of passengers and the storage capacity of each ATB area, the interaction of these components and their combined effect on capacity is difficult to determine.

The needed variables for capacity determination are as follows: maximum practical capacity (MPC); peak system utilization index (PSI); hourly system utilization index (HSI); and mean-to-peak ratio (MPR). The capacity of the airport system as a whole--the MPC--is a function of the demand pattern placed upon it. It is defined as the maximum number of passengers and non-passengers per hour that can be processed through the ATB without exceeding either the storage capacity or the processing capacity of any subsystem. System utilization or congestion indices can be calculated for ATBs using the MPC. Other indexes such as the PSI (the measure of intensity of use during the planning peak), the HSI (the measure of utilization during all airport operating hours), and the MPR (a measure of the severity of peaking) might also be of use.

Other indices of capacity relate to spatial and non-spatial ATB limitations. Spatial limitations include the airport size (measured in total floor space or ATB user walking distance). Non-spatial capacity measures included the number of processing stations (including ticketing, baggage handling, and security). Measures include ATB active walking space and mean walking distance.

10.4.3 Quantification of Landside Delay Reduction: Automobile traffic simulation models are available through public and proprietary sources. However, the FAA has not extensively studied them. Once such model is the MicroBENCOST model,[7] but other traffic models exist and are acceptable. Assistance should be sought through State and local planning boards and highway departments, who will also have important inputs with regard to overall traffic planning for the airport environs. Simulation analysis must consider capacity and peak factors comparable to those of ATB modeling, although the focus of the analysis should include vehicles as well as passenger volumes.

10.4.4 Improved Schedule Predictability: Measurement of the time and resources allocated by aircraft operators specifically to accommodate potential airport delays is difficult. Delay

[7]See "MicroBENCOST Program Documentation" and "Microcomputer Evaluation of Highway User Benefits: Final Report for NCHRP 7-12" prepared for the National Cooperative Highway Research Program by the Texas Transportation Institute, Texas A&M University System, College Station, Texas 77843, October 31, 1993.

accommodation practices will vary by operator, airport and city, prevailing weather conditions, and time of day. Passengers will also adjust their schedules to different degrees to accommodate potential delay at airside, ATB, and/or landside depending on their past experience with delay at the airport, the time sensitivity of their trips, and other factors.

Surveys of aircraft operators, passengers, and freight companies are the best means to quantify the amount of time allowed for potential delay. Operators and passengers should provide information on their delay accommodation behavior given present delay experience, and should be asked to provide information on their anticipated delay accommodation behavior if the frequency and/or severity of delays is altered. These responses can then be matched to the estimated delays associated with the base case and investment alternatives.

The estimated reduction in total hours of time and resources allotted for potential delays as a result of an investment alternative must be reduced by the total estimated hours of actual delay reduction caused by that alternative to avoid double-counting. In other words, if a 2 minute average delay reduction induces the passenger to reduce time allotted to potential delays by an average 3 minutes, the net saving per passenger attributable to schedule predictability is 1 minute (the other 2 minutes are already accounted for by the actual delay reduction). Time savings attributable to schedule predictability should be attributed to the source of the improved predictability, either at airside, ATB, or landside.

10.4.5 More Efficient Traffic Flows: Benefits to aircraft operators and passengers associated with more efficient airside traffic flow derive from shorter travel distances (in vectoring and taxiing) and the associated reduction in aircraft operating hours. These reductions are generally captured in the airfield modeling exercise used to measure delay, but are not, strictly speaking, delay benefits. This is because the same time savings will be realized regardless of congestion levels. Time savings associated with improved aircraft traffic flows (as distinct from delay reductions associated with decreased congestion) should be quantified and presented separately in the BCA.

Benefits to passengers from shortened pedestrian traffic distances in redesigned ATBs can be measured in reduced passenger time required to transit these distances. These time reductions measured in the ATB modeling exercise should be quantified and presented separately from time savings associated with reduced ATB congestion, if possible. Alternatively, in the case of some ATB expansions, walking distances may actually be lengthened. In such cases, the benefits of reduced congestion will be offset to some extent by the longer walking times.

10.4.6 Use of Larger, Faster and/or More Efficient Aircraft: The ability of a new project to enable the use of larger, faster, and/or more efficient aircraft is a potentially important but difficult-to-quantify capacity benefit. Whereas a new, long runway may permit an airport to accommodate larger aircraft for flights to more distant locations (thus reducing circuitous routing through hubs and/or operating costs), actual use of this new capability at an airport by aircraft operators is uncertain. Similarly, it is often difficult to anticipate how airlines may change their aircraft mixes and route structures in response to greater flexibility.

The airport sponsor must obtain data to measure the following impacts of service by more larger, faster, and/or more efficient aircraft:

- The impact of new services and aircraft on the prevailing cost and fare structure at the airport; and
- The reduced transit time enabled by new routes and/or aircraft.

These data can be developed from one or more of the following methods:

- Analysis of air service at comparable airports with runways of similar length to the proposed extended runway;
- Interviews with air carriers and other air service concerning their interest in, plans for, and commitment to the extension; and
- Surveys of passengers concerning potential demand for expanded services.

Selection of a particular method will depend on several factors, including the complexity and cost of the project and difficulty in collecting data. Complex or costly projects may require all three methods.

10.4.6.1 Interviews with Air Service Providers. Conferring with potential air service providers at the study airport can yield important information. The air service providers may have well-developed business plans for new services they intend to provide from an expanded facility, developed using sophisticated route and network analysis models. Care should be taken to acquire from each operator any available documentation which supports its assessments of the potential time or cost savings of the expansion (e.g., market surveys, cost savings attributable to more efficient aircraft) of the project in question.

Particular care should be used in assessing the realism of planned business expansions. FAA will heavily discount benefits claimed for projects that are not supported with documentation from current airport users. Similar scrutiny will be applied to benefit estimates for unspecified future operators or start-up operators who lack sufficient capitalization to support major activity expansions. Finally, FAA will view with caution claims for future use by operators who have little financial exposure should their plans for the new facility prove too optimistic.

10.4.6.2 Passenger Surveys. In the case of large or expensive projects, it is advisable that interviews with aircraft operators be supplemented with surveys of passengers and freight shippers with access to the study airport. Surveys should seek to determine whether passengers and/or air freight shippers would be responsive to proposed new services at the study airport based on expected routes, fares, schedules, and convenience of access to the study airport. Air carriers and other users of the airport should be consulted on the outcome of these surveys to check for reasonableness.

10.4.6.3 Analysis of Air Service at Comparable Airports. This approach involves collecting data on the actual types of services, fares, trip times, and other service measures at airports comparable in size and situation to the study airport. Ideally, if comparison airports can be found which vary from the study airport chiefly with regard to the facility being studied, benefits for the proposed facility can be estimated from the difference in the service measures between the comparison and study airports.

Comparability of airports should be established at several levels. Comparison airports should be selected based on:

- Comparable airport size and traffic levels to the study airport;
- Similar airport infrastructure, both before and after the investment being studied; and
- Location in communities with demographic (population, per capita income) and economic (business and industry) bases similar to those of the study airport.

As many comparison airports as possible should be studied, with at least 5 identified and analyzed. To the extent possible, airports should be from the same geographic region, in that regional factors such as weather, labor costs, and service providers can cause significant cost and service differences among regions. In addition, airports from the same region are more likely to have comparable average trip lengths (which reflect distance from the airport to the final destination).

Analysis should focus on the different passenger enplanements, air routes, trip times, and fare structures between the comparison and study airports. Data of this type are available from commercial vendors of aviation data provided by air carriers to the Department of Transportation Bureau of Transportation Statistics.[8] To the extent possible, causes for differences in service factors other than facility constraints at the study airport should be identified and discussed. The more comparison airports that are identified, the more confidence can be assigned to identified differences.

Of particular interest to a benefits analysis are differences between the airports with regard to fares and average trip times. In a competitive service market, lower fares per passenger are likely to reflect lower costs of providing air service at the airport. Lower costs may, in turn, reflect the use of more efficient aircraft. Average fares can be derived by multiplying average yield per revenue passenger mile (RPM) by average trip length. Assuming travel patterns (destination cities) and other non-infrastructure factors (passenger volumes) do not vary significantly among the comparison and study airports, systematically lower fares at the comparison airports may indicate lower costs attributable to their possession of the facility in question. Similar inferences can be considered in the case of shorter overall trip times. Shorter trip times may be the result of faster aircraft (jets rather than turboprops) and more direct flights.

[8]Unfortunately, aircraft cost information is not available on an airport specific basis.

A methodology for interpreting and valuing fare and trip time differences on a per passenger basis is presented in the Section 10.5.8.

10.4.6.4 Other Methods. FAA is receptive to any additional methodology for measuring the potential impact of infrastructure that accommodates larger, faster, or more efficient aircraft. Such methodology should be clearly described and documented.

10.4.7 Safety, Security, and Design Standard Benefits Associated With Capacity Projects: As noted in Section 10.3.4, FAA does not require a BCA for projects principally intended to accomplish safety, security, or design standards objectives. However, there are safety, security, and design standard benefits associated with some capacity projects.

10.4.7.1 Compliance With Safety, Security, and Design Standards. No benefit can be claimed for the compliance of a capacity project with FAA design standards (Section 10.3.1.5). However, some capacity projects may have a positive impact on standards compliance of pre-existing airport infrastructure. When this occurs, a standards benefit can be assigned to the capacity project BCA equal to the cost-saving associated with the mitigation of the standards problem elsewhere on the airport.

The compliance credit cannot exceed the cost of the least-cost alternative means of accomplishing the remedial compliance objective that is also acceptable to FAA. In other words, if the capacity project eliminates the need to expand a runway safety area elsewhere at the airport, the credit allowed in the BCA would not necessarily be the cost of expanding the safety area. Instead, it might be the cost of implementing a declared distances policy or some other operating restriction that would accomplish the same safety objectives. The costs of physical corrections should be derived from engineering estimates. The impact of a safety-related operating restriction on hours of delay at the airport can be measured using capacity simulation models.[9]

10.4.7.2 Increased Safety Associated with Precision Approaches. In instances where a potential capacity improvement will lead to an overall increase in the level of the precision approach to an airport (e.g., moving from only non-precision approaches to an ILS 1 system), FAA's Office of Aviation Policy and Plans will calculate the safety benefits attributable to this improvement. In doing so, FAA will comply with the current precision landing systems establishment criteria.

[9]In many cases where an airport does not meet FAA standards an operating restriction will already be in place. Delay reductions attributable to the removal of a pre-existing operating restriction will most likely already be captured through the simulation analysis described in section 10.4.1 and should not be double-counted. However, to the extent possible, this source of benefits should be separately categorized.

10.4.8 Environmental Benefits Associated With Capacity Projects: Projects undertaken principally to meet environmental objectives are not subject to FAA BCA requirements (see Section 10.3.5). Moreover, no benefit can be claimed for the compliance of a capacity project with Federal environmental standards (see Section 10.3.1.7). However, most airport capacity projects will have environmental impacts which should be included in the BCA as either benefits (positive environmental impacts) or costs (negative environmental impacts).

10.4.8.1 Noise Benefits. Measurement of noise impacts associated with capacity projects can be performed using various models. The Integrated Noise Model (INM) (Version 4.11) is currently used by FAA and is required in most noise assessments prepared for FAA. INM and related models reveal the extent of aircraft noise impacts by mapping regions that are unacceptably impacted. As such, noise models indicate the number of residences or structures that must either be purchased or modified to mitigate impacts under various scenarios.

INM analysis of a capacity project may reveal that a runway distributes noise away from an impacted area and thus reduces the number of homes (now or in the future) within the 65 and 70 DNL zones. This reduction would eliminate the need to purchase or soundproof these homes. The analyst should be specific about the timing of this impact. For instance, relative to the base case, the 65 DNL zone might be reduced by 250 homes in year X and 500 homes in year X+5. In this case, a benefit of 250 homes would be cited in year X and 250 homes in year X+5 (the increment in homes from year X to year X+5).

10.4.8.2 Air Emissions. The Emissions and Dispersion Modeling System (EDMS) enables analysts to calculate the air quality at airports caused by all pollution sources (e.g., aircraft and passenger and employee automobiles). EDMS and other models will indicate the amounts of pollutants emitted by various airport sources under different operating scenarios. The FAA Office of Environment and Energy (AEE) should be consulted on the potential use of this model.

10.4.9 Lower Airport Operations and Maintenance (O&M) Costs: Airport investments will frequently lead to reductions in the resources needed to operate and maintain the airport, thus providing greater efficiency and productivity. For example, rebuilding of an ATB to accommodate additional passengers will also provide cost savings in the form of lower resources needed to operate and maintain the new structure. Efficiency savings may involve reductions in the number of airport personnel required to serve each passenger, reduced electrical power requirements, and other reductions in utility requirements. Although these savings are often treated as benefits (i.e., foregone costs), FAA categorizes O&M as a life-cycle cost item. As such, FAA recommends that O&M savings associated with different investment alternatives be summarized in the project cost component of the BCA.

10.5 Step 3--Valuation of Benefits: The methods described in Section 10.4 will yield estimates of the actual units of resources saved or generated by alternative investments relative to the base case. In order to aggregate these benefits into one overall monetary measure so that they can be compared to costs, economic values must be attached to each measured resource unit. Prior to discussing the valuation of individual benefit units developed in Section 10.4, it is

appropriate to describe some of the general economic concepts that underlie the valuation of resource units, including the use of constant dollars and the treatment of incremental and fractional units.

10.5.1 Constant Dollars: All economic values for benefits and costs should be assigned in terms of constant (real) dollars of given year--usually the year in which the BCA is conducted. If the BCA study takes place in 1999, the value of a unit of output from a project (regardless of the future year in which it is realized) should be presented in terms of its 1999 dollar value.

A unit of a given output will generally maintain the same constant dollar value throughout a project's life. Only in a situation where the relative value of an output is expected to change over time (i.e., a unit of this output will become relatively more valuable when valued in terms of other real outputs) would application of a changing value (in constant dollars) be appropriate. The use of constant dollars greatly reduces the complexity of later discounting of benefits and costs.

10.5.2 Equal Valuation of Incremental Units: FAA recommends that incremental benefit units of the same type be valued equivalently to each other. That is, the hundredth unit of benefit X should be assigned an economic value equivalent to the thousandth unit of benefit X. For certain projects generating very large benefit flows, this practice may lead to an incorrect valuation of incremental benefits (due to the economic concept of diminishing marginal utility). However, the difficulty and uncertainty associated with accurate measurement of marginal changes in unit value will generally exceed the potential addition to accuracy associated with adjusting values.

10.5.3 Valuation of Fractional Benefit Units: Aggregate measurements of benefits are often composed of large numbers of fractional unit savings. For instance, a total annual time saving associated with a project may be 2,000 hours, but this total may be assembled from many thousands of individual times savings ranging from 1 minute to half an hour or more. It is Department of Transportation policy that fractional benefit units be valued at the same per unit value as whole units. In other words, if an hour of passenger time is worth $X, a saving of 5 minutes of passenger time should be valued at 1/12 $X. This recommendation is economically justified and greatly simplifies the valuation of total project benefits.

Some economists argue that small, fractional-hour time savings should be valued at a lower per unit rate than longer time savings (e.g., an hour per person) because they are too small to be used effectively or to be noticed by the traveler. FAA has contended that all time savings, fractional or otherwise, be valued at the same per hour rate for following reasons:

- The generally accepted theory of the value of time savings does not distinguish between fractional units of time and larger amounts;
- There is no evidence that travelers value small time saving at a different rate than larger time savings;
- Average time savings generated by simulation models may mask wide variations in individual delay experiences. For instance, an investment may save 3 persons out of 60

one hour of delay each, whereas the other 57 persons may experience no saving. The average delay saving per passenger would be 3 minutes--an amount that may appear to be too small to be useful even though it is actually realized in larger units;

- The definition of a particular "threshold" (e.g., 10 minutes) for useful time savings would be arbitrary;
- Time savings are cumulative over the length of an entire trip. For instance, if a person incurs nine minutes of delay savings from non-airport sources (either aviation or non-aviation), a one minute additional delay saving at the study airport would push this person over a 10 minute "threshold" (were such a threshold valid); and
- Similarly, suppose several separate projects are under consideration at an airport and each would save the same traveler one to 3 minutes. If the small time savings were valued at a lower rate or not at all, it is likely that none of the projects would pass a BCA. However, if considered collectively, the projects' benefits could exceed a particular threshold and receive full value. Under this scenario, the projects may be shown to be cost-beneficial.

10.5.4 Summary of Unit Values for Benefits: Table 10.4 summarizes the unit values that should be applied to each of the benefit types quantified in Section 10.4.

10.5.5 Valuation of Delay Reductions: Once the number of hours of delay reduction for aircraft, passengers, cargo, and (if quantified) passenger meeter/greeters has been determined, a per hour value should be assigned. The following information expands on Table 10.4.

10.5.5.1 Valuation of Aircraft Delay Reductions. Estimated annual hours of reduced delay should be multiplied by appropriate per hour variable operating costs to yield annual estimates of the value of saved aircraft delay. The value of an hour of reduced aircraft delay is usually

TABLE 10.4: VALUATION OF AIRPORT PROJECT BENEFITS

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
Reduced Aircraft Delay Hours		
• Reduced aircraft delay hours by airborne, taxi, or gate status for each aircraft class (air carrier, commuter, GA, military)	Operating cost per aircraft hour, adjusted for aircraft class and delay location status. In limited cases, saved aircraft capital cost may be considered.	Documented operating cost data (net of depreciation) provided by aircraft operators (if available). Consult FAA-APO-98-8for aircraft type or class values by block hour. Where aircraft fleet size can be reduced due to large delay savings, use published used aircraft values (see FAA-APO-98-8). FAA-APO-98-8 also contains current lease values.
Reduced Passenger Delay Hours		
• Reduced business and non-business passenger delay hours by airside, ATB, and landside status	Passenger willingness to pay to avoid one hour of travel delay	FAA-APO-98-8 contains the passenger travel time values which OST has developed and requires FAA to use.
• Reduced passenger vehicle hours in landside access	Passenger vehicle operating costs	Current FHWA estimates.
Reduced Air Cargo Delay Hours		
• Reduced air cargo ton hours by airside, ATB, and landside status	Opportunity cost of cargo delayed in transit/Spoilage of time sensitive cargo	Documented data on value of cargo provided by operators (if available). Apply 7 percent real opportunity cost (annual basis) to value of cargo for period delayed.
• Units of express cargo arriving late at airport after time required to make guaranteed delivery time	Refunded shipping revenue for late package delivery or greater resource costs expended to compensate for airport delays	Documented data provided by operators.
• Reduced trucking hours in landside access	Cargo vehicle operating costs	Current FHWA estimates for light trucks (including driver costs).
Reduced Meeter/Greeter Delay Hours		
• Reduced meeter/greeter delay hours by airside, ATB, and landside status	Meeter/greeter willingness to pay to avoid one hour of delay	FAA has not assigned a value to meeter/greeter time. Sensitivity analysis should assume half the values applied to passenger time in FAA-APO-98-8.

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
Improved Schedule Predictability		
Reduced Aircraft Delay Hours		
• Reduced resources needed to meet flight schedules	Cost of resources allocated to accommodate potential delays	Documented cost data provided by operators (if available).
• Reduced hours of passenger travel time scheduled to accommodate potential delay, less reduced actual delay, by airside, ATB, and landside status	Passenger willingness to pay to avoid one hour of scheduled travel time	Use passenger travel time values in FAA-APO-98-8.
More Efficient Traffic Flows		
• Reduced aircraft hours in airspace and on ground due to more efficient layout of runways, taxiways, and aprons	Operating cost per aircraft hour, adjusted for aircraft class and airborne, taxi, or gate status (if available).	See Reduced Aircraft Delay
• Reduced passenger hours due to more efficient airside, ATB, and landside traffic flows	Passenger willingness to pay to avoid one hour of scheduled travel time	See Improved Schedule Predictability/Reduced Hours of Scheduled Passenger Time
Use of Larger, Faster and/or More Efficient Aircraft		
• Lower cost due to more efficient aircraft	Cost or fare reduction per passenger/cargo unit	Information provided by aircraft operators (if available). Commercially available data on average yield, destinations, and trip distance at subject and comparison airports.
• Reduced passenger hours on direct flights or jet flights	Passenger willingness to pay to avoid scheduled travel hour	See Improved Schedule Predictability/Reduced Hours of Scheduled Passenger Time for valuation of reduced trip hours.
• Reduced cargo hours on direct or jet flights	Opportunity cost of cargo in transit/Reduction in resources to meet guaranteed delivery times	See Reduced Air Cargo Delay
Safety, Security, and Design Standard Benefits Associated With Capacity Projects		
• Accommodation of safety, security, and design standards of pre-existing airport infrastructure	Lowest-cost alternative means to achieve compliance of pre-existing infrastructure with FAA standards	Engineering cost estimates of alternative project designed specifically to correct sub-standard conditions. Compare to delay cost imposed by an operating restriction to accomplish same objective.

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
Safety Benefits of Capacity Projects		
• Precision approaches enabled by new landing system	Reduced fatalities, injuries, and property damage per precision approach	Benefits calculated by FAA.
Environmental Benefits of Capacity Projects		
• Accommodation of environmental standards for pre-existing airport operations	Lowest-cost alternative means to attain compliance with standards	Engineering cost estimates of project designed specifically to correct sub-standard environmental compliance. Compare to delay cost imposed by an operating restriction to accomplish same objective.
Airport Operating and Maintenance Benefits		
• Reduced employee, power, fuel, and maintenance per passenger	Cost reduction in personnel, energy, and supplies. To be treated as cost element (see Section 11).	Airport accounting records and management cost estimates.

assumed to equal the aircraft's variable operating cost. Variable operating costs include crew costs, maintenance, and fuel and oil consumed.

Variable operating costs used to value aircraft delay reductions at an airport will depend on the type of aircraft affected by the investment and whether the delay reduction is realized in flight, while taxiing, or at the gate. Clearly, delay savings at an airport serving primarily commuter and light aircraft will be valued at a lower per hour rate than delay savings associated with a major hub airport serving large jet aircraft.

Similarly, an hour of aircraft time in flight is more costly than an hour or aircraft time at an ATB gate with engines off (due to fuel burn and maintenance factors). Thus, it is especially important that variable operating cost values reflect the conditions under which the delay would have been realized had the investment not been in place. Use of full, in flight aircraft operating costs would clearly overstate actual savings from delay reduction if most of the time saved would have been realized at an ATB gate with engines off. Special care should be taken in the interpretation of arrival delay as airborne delay. Arrival delay at the study airport will often take the form of a flow control ground hold at another airport.

Fixed cost savings (the capital cost of the airplane) are usually not included as benefits for projects involving small to moderate reductions in delay, in that such delay savings will generally not affect fleet allocations by operators. Only in a case where a project leads to very large delay reductions such that an operator could accommodate a given service level with fewer aircraft should aircraft capital cost savings be considered as a benefit.

At airports served by a relatively small number of air carriers, variable operating cost data can be collected directly from the aircraft operators. However, at many airports, comprehensive surveys of aircraft operators may be impractical due to the reluctance of some to share data or simply due to the large numbers of operators (particularly where GA is a major component of traffic).

A comprehensive discussion of aircraft operating cost and other economic values relevant to airport project BCAs is available in the FAA publication "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs" (FAA-APO-98-8, June 1999). This publication specifically addresses aircraft operating costs (for both air carrier and GA) and also covers aircraft capital costs (in the form of aircraft replacement costs). In addition to describing data sources, the publication presents tables of values for different aircraft types. Values should be converted to current dollars using the methodology described for aircraft variable operating costs in FAA-APO-98-8 (also see Appendix A of this guide for more information on use of price indexes).

10.5.5.2 Valuation of Passenger Delay Reductions. Reductions in delay hours to passengers are valued according to the willingness of passengers to pay to avoid travel delay.

The value used in the BCA should that described in FAA-APO-98-8. If the mix of business and non-business passengers is known, the separate value estimates for these categories can be applied to the pro-rated portions of the delay reduction reflecting these two passenger groups.

In the case of landside project where delay reductions lead to decreased use of passenger vehicles, a value equal to the reduced variable operating costs of the vehicles may be attributed to reduced vehicle hours. The Federal Highway Administration should be consulted for data on automobile variable operating costs.

10.5.5.3 Valuation of Air Cargo Delay Reductions. Whereas Section 10.4.1.6 propose a basic means for quantifying cargo delay in terms of hours, FAA has not settled on a general methodology for valuing reductions in shipping time for air cargo. Thus, the following guidance on valuation is intended only to suggest possible approaches that would be acceptable to FAA. FAA encourages the development of innovative alternative approaches, provided they are well-documented and reproducible.

Conventional Air Cargoes. In most cases, the cost of delay in the delivery of conventional air cargo (belly cargo and cargo carried by traditional all-cargo carriers) will be absorbed by the shipper and/or recipient of the air cargo. Delay to shippers and/or recipients in delivery of non-perishable cargo can be conservatively valued based on the average value of a ton of air cargo multiplied by OMB's estimate of the return to capital in the U.S. economy.[10] By way of example, if a ton of cargo valued at $5 million is delayed by 2 hours, the cost of this delay would equal $5 million multiplied by 2, divided by 8760 hours (the hours in one year), and

[10]See Section 12 for a discussion of the time value of money.

then multiplied by 7 percent (yielding $80). In the case of perishable cargoes, such as fresh produce or flowers, the cost of spoilage or reduced shelf life should be estimated, documented, and added to the estimated time value of an hour of delay.

Delay may also result in critical logistical problems for shippers, leading to large expenses or revenue losses. Unfortunately, estimation of these costs is highly situation-specific and extremely difficult to document.

Guaranteed Delivery Cargoes. Delays incurred by integrated, door-to-door package carriers can result in direct monetary losses to the carrier, either due to refunded shipping fees or higher operating costs needed to expedite late packages. If clearly documented, these higher costs per package delay hour could be used to measure the value of measured delay savings. As in the case of conventional air cargo, the package recipient may have important logistical needs for package. In many cases, the refund of the shipping fee will not compensate these parties for the late delivery of a critical package or part. Unfortunately, there is no method to capture fully this impact, which will vary widely based on circumstance.

Required Documentation. Both in the case of conventional and integrated cargoes, it is clear that the high degree of reliance on data provided by proprietary operators places a premium on documentation of claimed benefits by the operators in question.

10.5.5.4 Valuation of Meeter/Greeter Delay Reductions. FAA has not yet established a formal policy recognizing the role of benefits to persons who meet or escort people at ATBs, nor has it developed formal values to be applied to reductions in meeter/greeter delay time. Meeter/greeter activity is often voluntary and not essential to completion of the air trip. On the other hand, the meeter/greeter's time clearly has a real value to both the meeter/greeter and, presumably, to the passenger accompanied. Until FAA is able to establish a firm value per hour of meeter/greeter delay, it is recommended that meeter/greeter time be valued at one-half of the value assigned to the passenger associated with the meeter/greeter. Moreover, it is recommended that the measured benefit should not be included as a core benefit in the BCA, but rather should be treated as qualitative information to the BCA.

10.5.6 Improved Schedule Predictability: Valuation of reduced time allotted for potential delays (whether incurred airside, landside, or in the ATB) is done by multiplying the reduction in time allocated for delays (less the reduction in actual delays) by the appropriate opportunity cost of that time. Aircraft, passenger, and cargo schedule time savings should be valued at the per hour rates defined in Section 10.5.5.[11]

[11]Time allocated to accommodate potential delays, as well as time spent in non-delayed travel, may be valued at a somewhat lower rate than time spent in unexpected delay. Consequently, Table 10.4 is structured to allow the potential placement of different time values for scheduled travel time as opposed to unscheduled time. FAA official values for time should be used pending further notification.

10.5.7 More Efficient Traffic Flows: Estimated reductions in travel time attributable to more efficient airside, ATB, and landside infrastructure are frequently mixed in with estimated reductions in delay as determined by capacity models. However, when possible, benefits associated with more efficient design should be isolated and valued separately according to the same values defined for delay in Section 10.5.5.

10.5.8 Use of Larger, Faster, and/or More Efficient Aircraft: Benefits associated with airside improvements that enable larger, faster, and/or more efficient aircraft to serve an airport are measured both in the form of reduced cost per revenue passenger mile and reduced passenger time in transit.

10.5.8.1 Lower Cost Per Revenue Mile. Information provided by carriers on cost reductions associated with the use of more efficient aircraft may be used directly if the information is well documented.

10.5.8.2 Reduced Time In Transit. Trip time reductions due to faster aircraft and/or more direct flights can either be derived from carrier-provided information or by study of trip times at comparison airports. Reduced time in transit should be valued at the standard value per hour of passenger time or cargo time (see Section 10.5.5).

10.5.9 Safety, Security, and Design Standard Benefits Associated With Capacity Projects: The standards compliance credit that can be taken for a capacity project that corrects a pre-existing standards problem at an airport cannot exceed the most cost-effective alternative means to have corrected the problem. Determination of this value will equal the lesser of the lowest cost physical correction (determined through engineering estimates) or the lowest cost operations restriction (estimated by simulation modeling of delays and other inefficiencies imposed by the restriction). Aircraft, passenger, and cargo delays associated with operating restrictions would be valued using the methodologies described in section 10.5.5.

10.5.10 Safety Benefits of Capacity Projects: FAA will assign appropriate values to safety benefits associated with upgrades in precision landing systems. Guidance on appropriate values to assign to avoided fatalities, injuries, and property damage are provided in FAA-APO-98-8. Values for avoided fatalities and injuries, when updated by the Office of the Secretary of Transportation, are published in FAA/APO bulletins.

10.5.11 Environmental Benefits of Capacity Projects: The environmental credit that can be taken for a capacity project that mitigates a pre-existing environmental problem at an airport cannot exceed the most cost-effective alternative means to have corrected the problem. Determination of this value will equal the lesser of the lowest cost physical correction (determined through engineering estimates) or the lowest cost operations restriction (estimated by simulation modeling of delays and other inefficiencies imposed by the restriction). Aircraft, passenger, and cargo delays associated with operating restrictions would be valued using the methodologies described in section 10.5.5.

10.5.12 Airport Operating and Maintenance Benefits: Reductions in the resources needed to operate and maintain the airport (relative to the base case) should be treated in the cost side of the BCA. The analyst should consult airport accounting records and management cost estimates to value these savings.

10.6 Hard-To-Quantify Benefit and Impact Categories: A natural follow-on to valuation of the benefits described in Section 10.3 is the identification and description of benefits and impacts which are too difficult to quantify or cannot be evaluated in dollar terms--referred to in this guidance as "hard-to-quantify" benefits and impacts. Hard-to-quantify benefits and impacts should not be neglected and can be very important to the outcome of the analysis and a decision on whether to pursue a particular alternative.

Hard-to-quantify benefits described below include:

- Measurement of systemwide delay caused by local airport delay;
- Passenger comfort and convenience; and
- Non-aviation macroeconomic and productivity impacts.

10.6.1 Systemwide Delay: Simulation modeling of delay at the study airport does not capture the effect of "follow-on" delays, e.g., delays that result at other airports as a result of delays originating due to congestion at the subject airport. Whereas FAA attempts to consider systemwide delay impacts in its capacity analyses, it has been unable to develop a robust simulation methodology for measuring these impacts.

Efforts by FAA to simulate follow-on delay have emphasized the use of systemwide delay models such as the National Airspace System Performance Analysis Capability (NASPAC) model and the Airport Network Model (AIRNET). These tools permit the analyst to study the potential effects of system performance problems, usually measured in terms of delays, as they propagate through the nation over the course of a day. However, in practice, the models have proved more useful for general diagnostic analysis (e.g., indicating which destination airports are most sensitive to schedule disruptions) than in quantifying follow-on delay impacts. Problems with the models include their inability to recreate the dynamic rescheduling undertaken by airlines in the event of major schedule disruptions or permanent changes in airport capacity.

Consideration of follow-on delay impacts is probably unwarranted for projects with fairly small reductions in average delay (e.g., 2 minutes or less). However, in the case of projects with major average delay reductions (5 minutes or more), the analyst may attempt to quantify follow-on effects. FAA will consider follow-on delay reduction estimates developed from any methodology that is well documented.

An example of a potentially usable methodology is one developed by Lincoln Laboratory.[12] The Lincoln Laboratory approach is based on a matrix of probabilities that delays of various lengths (less than 10 minutes, 11 to 20 minutes, etc.) at one airport will carry over to downstream airports. The analyst could retrieve data on flight delay reductions by flight from simulation model results and apply the specified probabilities from the Lincoln Laboratory matrix as a first approximation of total delay saved. Technical Supplement No. 3 of "A Study of the High Density Rule" (July 1995) illustrates one application of this methodology.

10.6.2 Increased Passenger Comfort and Convenience: Some capacity investments made at airports, particularly in ATB facilities, have the specific goal of improving the comfort and convenience of passengers and persons accompanying them. Such improvements may have a significant impact on the passenger's perception of the utility of flying from a particular airport and may yield benefits to both the airport and the airlines through increased enplanements and concession revenues. Unfortunately, comfort and convenience are highly subjective benefits that are difficult to quantify, particularly with regard to the utility of aesthetic considerations.

One gross measure of passenger comfort is the increase in square feet of non-concession public areas. Other parameters that may be measured are seats available in waiting areas, number of rest facilities, etc. Expanded concession areas also may be viewed as enhancing public comfort, but are not eligible for AIP grants and should not be included in project BCAs submitted to FAA for consideration for AIP grants.

FAA does not have official economic values for measures of passenger comfort and convenience. Consequently, presentation of data on improved passenger comfort (e.g., increased square footage of public areas) will in most cases be supplemental to the BCA calculation. However, for projects where a major benefit is expected from improved passenger comfort, it may be appropriate to undertake a contingent valuation study based on a survey of passengers.

A contingent valuation study involves constructing a survey methodology that asks people what dollar amounts they would be willing to pay for improved comfort. The main disadvantage of this approach is that there is no assurance that the analyst will obtain reliable answers to survey questions since, unlike market decisions, individuals may have less of an incentive to give an honest and thoughtful response to a survey question. Moreover, respondents may not accurately process amenity information presented to them. Special care must be taken in the contingent valuation study to present benefits in a manner understandable to the passenger. Despite these limitations, the contingent valuation survey methodology has potentially great usefulness, particularly in contexts in which good market data are not available.

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[12]Boswell, Steve, Lincoln Laboratory, Massachusetts Institute of Technology: "Analysis of Downstream Impacts of Air Traffic Delay and Estimation of Downstream Delay Reduction Due to ITWS," (August 1994, unpublished).

10.6.3 Non-Aviation Impacts: FAA is charged with making investments that improve the airport and airway system--investments that are funded by taxes on aviation users. As noted in Section 2 of this guidance, non-aviation impacts to communities from airport investments are generally not included in FAA BCA studies. In addition, Section 6(b)(3) of OMB Circular A-94 generally rules out consideration in BCAs of employment or output multipliers that purport to measure the secondary effects of government expenditures in measured social benefits and costs. On the other hand, OMB believes that true non-aviation benefits which result from investments in aviation infrastructure should be counted. An example might be preservation of wetlands as a result of airport landbanking.

However, the FAA is receptive to information on certain classes of non-aviation impacts, including macroeconomic and productivity gains. Macroeconomic gains include the expansion of employment and income as a result of the investment project. Productivity gains include benefits such as the restructuring of business logistics systems to take advantage of improvements in air service. Macroeconomic and productivity gains should be listed separately from the aviation user benefits estimated for the project and should not be included in BCA measures.

10.6.3.1 Macroeconomic Gains. Methodologies for estimating direct employment creation (via survey or input-output analysis) and indirect and induced employment multipliers (from input-output analysis) are well established. However, macroeconomic gains can only be treated as a form of benefit if they are "incremental." That is, they are gains only if they would not have accrued to the national economy in the absence of the project.

Applications of input-output methodologies often fail to measure incremental impacts properly. The relocation of an operation from one region to another (e.g., the relocation of an air cargo hub) will generate apparent macroeconomic gains for the recipient region but will cost the donor region comparable gains. Measurement and comparison of the macroeconomic impacts for each region (or at a national level) could well yield a neutral macroeconomic impact.

Similarly, the incrementality of direct, indirect, and induced multiplier effects hinges upon the extent of structurally unemployed labor and surplus productive capacity in the regional economy. A key element in evaluating incremental impacts involves comparing the direct employment expected to be generated by a project to the number of unemployed in the city or greater metropolitan area where the investment is being undertaken. Only if (1) the expected number of unemployed persons in the regional economy in a particular year is greater than or equal to the direct, indirect, and induced employment impact in the same year and (2) the jobs are not displaced from another region, can the complete set of direct, indirect, and induced impacts be assumed to be fully realized. In the case when the estimated employment impact exceeds the expected number of unemployed, the direct, indirect, and induced impacts are limited to the number of job vacancies in the local economy.

Presentation of macroeconomic gains should be accompanied with a detailed description of the methodology used to calculate these gains. However, even with the precautions recommended above, macroeconomic gains estimates will still be subject to large uncertainties because the stimulative macroeconomic effects of airport projects are generally small in relation to the overall volume of national and regional macroeconomic activity.

10.6.3.2 Productivity Gains. Companies and workers may obtain productivity gains if they restructure their logistics of doing business due to improved airport facilities. These improved logistics are not measured in input-output models since these models almost always reflect a fixed logistics technology.

Only a limited number of studies to date have attempted to quantify productivity gains.[13] In these studies, data collected from a survey of industry are used to estimate elasticities (measures of sensitivity) of gains to industry from changes in transportation system attributes. Based on these estimates, schedules of gains corresponding to different levels of transportation system improvements can be derived.

As would be expected, potential gains from the logistics response by industry is contingent upon specific firm and industry characteristics. Firms for which logistics costs are a large share of total cost and which operate on low margins are most likely to take advantage of the ability to improve their logistics systems.

Relatively few airport projects will be candidates for productivity analysis, in that the project must result in a fundamental change in the cost of doing business. Such projects may include new airports, major airport or access road expansions, or installation of runways that permit larger aircraft to use the airport. Given the early stage of development of this type of analysis, FAA will consider claimed productivity gains separately from conventional BCA results.

10.7 Special Case of New Airports: One of the most difficult applications of BCA criteria is to new/replacement airports. Proposals for new airports could include the following:

- Construction of a regional airport to consolidate traffic from several smaller airports and thus realize more service and/or lower fares;
- Construction of an airport to replace an obsolete or poorly-situated airport that is subject to severe delays or service limitations; and
- Construction of an airport to supplement a nearby congested airport.

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[13]One such study is by Hickling Lewis Brod Inc., Measuring the Relationship Between Freight Transportation and Industry Productivity, Transportation Research Board, National Research Council, 1995.

Benefits associated with each proposal are similar to those described for specific projects in previous sections of this guidance. However, the uncertainty associated with the benefits of new airports is often much more severe. Moreover, by shifting the location of the airport, issues not relevant to investments at existing airports, such as additional commuting distance to the airport, must be specifically addressed.

10.7.1 Regional Airports: Regional airports are generally intended to consolidate air service from two or more smaller commercial service airports elsewhere in the region into a central location. In most cases, the regional airport is designed to provide significantly greater capacity and capability than the predecessor airports, including more and/or longer runways and larger and more diversified ATB complexes.

The principal aviation objective of consolidation is to generate passenger and cargo volumes sufficient to support air service to more destinations by larger aircraft and at lower fares. Passenger volumes are expected to increase from the merging of passengers from the smaller airports and the capture of local passengers who currently make use of more competitive out-of-region airports. In addition, the new regional airport can provide facilities to meet the needs of specialized service providers, such as air cargo operators. Finally, the regional airport is often intended to bolster regional economic, business, and employment objectives (see discussion in Section 10.6).

Aviation benefits associated with higher passenger volumes and more diverse air service may be measured through the methods discussed in Section 10.4.6. These methods include operator and passenger surveys and comparisons to types of service and fares at comparable regional airports elsewhere. For instance, if consolidated passenger flows would create passenger traffic comparable to airports in nearby regions, a study of the type and cost of services received at these airports is informative.

Similarly, the experience of comparison airports with air cargo may be relevant to the new regional airport. In this case, lower air cargo expenses (assumed to be a proxy for lower expenses of the carriers of air cargo) to shippers in the comparison regions may be used to estimate cargo expenses in the study region once the airport is in place. These values should be obtained by surveys of regional air cargo rates.

Other benefits that may be associated with the new regional airport include:

- Reduced delay (assuming delay was a problem or potential problem at the local airport facilities);
- Reduction or elimination of the cost of maintaining or refurbishing the local airports (which may have facilities approaching the end of their economic lives that would have to be rebuilt if traffic is not shifted to a new airport); and
- Reduction or elimination of the need to bring the local airports into compliance with FAA design standards due to the shift of critical aircraft to the new airport (this benefit will

vary depending on the aviation role of the local facilities after the start-up of the regional airport).

10.7.2 Replacement Airports: A replacement airport may be viewed as a special case of a regional airport. However, rather than consolidating traffic into one facility, its primary purpose is to replace a former central facility which has reached its maximum physical potential and/or is subject to some other permanent capacity constraint inherent to its location.

In general, the principal benefit associated with a replacement airport will be a reduction in delay associated with alleviation of the capacity constraint at the former airport. However, benefits may also result from the accommodation of larger, faster, and/or more efficient aircraft which could not physically be accommodated at the predecessor airport. Other benefits described above for regional airports may also apply.

10.7.3 Supplemental Airports: Supplemental airports are those intended to accommodate regional demand that cannot be met by the existing, primary airport. Most typically, these airports are termed reliever airports and are designed to accommodate general aviation traffic that would otherwise use congested primary airports. However, in some cases, supplemental airports may take the form of full-fledged commercial service airports designed to accommodate all traffic types.

Benefits associated with supplemental airports are usually airspace and taxiway delay reductions occurring to users of both the reliever and the primary airport. These benefits can be modeled using SIMMOD or other simulation models that can account for multi-airport airspace management.

An important potential consideration is accessibility of the supplemental airport. Reallocation of traffic to the airport on a voluntary basis may not occur if the reliever facility is too far removed from population or business centers of interest to its potential users. The issue of access and how it factors into BCA of new airports is discussed immediately below.

10.7.4 Uncertainties of Traffic Forecasts at New Airports: Extreme care must be used in assessing potential benefits attributed to higher traffic levels at new airports. In particular, passenger and cargo use of the airport may fall below expectations for the following reasons:

- Continued operation of the local airports the airport is intended to replace;
- Lack of carrier interest in the new airport due to high user fees;
- Poor location of the new airport relative to regional population centers; and
- Proximity of a major hub airport within reasonable driving distance (e.g., 90 minutes) of the new airport.

If smaller, local airports continue to operate after the opening of the new regional airport and are not subject to major operating disadvantages, it is likely that some air service will continue to be provided from the local airports. The degree to which this service will erode the level of traffic

at the new regional airport depends on locations relative to population centers, comparative landing fee levels, and inducements offered to air service providers by local communities. The uncertainty of traffic flows due to these factors should be assessed using surveys of potential carriers and passengers. For obvious reasons, lack of carrier support for the new airport must be given major weight in situations where existing airports will remain open.

Landing fees associated with the pre-existing airports will generally be substantially less (for a given level of traffic) than they would be for the new regional airport. This discrepancy results because the pre-existing airports have, in most cases, been fully amortized whereas the new airport will have significant bond payments to meet, even with AIP participation. Higher airport fees may mitigate variable operating cost savings that would result from the use of more efficient aircraft at the new airport (see Appendix C for more discussion on the effects of airport fees on passenger travel decisions).

Location of the new airport at distances far away (20 miles or more) from regional population centers is another basis for concern about future traffic volumes. Ground access time is a major consideration of passengers who make trip decisions based on total transit time and air fare. In particular, benefits of estimated lower air fares and air transit times to passengers can be partially or completely eliminated by higher ground access times and expenses. Moreover, the lower fares and air transit times that are the assumed inducement for passengers to use the new airport will not be realized in the first place if sufficient passengers volumes are not attained at the new facility. In this latter case, air service to the region could actually end up more fragmented and expensive than it was before (especially if the pre-existing airports continue to operate).

Proximity of a major hub airport to the region (particularly an airport served by a discount air carrier) introduces yet another element of uncertainty with regard to the recapture of lost regional traffic. Major fare savings may be associated with travel to the out-of-region airport which cannot be matched at the new airport. In addition, if the air service from the more distant airport is more direct, longer ground travel time to get to the out-of-region airport may be discounted by the passenger. (In many cases, the passenger would have to hub through the larger airport even if he or she departed from the regional airport).

Unfortunately, comparison of travel choices to passengers in the situations described above can be very complicated. Total ground/terminal/air transit times and fares for a representative sample of trip destinations must be measured from the competing airports and compared to the estimated times and fares at the regional airport if expected traffic levels are reached. Should the total trip cost from the study airport compare unfavorably to the competing airport, this would indicate that expected traffic levels at the new airport probably will not materialize. Data at this level of detail will generally need to be collected through surveys of passengers, travel agents and corporate travel managers, and air carriers.

Section 11: COST ESTIMATION

11.1 Costs of Capacity Projects: Cost is defined as the resources that will be consumed if an objective is undertaken. The value of consumed resources is measured in constant dollars, which makes different cost elements comparable with themselves as well as with the benefits described in Section 10.

Each alternative method of accomplishing the objective will have its own associated cost. Costs include all capital, labor, and natural resources necessary to undertake each alternative whether they are borne by governmental units (including the FAA), various components of the total flying public, the general public, or some other particular group.

11.2 Cost Concepts: Assignment of correct costs to infrastructure projects requires an understanding of the following cost concepts:

- Opportunity cost;
- Incremental cost;
- Sunk cost;
- Depreciation;
- Principal and interest expense; and
- Inflation.

11.2.1 Opportunity Cost: Opportunity cost is the value of the benefits foregone when resources are shifted from satisfying one objective to satisfying another. An all inclusive measure, it represents what society as a whole--government and all private groups--must give up to obtain the desired objective. It is the theoretically correct measure of cost for use in economic analyses of projects funded with government funds. As an example, the opportunity cost of a new runway is what the resources used to construct it--concrete, steel, electronic components, labor, etc.--could produce in their next best use.

Project-related opportunity costs generally equate to their actual cash outlay, or out-of-pocket, costs, including construction costs, wages, fringe benefits, overhead, and other expense items. However, the following three qualifications apply to the general use of cash outlay valuations:

- Costs can arise if a resource which is required by a project is already owned by the sponsor (e.g., land to be used for a terminal). When it is consumed by a project there is an opportunity cost in that it cannot be used in another use (e.g., an industrial area), but there is no cash outlay. Care must be taken to assign an opportunity cost equal to the value of the resource in its next best use;
- If a resource is subsidized, the value of the subsidy must be quantified and added to the price of the resource; and
- Sales or excise taxes that form part of the expenditures for a project do not represent resources consumed in a project, and should be excluded from project-related opportunity costs.

11.2.2 Incremental Cost: A BCA is concerned with the differences between options (the base case and its alternatives). All cost elements which differ between options are defined as incremental costs, and must be reflected in the comparison of options. Costs which are common to all options are not relevant to the investment decision and should be netted out when calculating differences among options.

11.2.3 Sunk Cost: Sunk costs are costs of resources which have already been consumed and cannot be recovered at the time the BCA is being conducted. As a consequence, they are not relevant for current decisionmaking and should not be included in the BCA. Occasionally, projects can be implemented for very little additional or incremental cost because they make use of existing fixed assets. If these assets have no opportunity cost (i.e., no alternative uses), they are free to the project under consideration.

11.2.4 Depreciation: Frequently, large costs must be incurred in the beginning of a project in order to obtain benefits (or revenues) in later years. It is often useful to know by how much annual benefits (or revenues) exceed annual costs, or the net benefit (or income) of the project. In order for this value to be reasonable, it is necessary to allocate the large initial costs to later years when benefits occur. This is done by the accounting methodology of depreciation.

While depreciation is important in determining reasonable annual accounting of net benefits or income, its use in BCA is limited to the estimation of salvage values. BCA analysis is concerned with when resources are actually consumed (e.g., during the initial construction of the facility and subsequent operating and maintenance expenses) and when their benefits occur. Thus, BCA determines the capital cost of a project based on the value and timing of the resources (e.g., concrete, labor) used in the initial construction period. Depreciation, which reflects an artificial spreading of resource consumption over a long period of time, does not accurately reflect the timing of resource consumption. In fact, inclusion of depreciation in a BCA would lead to double counting of capital costs.

Depreciation methodology has applications in estimating salvage values. To yield reasonable results, such depreciation must relate the asset's age to its actual value. However, essentially arbitrary depreciation schemes designed for tax or other purposes must not be used for calculating salvage values.

11.2.5 Principal and Interest Expense: As in the case of depreciation, the resource costs associated with project construction are considered directly in BCA. Interest and principal costs payable on the capital funds required to implement a project should therefore not be included in a BCA. Both of these cost items are implicitly taken into account by means of the discount rate in the computation of present value (see section 12.5).

11.2.6 Inflation: The dollar is the measure into which all costs and benefits must be converted in order to be compared. However, due to the process of inflation, the amount of physical resources that may be purchased by a dollar will decrease over time. Consequently, it is

necessary to cost all resources in the form of dollars of a given year, known as constant dollars, to facilitate year-to-year comparisons.

In some instances, the analyst may expect that the constant cost of a particular resource will increase or decrease over time. That is, due to a changing scarcity relative to other resources, its value in dollars of a given year may change. When this occurs, the constant cost should be escalated or decreased from year to year. A much more detailed discussion on the treatment of inflation, with instructions for converting current dollar values to constant dollar values, is provided in Appendix A of this guidance.

11.3 Life Cycle Cost Model: The fundamental cost problem is to determine the total economic costs of proposed alternative future investments. The life cycle cost model accomplishes this objective. It systematically identifies the total cost to government, public, and private entities of establishing and operating an investment project. It also specifies when specific costs are incurred.

This subsection develops a generalized scheme by which to classify the costs of all proposed investment projects. Costs are organized under four general headings: Research and Development Cost; Investment Cost; Operations and Maintenance Cost; and Termination Cost. Numerous specific costs are indicated under each of these headings. The classification of specific costs is intended to cover many potential situations. It is not expected that all items identified below will be relevant to the evaluation of any particular proposed project. On the other hand, it is likely that some of the costs below which are specific to particular projects, or useful for understanding particular project components, may be omitted.

Unlike the preceding section on project benefits, the following discussion treats the various cost categories without differentiating by project type. This is because the various major project cost categories tend to be straightforward and uniform for most airport projects. However, a discussion on special problems in the correct specification facility reconstruction costs is included at the end of this section.

11.3.1 Planning and Research and Development Cost: This category should include all costs that will be incurred prior to beginning construction of the project under evaluation. The exception is that costs that have already been incurred at the time the BCA is undertaken or which must be developed in order to complete the BCA must be excluded. Incurred costs are sunk costs and are not relevant for decisionmaking purposes.

Typical planning costs for airport projects include the following:

- Any necessary research and development expenses associated with the project;
- Project environmental assessment;
- Detailed project design and engineering plans;
- Coordination with regional development and transportation plans;
- Arrangement of project financing; and

- Public outreach.

11.3.2 Investment Cost: This category should include all opportunity costs associated with getting the investment implemented. Investment costs occur early on in an activity's life time and typically consist of land costs, construction and equipage costs, operating costs, and termination costs.

11.3.2.1 Land Cost. Land cost includes all interests in land that are acquired for the project, such as purchases, leaseholds, easements, air rights, mineral rights, etc. Land that is already owned should be valued according to its opportunity cost or market value.

11.3.2.2 Construction Cost. Construction cost includes all expenses associated with the building of a new facility or the expansion, modernization, or refurbishment of an existing facility. Construction cost should also include any costs to expand, modernize, or refurbish any other portion of the airport or its infrastructure necessitated by the implementation of the project. Estimates of construction cost are generally site-specific and should be developed based on engineering estimates. Estimates of the cost (if any) incurred in building or modifying any of the items listed in Table 11.1 should be provided.

Construction cost includes all labor and materials, including any relevant transportation cost for materials, needed to implement the project regardless of who will incur the cost. Construction costs should be scaled up by an appropriate contingency factor (usually 15 percent). Costs including the contingency should be increased again by a professional service fee (which may vary from 0 to 15 percent). Finally, the scaled-up estimate should be augmented by some factor (e.g., 2 percent) to address project administrative costs. As noted above, all costs should be specified in constant study year dollars and by the year in which the costs incurred.

FAA should be consulted for cost estimates of facilities (e.g., air traffic control towers or precision landing systems) to be built by or in coordination with FAA.

11.3.2.3 Equipment, Vehicle, and Provisioning Costs. Equipment, vehicle, and provisioning costs consist of items in addition to physical facilities that are required to accomplish an activity. Equipment costs could include the non-facility components of ATBs. Vehicles could include emergency and maintenance vehicles required to service an expansion of airfield infrastructure. Provisioning costs are incurred for initial spare parts, special tools, and technical documents. Other items such as furniture would also be classified as equipment. All cost estimates should include any charges for transportation to the airport site.

TABLE 11.1: CONSTRUCTION COST ELEMENTS

Project and Project Components
Relocation of existing buildings and utilities at site
Site development
Clearing
Runway and taxiway facilities
Subgrade preparation
Paving and lighting
Shoulders and blast pads
Runway safety areas and other conformance to FAA design standards
Environmental mitigation costs (sound insulation, residence acquisition)
Precision landing system
Supplemental grading
Obstacle removal
Installation of precision system
Approach lights and MALSR
PAPI, NDB, and beacon
Air traffic control facility
ARFF facility
Air Terminal Building (ATB) access
ATB access taxiways
ATB access taxiway shoulders
ATB/cargo apron
ATB
Passenger terminal
Cargo terminal
Jetways
ATB Parking
Entry roadway and transit system
Water supply system (on- and off-site)
Sanitary sewer system (on- and off-site)
Storm water system (including water treatment)
Electric, gas, and telephone
Perimeter and security fencing
Fuel facilities
Airport maintenance facility

11.3.2.4 Initial Training Cost. Some projects may require new operating skills that require the training of airport and/or airline staff, as well as additional training of pilots. Initial training cost includes travel, subsistence, and lodging associated with training, instructional cost, and compensation of employees or persons being trained.

11.3.2.5 Transition Cost. Transition cost reflects the impact on airport operations of building and/or transitioning to the new project. This impact can be very large, particularly if the construction of the project leads to the temporary closure of major facilities of the airport. A runway reconstruction project will lead to the total or partial closure of the runway itself, and may cause the temporary closure of any runway intersecting with it. Disruption and delay associated with the project may result in millions of dollars of additional costs to airlines, general aviation users, passengers, and others using the airport, and must be measured and included as an important cost element of the project.

Measurement of transition costs should be undertaken as a subset of the capacity simulation exercise described in section 10.4.1 of this guidance. Additional guidance on the subject of transition costs associated with runway and facility reconstruction is provided in section 11.4.

11.3.3 Operations and Maintenance Cost (O&M): O&M costs are the recurring costs required to operate and maintain the proposed investment project. The sponsor must demonstrate to FAA that the proposed O&M regime will be adequate to sustain the project in good condition over the full economic life assumed for the project. Expenses associated with O&M may occur annually or periodically every so many years.

11.3.3.1 Personnel Cost. Personnel cost is a major component of recurring O&M costs. Estimation of personnel cost is a multi-step process. The first step requires the determination of the annual labor hours required by type of skill. These hours should include not only direct labor, but such other items as recurring training, travel time, break time etc. Estimates for new systems can be developed based on engineering data or previous experience with similar types of undertakings. The second step in estimation of recurring labor costs is to adjust the required labor hours for annual leave, sick leave, and other absences. The third step is to compute the effective compensation rate (including fringe benefits) for each labor category. The final step is to translate annual labor requirements for each required skill into dollars by multiplying the annual labor hours required (from step 2) by the appropriate effective hourly compensation rate (as determined in step 3).

11.3.3.2 Materials. Materials consist of items as such as repair parts, small tools, lubricants, sealants, and other items which are consumed annually by the operation and maintenance of a system.

11.3.3.3 Utilities. Included here are the costs of electricity, gasoline, natural gas, water, etc. Estimates of these expenses for the initial year of implementation should be based on current experience for existing systems and engineering estimates for new systems. Future estimates should be made by adjusting initial year estimates for anticipated future experience.

11.3.3.4 Recurring Travel and Transportation. This item represents the direct cost of travel and transportation necessary to operate a project. In most cases, this will be a minimal consideration in airport investments.

11.3.4 Termination Cost: For some airport investments, it may be necessary to make an allowance for costs associated with their discontinuance.

11.3.4.1 Dismantling Cost. This is the cost, if any, required to disassemble and remove old facilities and equipment at the end of a project's lifetime.

11.3.4.2 Site Restoration. This is the cost, if any, to restore the site on which the old facilities were located to its original or near-original condition. It may involve grading of earth, reforestation, or landscaping.

11.3.5 Salvage Value: Salvage value is the value, if any, of the project at the end of its expected life. Note that it is treated in this guidance as an offset to termination costs, but could also be treated as a benefit of the project.

11.3.6 Relationship of Cost Components: Figure 11.1 presents an "idealized" summary of major life cycle cost components over a project's life. Of course, not all life cycles will follow this pattern. As indicated, planning cost increases every year from project inception up until the beginning of the investment phase, after which it rapidly diminishes. Investment cost does not necessarily follow a particular pattern except that it occurs over a relatively short period. O&M cost rises rapidly following initial investment as the facility is brought on-line. Thereafter, O&M cost will continue to rise slowly as a result of increasing equipment age. Near the end of the project's life, O&M cost will decline as the project is retired. Retirement also gives rise to termination costs and compensating salvage value.

11.4 Application of Life-Cycle Costing to Facility Replacement Decisions: Eventually, all facilities will need to be either replaced or retired even if they are carefully maintained. Once a facility begins to show pronounced signs of aging and/or degradation, the airport sponsor will want to determine whether action should be undertaken to mitigate possible delay or other service disruptions associated with the facility's failure (see Section 4.1). One obvious course of action (but not the only one) to meet this objective involves reconstruction of the aged facility. However, there is a broad range of potential reconstruction alternatives, and costing of these alternatives can be difficult.

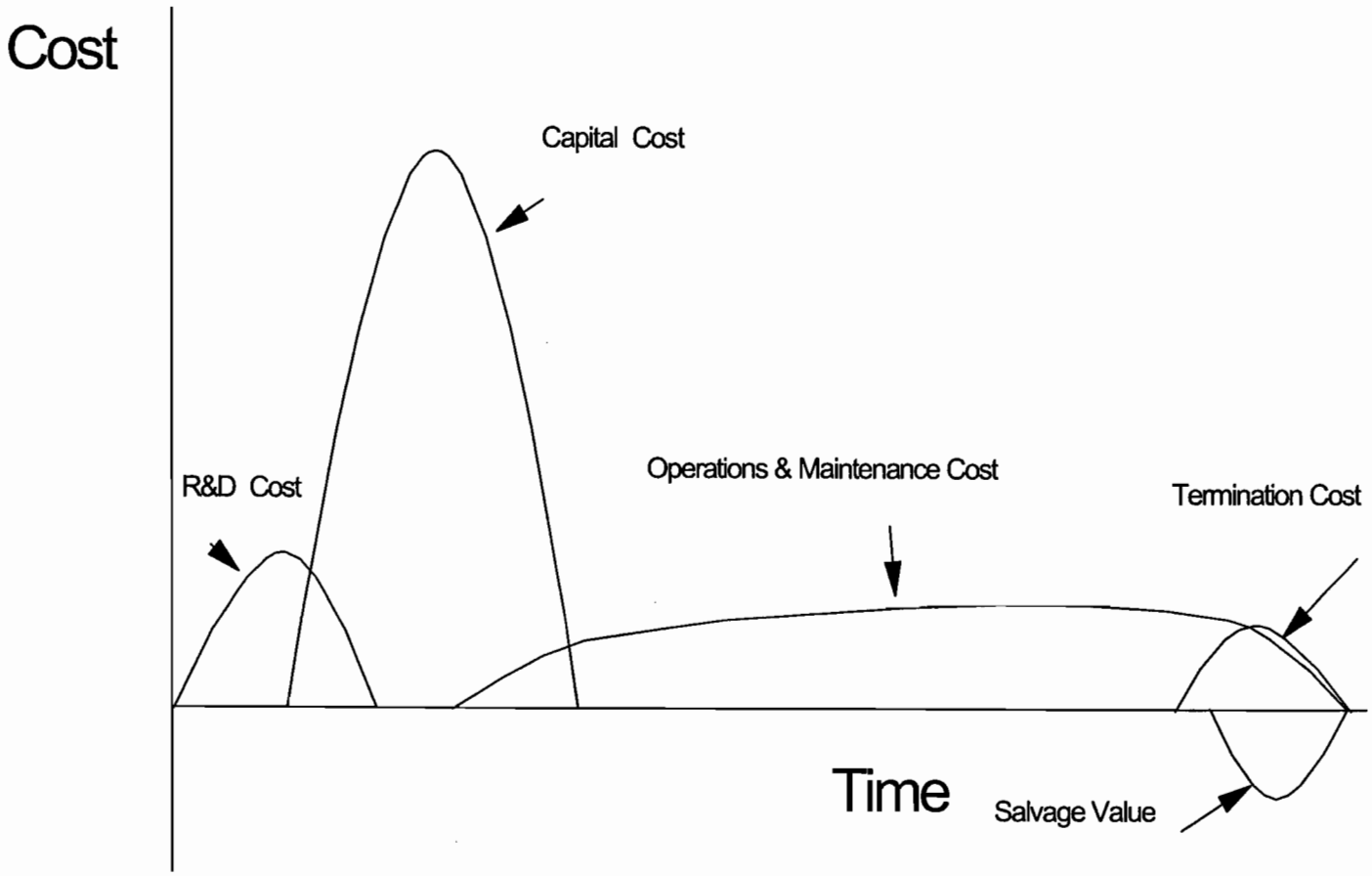

Figure 11.1: Life Cycle Cost Summary

11.4.1 Justification for Reconstruction Projects: The sponsor seeking to reconstruct a facility must show that its particular recommendation for reconstruction does the following:

- Generates net benefits relative to the base case; and
- Produces greater net benefits than all other alternatives (e.g., relocating the facility, building an alternate facility, etc.).

The base case for the above analysis should assume escalating O&M costs for the aged facility, followed by closure of the facility at some point when additional maintenance is no longer cost-effective.

11.4.2 Consideration of Degree of Reconstruction: There are several critical and interrelated steps that must be explicitly measured in costing potential reconstruction options:

- Timing of the reconstruction;
- Degree of reconstruction needed;
- Least-cost means of accomplishing a given degree of reconstruction (this analysis must factor in the disruption costs to airport users during the reconstruction); and
- Costs and benefits of associated projects in reconstruction decision.

11.4.2.1 Timing of Reconstruction. The sponsor must consider alternatives involving near-term reconstruction (within several years) and far-term reconstruction (e.g., in 10 years). Deferring reconstruction will lead to higher O&M expenses in the near-term and may lead to more extensive damage of the aging facility and its subgrade, thus requiring a more extensive reconstruction in the future. In addition, if traffic is growing rapidly at the airport, deferring reconstruction may lead to greater traffic disruption once reconstruction is finally undertaken. Alternatively, if reconstruction can be deferred until a time when an already-planned substitute or additional facility becomes available, the cost of the deferred reconstruction alternative may be much less than the cost of the immediate reconstruction alternative.

11.4.2.2 Degree of Reconstruction. The degree or extent of a potential reconstruction can be highly variable. In the case of a runway, reconstruction may involve the removal of a layer of pavement with a subsequent replacement overlay. At the other extreme, a full-depth reconstruction of the runway and the subgrade could be undertaken.[14] Both extremes (with appropriate intermediate levels) should be evaluated and costed.

[14]The overlay may last only half as long as the full depth reconstruction, in which case the cost of the overlay option would need to reflect two separate overlays to be comparable to the full depth reconstruction.

11.4.2.3 Least-Cost Means of Reconstruction. The cost of a given reconstruction option (e.g., partial pavement replacement) can vary significantly based on the assumptions concerning the reconstruction method and schedule. In many cases it is possible to reconstruct a runway at night or in segments, thus keeping it partially open to airport users (who therefore incur lower disruption cost) but at higher cost for labor and materials. Alternatively, if the runway is closed completely to enable full-time reconstruction, physical construction costs will be lower but disruption cost to airport users will be higher. Consequently, it is essential that a complete range of reconstruction schedules be explored and costed.

Impacts on users caused by reconstruction should be estimated using appropriate capacity models (see Section 10.4.1). In general, delay or other disruption associated with the reconstruction option must be assigned a value and considered along with other measured costs.

11.4.3.4 Consideration of Linked Reconstruction Projects. A capacity project may be proposed principally to accommodate airport users during the reconstruction of a separate item of airport infrastructure. In such cases, the two projects (the reconstruction project and the facility intended to accommodate disruption associated with it) must be linked into one overall project and subjected to one BCA.

Section 12: MULTI-PERIOD ECONOMIC DECISION CRITERIA

12.1 Requirement for Multi-Period Analysis: The emphasis of this guidance until now has been on the fullest practical identification, quantification, and monetization of benefits and costs for various project types. These benefits and costs are developed in constant dollars for a limited number of focus years. This section of the guidance will accomplish three principal objectives:

- Provide instructions on how to interpolate/extrapolate focus year benefits and costs to each year of the project's construction and/or operating life;
- Describe analytical methods for quantifying and comparing multi-period benefit and cost streams; and
- Recommend appropriate methods for selecting optimal alternatives.

A brief discussion on the measurement of optimal timing for investments is also provided.

12.2 Creation of Multi-Period Benefit Series: With the exception of project capital costs (which are developed for each year of the construction period), benefit and cost data in the previous sections are developed for several levels of future demand (measured in terms of enplanements and/or operations) that correspond to selected project years, called focus years. These years are selected from the beginning, middle, and late stages of the project's expected life.

The limitation of benefit and cost measurements to focus years is largely a function of the excessive level of effort and expense that would be required to simulate capacity benefits for each project year. However, BCA requires that benefits and costs be developed for each year of the project life. Thus, the analyst must interpolate and/or extrapolate benefit and cost results of the focus years to those years and traffic levels for which benefits and costs were not directly measured.

The principal benefit of most capacity projects will be delay reduction. As such, selection of focus years should be done in a manner that allows the analyst to approximate the comparative delay trends of the base case and its alternatives. Section 10.4.1 provides a detailed methodology for selection and adjustment of focus years to enable a good linear approximation of curvilinear delay growth trends.

If focus years are properly selected, the interpolation of benefits between two points can be done by a simple per operation or per passenger pro-ration process. That is, if aircraft operating delay savings of an alternative relative to the base case are 1,000 hours at 500,000 operations, and 2,000 hours at 550,000 operations, then it may be assumed that savings would be 1,500 hours at 525,000 operations. Moreover, to the extent that other benefits attributable to the project are related to operations and/or passenger levels, this linear pro-ration approach is also appropriate.

Assuming that one of the focus years selected for the project corresponds to a demand level at the end of the project's projected life, the need to extrapolate benefits beyond this year is limited. However, to conform with the guidance in Section 8.3, it will be necessary to extrapolate project

benefits from the final focus year by at least 5 years to accommodate analysis of optimal timing of projects. In this case, extrapolation of benefits from the final focus year should occur at the same rate of benefit per operation (or passenger) as measured between the next-to-final and final focus years (provided the delay benefit level does not exceed 20 minutes per operation--see Section 10.4.1.)

12.3 Creation of Multi-Period Cost Series: O&M cost data will generally grow at a constant per operation or per passenger unit rate and can safely be pro-rated on this basis. In some cases, the cost of periodic maintenance events may be scheduled for discreet years.

12.4 Conversion of Benefit and Cost Series to Present Value: Most airport investments involve the expenditure of large blocks of resources at the outset of the project in return for an annual (usually rising) flow of benefits to be realized in the future. Although these benefits and costs are in the form of dollars, year-to-year benefits and costs cannot simply be summed into totals and then compared. Rather, the BCA must take into account the fact that dollars paid out or earned in the near-term are worth more in "present value" than are dollars paid out or earned in the far-term. The process of converting future cash flows into present value is called discounting.

The opportunity cost of money accounts for the need to discount dollar amounts to account for the passage of time. Another factor that may affect the perception of the value of future revenue streams--risk and uncertainty--should be dealt with explicitly in the BCA and not through discounting future dollar streams.

12.4.1 Opportunity Cost of Capital: The opportunity cost of capital reflects the fact that, even without inflation, the present value (the value today) of a dollar to be received a year from now is less than the value of a dollar in-hand today. This outcome can be easily understood from the standpoint of lost revenue-earning opportunity. A dollar in-hand can be invested immediately in an interest-bearing account (or some other investment instrument) and earn interest for a period of one year. A dollar to be received one year from now cannot earn income for the investor during this period. Thus, the BCA must account for the opportunity cost of capital.

12.4.2 Inflation: Inflation reflects the diminishing value of a dollar from year to year as measured in the real resources and services for which it can be exchanged. Although inflation is an important issue in investment analysis, FAA recommends that benefits and costs of projects be valued in terms of constant study year dollars (see Sections 10.5.1 and 11.2.6). As such, the role of inflation is already removed from the benefit and cost streams developed in Sections 10 and 11 of this guidance and no discounting of future revenue streams for inflation is required.

12.4.3 Risk: Investors will frequently discount future revenues more severely if these revenues are characterized by a high degree of risk and uncertainty. Consequently, market interest rates associated with risky bonds are substantially higher than those for secure bonds. However, the U.S. Office of Management and Budget states that risk and uncertainty should be dealt with

explicitly in the BCA using sensitivity analysis, probability distributions, and expected values--not through the discount rate applied to future monetary flows (see Section 13).

12.5 Discount Rate: Discounting requires the division of an annual discount rate into future benefits and costs. The annual discount rate (also known as the marginal rate of return of capital) represents the prevailing level of capital productivity that can be achieved at any particular time by investing resources, i.e., the opportunity cost. Because FAA recommends the use of constant dollar cash streams, the discount rate should be net of inflation. This net-of-inflation rate is called the real discount rate.

The Office of Management and Budget (OMB) of the Executive Office of the President of the United States specifies appropriate real discount rates for investments of Federal funds in Circular No. A-94 (October 29, 1992). The real discount rate relevant to all airport projects to be funded with Federal grant funds is 7 percent.

12.6 Basic Discounting Methodology: The present value (PV) of a future cost or benefit for a given year "n" is determined by the following formula:

$$PV = \frac{V_n}{(1+r)^n} \qquad 12\text{-}1$$

where:

V = future value in year n in constant dollars
r = annual real discount rate
n = number of years from the base year (study year)

When whole numbers are used for "n", the above formula assumes that all costs and benefits in a year occur at the end of the year. A mid-year accrual can be simulated by the use of half values for "n" (i.e., n = ½, 1½, 2½, etc.). Finally, a discounting formula can be applied which assumes continuous accrual of costs and benefits over the course of a year.[15]

From a practical point of view, the mid-point and continuous discounting procedures are about the same. Either can be used to approximate the continuous characteristic of benefit and cost streams. Also, there is not a large difference between the end-of-period discounting and either mid-period or continuous discounting--less than 4 percent at a 7 percent discount rate. The relatively small changes produced by different discounting procedures suggests that, with respect to project evaluation, any of the methods is acceptable.

[15]Present value tables, located in various financial text books, can also be used.

Table 12.1 shows the application of an end-of-year discounting convention to a hypothetical project with a one year construction period and a 5 year life span. All costs and benefits represent increments over a hypothetical base case. The base year for the analysis is the study year (in this case 1996), with costs and benefits expressed in real 1996 dollars and discounted back to December 31, 1996. The project life span (discussed in Section 8) would reflect the expected economic life of the project.

TABLE 12.1: DISCOUNTING OF PROJECT COSTS AND BENEFITS

Project Year	Cost	Benefit	Discount Rate Factor	PV Cost	PV Benefit
1997	$50,000	$0	$(1+.07)^1 = 1.07000$	$46,729	$0
1998	$5,000	$15,000	$(1+.07)^2 = 1.14490$	$4,367	$13,102
1999	$5,000	$15,000	$(1+.07)^3 = 1.22504$	$4,081	$12,244
2000	$6,000	$17,000	$(1+.07)^4 = 1.31080$	$4,577	$12,969
2001	$6,000	$17,000	$(1+.07)^5 = 1.40255$	$4,278	$12,121
2002	$7,000	$20,000	$(1+.07)^6 = 1.50073$	$4,664	$13,327
Total	$79,000	$84,000		$68,697	$63,763

As evidenced by the table, a simple summation of undiscounted costs and benefits would lead to the (incorrect) conclusion that the project's benefits exceed costs. However, when converted to PV using the real discount rate of 7 percent, it is apparent that the opportunity costs of the resources invested into building and operating the project exceed the monetary value of the benefits of the project. Alternative means to present and interpret the results of discounted cost and benefit flows are described in the next section.

12.7 Alternative Evaluation Procedures: The present value of incremental costs and benefits can then be compared in a variety of ways so as to determine which, if any, option is most worth pursuing. In some cases, no alternative will generate a net benefit relative to the base case--a finding that would argue for pursuit of the base case scenario. The following are the most widely used present value comparison methods:

- Net present value;
- Benefit-cost ratio; and
- Internal rate of return.

These methods are discussed in sequence below. A fifth evaluation procedure (one that does not involve discounting) called the payback period method is also discussed.

12.7.1 Net Present Value (NPV): The net present value (NPV) method requires that an alternative meet the following criteria to warrant investment of funds:

- Have a positive NPV; and
- Have the highest NPV of all tested alternatives.

The first condition insures that the alternative is worth undertaking relative to the base case, e.g., it contributes more in incremental benefits than it absorbs in incremental costs. The second condition insures that maximum benefits (in a situation of unrestricted access to capital funds) are obtained.

The formula for the calculation of NPV is as follows:

$$NPV = \sum_{t=0}^{k} \frac{(B - C)_t}{(1+r)^t} = \sum_{t=0}^{k} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{k} \frac{C_t}{(1+r)^t} \qquad 12 - 2$$

where:

B = future annual benefits in constant dollars
C = future annual costs inconstant dollars
r = annual real discount rate
k = number of years from the base year over which the project will be evaluated
t = an index running from 0 to k representing the year under consideration

As an illustration of the application of NPV, consider the example in Table 12.2. Three investment options are presented. The values for benefits and costs of each are incremental to the base case, in 1996 dollars, and are discounted to the present at the OMB-prescribed real discount rate of 7 percent.

Alternative A does not have a positive NPV and should not be pursued relative to the base case. Both alternatives B and C have positive NPVs, indicating either option would be preferred to the base case. However, alternative C has the highest NPV, making it the best alternative to pursue.

NPV is the most widely-used and theoretically-accurate economic method for selecting among investment alternatives, and should be used for all analyses prepared for the FAA's consideration. However, NPV does have certain conceptual and analytical limitations, which makes consideration of other present value evaluation methods appropriate in some instances.

TABLE 12.2: APPLICATION OF NPV TO THREE INVESTMENT ALTERNATIVES

Year	Alternative A		Alternative B		Alternative C	
	Cost	Benefit	Cost	Benefit	Cost	Benefit
1997	$46,729	$0	$28,037	$0	$65,421	$0
1998	$4,367	$13,102	$4,367	$10,481	$5,241	$20,089
1999	$4,081	$12,244	$4,081	$9,796	$4,898	$18,775
2000	$4,577	$12,969	$3,814	$9,155	$4,577	$19,072
2001	$4,278	$12,121	$4,278	$10,695	$4,991	$17,825
2002	$4,664	$13,327	$3,998	$9,995	$4,664	$18,658
Total	$68,697	$63,763	$48,577	$50,122	$89,792	$94,419
NPV	-$4,934		$1,545		$4,627	

The chief conceptual problem with strict reliance on NPV concerns the comparison of mutually exclusive projects of greatly different scales. Consider the case of two mutually exclusive alternatives--one with a $100 million cost and a $4 million NPV and the other with a $10 million cost and a $3 million NPV--intended to accomplish the same objective. When NPV as a selection criterion is strictly applied, the $100 million alternative would be preferred over the $10 million alternative (assuming equal risk). If the airport is able to borrow as much as needed to undertake all worthwhile projects, this would clearly be the correct choice. However, if the airport is restricted in the amount of debt it can issue (e.g., $100 million) *and* has several, additional smaller projects with $3 million NPVs, it may be appropriate to select the $10 million project and use remaining funds to undertake the smaller projects--thus yielding a higher overall sum of NPV amounts for the restricted amount of capital.

As with all present value methods, ranking of projects using NPV can be affected by the choice of the discount rate. In particular, the ranking of two projects can often be reversed through raising or lowering the discount rate. Use of a lower discount rate will cause a project with very large benefits falling predominantly in later project years to appear stronger than a project with more moderate benefits falling evenly over the project life. The reverse will occur at higher discount rates. In the case of BCAs prepared for FAA's consideration, the analysis should be based on a 7 percent rate. OMB requires sensitivity analysis on the effects of this 7 percent rate. APO recommends that the sensitivity analysis be done at 4 percent and 10 percent.

Another problem with NPV as a decision tool is that it is poorly understood by non-economists and may not appear compelling to a broad audience.

12.7.2 Benefit-Cost Ratio: The benefit-cost ratio is defined as the present value of benefits divided by the present value of costs. The formula for the calculation of the benefit-cost ratio is as follows:

$$B/C = \frac{\sum_{t=0}^{k} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{k} \frac{C_t}{(1+r)^t}} \qquad 12-3$$

where:

B_t = future annual benefits in constant dollars
C_t = future annual costs inconstant dollars
r = annual real discount rate
t = an index running from 0 to k representing the year under consideration

A proposed activity with a ratio of discounted benefits to costs of 1 or more will return at least as much in benefits as it costs to undertake--indicating that the activity is worth undertaking. In the case of the investment alternatives developed in Table 12.2, the benefit-cost ratios for alternatives A, B, and C would be 0.93, 1.03, and 1.05, respectively.

The principal advantage of the benefit-cost ratio is that it is intuitively understood by most people. Moreover, this method does provide a correct answer as to which objectives should be undertaken--defined as those with ratios greater than or equal to unity. However, it often fails to answer correctly the question of how to accomplish the objectives most effectively, particularly when comparing mutually exclusive projects of different scale or different levels of capital intensity and operating expense.

The difficulty associated with project scale is the flip side of the scale problem associated with NPV. In the case described above for NPV (where a $100 million investment would yield a $4 million NPV and a $10 million investment would yield a $3 million NPV) the benefit-cost ratios would be 1.04 and 1.3, respectively. Reliance on these ratios would lead to the choice of the $10 million investment. However, as already noted, only in a situation when an airport's ability to issue debt is constrained would the choice of the $10 million investment be appropriate (assuming equal risk). Where an airport is able to raise ample capital for its investment needs, the preferred project would be the $100 million one.

The benefit-cost ratio cannot properly compare capital intensive projects with others that have significant operating expenses. An example of this is shown in Table 12.3.[16]

[16]Adapted from De Neufville.

TABLE 12.3: APPLICATION OF BENEFIT-COST RATIO TEST

Project Element	Type of Project	
	Capital Intensive	Operating Intensive
Initial Investment	$1,000,000	$1,000,000
Annual Costs	$50,000	$500,000
Annual Benefits	$250,000	$700,000
Annual Net Benefit	$200,000	$200,000
Useful Life	10 Years	10 Years
Total Benefits (Discounted at 7%)	$1,641,000	$4,595,000
Total Costs (Discounted at 7%)	$1,263,000	$4,217,000
Benefit-Cost Ratio	1.30	1.09
Return on Investment	15%	15%
Net Present Value	$378,000	$378,000

As indicated by the table, the capital cost intensive alternative appears superior to the operating cost intensive alternative from a benefit-cost ratio standpoint, but is the same when measured by NPV or rate of return (see next subsection). This result follows even though the net annual benefits for the operating cost intensive project exceed those of the capital intensive project.

12.7.3 Internal Rate of Return: The internal rate of return (IRR) is defined as that discount rate which equates the present value of the stream of expected benefits in excess of expected costs to zero. In other words, it is the highest discount rate at which the project will not have a negative NPV. To apply the IRR criterion, it is necessary to compute the IRR and then compare it with OMB-prescribed 7 percent discount rate. If the real IRR is less than 7 percent, the project would be worth undertaking relative to the base case.

While the IRR method is effective in deciding whether or not a project is superior to the base case, it is difficult to utilize for ranking projects and deciding between mutually exclusive alternatives. It is not unusual for a project ranking established by the IRR method to be inconsistent with those of the NPV criterion. Moreover, it is possible for a project to have more than one IRR value, particularly when a project entails major final costs, such as clean-up costs. Although the literature on capital budgeting contains solutions to these problems, these are often complicated or difficult to employ in practice and present opportunities for error. As a

consequence, it is not recommended that the IRR method be used to evaluate airport projects for which AIP funds will be requested.

12.7.4 Payback Period: The payback period measures the number of years required for net undiscounted benefits to recover the initial investment in a project. One characteristic of this evaluation method is that it favors projects with near-term (and more certain) benefits. However, the payback period method fails to consider benefits beyond the payback period. Nor does it provide information on whether an investment is worth undertaking in the first place. Although often used in business applications, the payback period method is not appropriate for analyses conducted to justify the investment of AIP or other U.S. government funds.

12.8 Evaluation of Optimal Project Timing: The issue of optimal project timing is frequently ignored in economic analysis, but is particularly important in the case of large infrastructure projects typical of airports. In some cases, BCA may reveal that a greater net benefit can be realized if a project is deferred for several years rather than implemented immediately. Such a situation has a higher likelihood of occurring if the following conditions are met:

- The project benefit stream is heavily weighted to the later years of the project life;
- The project is characterized by large, up-front capital costs; and
- Capital and land cost escalation can be contained through land banking or other means.

Section 8.3 of this guidance recommended that benefit and cost figures be developed for a period of at least 5 years beyond the estimated project life. NPV can then be calculated for the project beginning in year X and year X+5, each with a benefit stream lasting the same number of years (e.g., 20 years beyond the completion of construction). Thus, the project NPV would be calculated for the following two time scenarios:

$$NPV = \sum_{t=0}^{k} \frac{(B - C)_t}{(1 + r)^t} \qquad 12 - 4$$

$$NPV = \sum_{t=5}^{k+5} \frac{(B - C)_t}{(1 + r)^t} \qquad 12 - 5$$

To resolve the issue of optimal timing, the NPV for each alternative should be measured for both the current and delayed time scenarios.

12.9 Selection of Best Alternative: Given equal risk and uncertainty, FAA recommends that the alternative/time scenario with the largest positive NPV be given primary consideration as the preferred course of action. In the case of Table 12.4, the preferred course of action would be

alternative C, but with project implementation delayed by 5 years.[17] If this course of action is selected, it would be appropriate to revisit the BCA within 5 years to make sure that data and assumptions contained in it are still valid.

TABLE 12.4: BCA RESULTS FOR THREE ALTERNATIVES

Option	NPV With Construction Beginning in Year t=1	NPV With Construction Beginning in Year t=6
Alternative A	$5 million	$10 million
Alternative B	$1 million	$1.5 million
Alternative C	$8 million	$14 million

Of course, not all alternatives will have equal certainty. Alternative A in year t+1 may be much less subject to cost overruns than alternative C in year t+5. The issue of sensitivity and its impact on investment decisions is described in the next section of this guidance.

[17] This assumes that it is not feasible to do Alternative C in Year t=1 and extend its life by 5 years, assuming Bi > Ci for i=1,..,5.

Section 13: UNCERTAINTY

13.1 Need to Address Uncertainty: The outcome of a BCA will depend on numerous estimates, forecasts, assumptions, and approximations of reality. Each of these factors has the potential to introduce error into the results. The importance of such errors in affecting the outcome of the BCA must be known to the decision-maker if informed decisions are to be made and confidence placed in such decisions. Moreover, the degree of uncertainty associated with each alternative is itself a factor to be considered in selecting between competing alternatives.

13.2 Characterizing Uncertainty: The treatment of uncertainty must be guided by the principles of full disclosure and transparency. Data, models, and their implications for risk assessment should be identified. Inferences and assumptions should be identified and evaluated explicitly, together with adequate justifications for choices made, and assessments of the effects of these choices on the BCA.

13.3 Sensitivity Analysis: Sensitivity analysis is an important tool for evaluating the impacts of uncertainty on proposed investment projects. The basic approach is to vary key assumptions, estimates, and forecasts systematically over appropriate ranges and observe the impact on the results. For certain items, the impact may be insignificant while for others it may be quite large. In some cases the relative desirability of competing alternatives may be altered while in others it will not be.

13.3.1 Probability Distributions: The actual procedure for varying a parameter depends on whether or not it may be described by a known probability distribution. If it can be so described, probability statements can be made about each value selected and the outcome of the analysis. Such an approach is known by convention as risk analysis.

If the probability distribution for each parameter is not known, alternative values of the parameter are selected over a range over which it is known or believed reasonable for it to vary. Probability statements regarding the likely occurrence of any particular value of the parameter are not possible. This approach is known as uncertainty analysis.

13.3.2 Methods of Sensitivity Analysis: There are several ways in which the analysis can be accomplished. Each depends on how the key assumptions, estimates, and forecasts are varied. One procedure is to vary only one at a time, holding the others constant so as to determine the independent, or partial, effect of this parameter. This procedure is known as a one variable uncertainty test. A second procedure is to vary two parameters simultaneously and is known as a two variable uncertainty test.

Similarly, three, four and more variable uncertainty tests can be constructed. These can easily produce large amounts of data and require the decision maker to consider an excessively large number of outcomes. An alternative is to allow all parameters to vary together in several predetermined patterns, each representing a relevant probable future state of affairs. This

procedure is known as alternative scenario analysis and makes use of probabilistic or "stochastic" computer simulation techniques.

13.3.2.1 One Variable Test. This procedure should be applied to the major cost and benefit components of each alternative. Its primary purpose is to identify the sensitivity of the NPV of each alternative to changes in value of each component. This permits additional effort to be devoted to improving the reliability of estimates for those components to which the results are sensitive. Where reliability cannot be improved, it puts the decision-maker on notice as to potential weaknesses of the BCA.

To carry out the one variable tests, the NPV of each alternative must be recalculated for different values of any one particular component while others are held constant. The range of values should extend over those that can reasonably be expected to prevail. Where a probability distribution for the component of interest is known, this range may be established by a confidence interval (usually 90 to 95 percent). Where such a distribution is unknown, the range should extend from the smallest to the largest value that could reasonably by expected to occur. The process should be repeated for each major component to be tested.

Once these computations have been completed, the problem arises as to how to display the results. If only a small number of components were tested, a tabular display may be appropriate. If more components were varied, a graphical display is often useful. Consider the following example of a new runway. Estimates indicate that installation of a new runway will generate benefits and costs over a 20 year economic life with present values of $45 million and $35 million, respectively, for a net present value of $10 million. These estimates are based on three basic forecast variables: traffic growth; economic life; and construction cost. Figure 13.1 indicates the impact on NPV that will occur if each of these items is allowed to vary over a range of plus or minus 100 percent of its value while the others are held constant.

As can be seen, increases in construction costs above 55 percent will result in a negative NPV indicating that the project should not be undertaken. Shortening the economic life by about 50 percent will also result in the NPV becoming negative. Changes in traffic growth will not affect the desirability of the project unless growth is about 90 percent less than predicted. From this information, the decision-maker can conclude that the project will have a positive NPV unless there are substantial changes in the key variables.

13.3.2.2 Two Variable Test. The one variable test permits examination of one factor holding all others constant. However, it may be useful to let two factors change at the same time, particularly if such changes may be expected to occur together. Or it may be necessary to determine the extent to which a change in one factor can be offset by a change in another.

As indicated in Figure 13.2, a different curve relating NPV to economic life may be constructed for each different level of construction spending. For any given NPV, it is shown

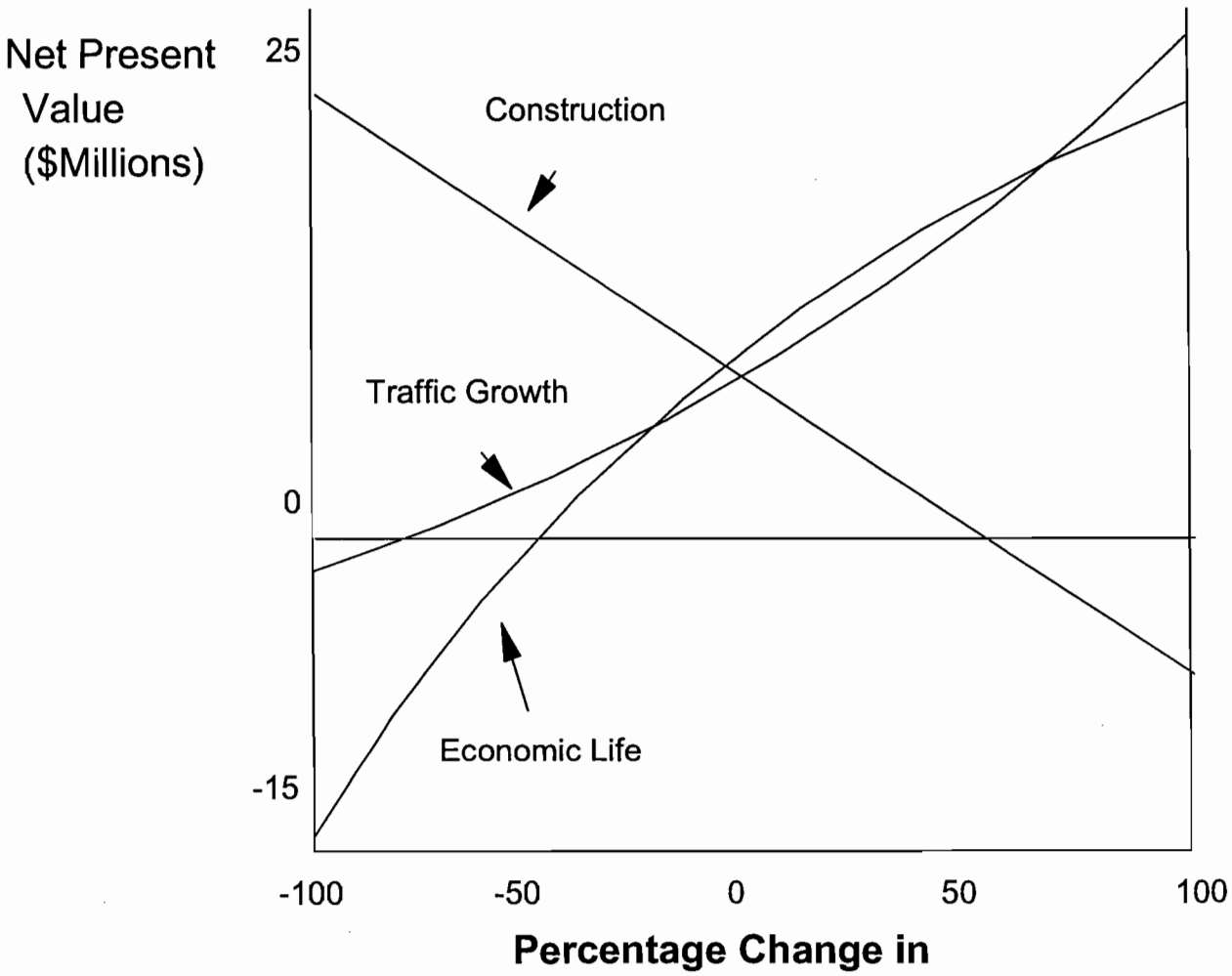

Figure 13.1: One Variable Uncertainty Test

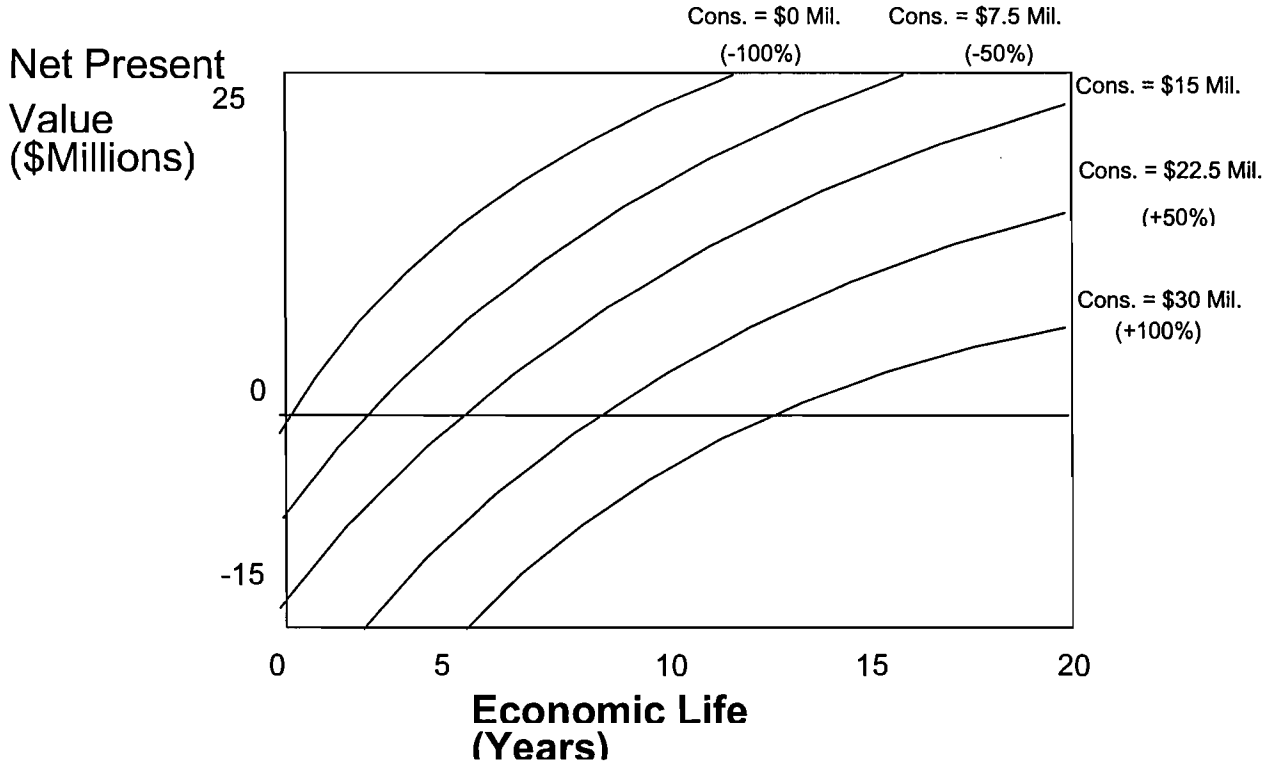

Figure 13.2: Two Variable Uncertainty Test

that an increase in construction cost requires a longer economic life. Specifically, to maintain an NPV of $10 million in the face of a 50 percent increase in construction cost (from $15 million to $22.5 million) requires a minimum project economic life of 14 years rather than 9 years. Similarly, a decrease in construction cost of 50 percent (to $7.5 million) would enable an NPV of $10 million after only 6 years of economic life.

13.3.2.3 Alternative Scenarios. The two variable test, above, is a special case of a multiple variable test. Consider the following abstract case:

$$NPV = f(X_1, X_2, X_3, \ldots, X_n) \qquad 13\text{-}1$$

Where: X_i = all the key variables; and
f = a function relating the key variables to net present value.

In the two variable case, two of the X_i's are allowed to vary while the others are held constant. Multiple variable tests could instead be carried out by solving the formula for large numbers of combinations of values for all of the X_i's. While possible, so many values for NPV would be generated that it would be difficult if not impossible to deal with them.

An alternative procedure is to select several combinations of the X_i's and evaluate these. Each such combination is known as a scenario. The analyst should make use of commercially available probabilistic or "stochastic" models to generate quickly hundreds or thousands of scenarios based on the specified probability distributions of uncertain variables. The models will use the results of these scenarios to determine a complete range of possible outcomes (in addition to most likely outcomes), also in the form of probability distributions. At a minimum, probability distributions of potential benefits, costs, and net benefits should be presented.

Section 14: SELECTION OF OPTIMAL PROJECT

14.1 Consideration of All Information: The final outcome of the BCA process is a recommendation on the best course of action, if any, to attain the proposed objective. The recommendation of the appropriate alternative will depend on measured benefits and costs, consideration of hard-to-quantify benefits and costs, and sensitivity of results to uncertainty.

14.2 Net Present Value: FAA recommends that the alternative with the largest positive NPV (if any) be given primary consideration as the preferred course of action. Note that the operative word here is "consideration". The recommend alternative is not automatically the one which has the largest positive NPV. All relevant data such as hard-to-quantify benefits and costs and uncertainty must also be considered in deciding on the preferred alternative

14.3 Hard-To-Quantify Benefits and Costs: In selecting between alternatives that have approximately equal NPVs, particular weight should be assigned to the alternative with the preponderance of qualitatively described benefits. Moreover, the airport sponsor may believe that a lesser-ranked project from an NPV perspective has very important hard-to-quantify benefits that would make it preferable to other alternatives. In this case, the sponsor may select the lesser-ranked project provided that the reasons for selecting this project are clearly described.

14.4 Uncertainty: Sensitivity analysis may reveal that an alternative with a lower NPV ranking also has a much lower risk of failing to realize net positive benefits. In such cases, the project sponsor may justify the selection of the lower-ranked alternative, particularly if potential failure of the higher ranked alternatives would lead to large economic losses. Comparison of alternatives from the standpoint of risk will be greatly facilitated by the generation of probability distributions around expected NPVs.

Appendix A: TREATMENT OF INFLATION

[Note: This appendix is taken from CHAPTER 7. INFLATION in *Economic Analysis of Investment and Regulatory Decisions -- Revised Guide*, Federal Aviation Administration, Report FAA-APO-98-4, dated January 1998.]

A.1 Introduction

The performance of economic analysis requires that benefits and costs be measured. The yardstick of measurement is the dollar. This yardstick must remain unchanged for all quantities measured if resulting measurements are to be meaningful and comparable with each other. But the value of the dollar is rarely constant from one year to the next. Changes in the prices of goods and services continuously effect the purchasing power of the dollar. This chapter deals with how to manage changes in the value of the dollar over time in order that benefits and costs occurring in different years may be consistently measured.

A.2 Price Changes

This section is divided into two parts: measuring inflation and measuring price changes for specific commodities. Inflation may be defined as a change in the general price level -- this is a change in the average price of all goods and services produced in the economy or which are regularly purchased by a defined buyer or class of buyers. It is conceptually distinct from the change in the price of any specific commodity, which most likely will be changing at a different rate than the price level or even moving in the opposite direction.

A.2.1 Measuring Inflation

Changes in the value of the dollar over time are measured using an index number. For the overall U.S. economy, a broadly based index representing the price of all goods and services such as the Gross Domestic Product (GDP) Implicit Price Deflator is commonly used. When considering the goods and services typically bought by a subset of purchasers, such as households, a more narrowly defined index is typically employed. Such numbers are a measure of relative value. They indicate the price of the group of goods and services of interest in one year relative to some other year. By convention, index numbers are usually computed as the ratio of the price of the goods and services of interest in one year divided by their price in the base year. The resulting ratio is then multiplied by 100 to produce the index number. Repeating the process for a number of years results in a series of index numbers.

To illustrate the methodology of working with index numbers, consider the two price measures for GDP reported in Table A.1: The GDP Implicit Price Deflator and the GPD Chain-Type Price Index. Both measures are currently published by the Bureau of Economic Analysis of the Department of Commerce. Because the two series differ only slightly, it is appropriate to use either. The following examples make reference to the deflator series.

TABLE A.1

GROSS DOMESTIC PRODUCT IMPLICIT PRICE DEFLATOR on a CHAIN-WEIGHTED BASIS and GROSS DOMESTIC PRODUCT CHAIN-TYPE PRICE INDEX (1986 – 1996)

YEAR	GDP CHAIN-TYPE PRICE INDEX	GDP IMPLICIT PRICE DEFLATOR
1986	80.6	80.6
1987	83.1	83.1
1988	86.1	86.1
1989	89.7	89.7
1990	93.6	93.6
1991	97.3	97.3
1992	100.0	100.0
1993	102.6	102.6
1994	105.0	104.9
1995	107.6	107.6
1996	109.9	109.7

Source: *Survey of Current Business*, Bureau of Economic Analysis, Department of Commerce, published monthly. In addition, GDP Implicit Price Deflators and Chain-Type Price Indexes are regularly reprinted in the *Economic Report of the President*, published annually, and *Economic Indicators*, prepared for the Joint Economic Committee by the Council of Economic Advisers, published monthly.

Note first that 1992 has a value of 100. Known as the base year, it is an arbitrary selection, which is changed from time to time. It indicates that all other values are measured relative to 1992 being equal to 100.

For example, the 1994 value of the GDP implicit price deflator of 104.9 means that the price Level for a given basket of good and services in 1994 was 4.9 percent higher that it was in 1992, which is readily apparent from inspection. Given the 1992 base, it is not readily apparent, how much greater the price level was in 1993 than in 1987. This can be easily computed as 23.5 percent by dividing the 1993 value by the 1987 value and subtracting 1: (102.6/83.1)-1=23.5%. Moreover, the entire index may be restated in terms of any other base year by dividing each value by that of the new base year.[18] Annual changes may be computed by dividing each value

[18] Restarting an index in terms of another base year is a simple arithmetic calculation. It is not the same as the complex statistical processes typically involved when the entity, which generates an index, officially changes its base year. Such a change involves many technical adjustments, which may include changes in scope of coverage and weighting schemes.

by that of the previous year and subtracting 1. For example, the rate of price change between 1995 and 1994 is: (107.6/104/9)-1=2.57%.

To make adjustments for general price level changes requires that the concepts of constant dollars and current dollars be recognized. Current dollar estimates are expressed in the price level of the year in which the resource flows they represent occur. They are the actual amount spent or received. Constant dollar estimates represent the same value as current dollar estimates but as measured by the yardstick of the price level of a fixed reference year. Constant dollars can be specified in terms of any reference year that is desired.

To convert a series expressed in current dollars to constant dollars of a particular year requires that all numbers in the series be adjusted for general price level changes. This requires two steps. First, the general price level index must be transformed so that its base year is the one in which the constant dollars are to be stated. As previously noted, this is accomplished by dividing the general price level index through by its value in the desired base year. The second step is to convert the specified price series to constant dollars. This requires that it be divided by the values produced by step 1. The procedure is illustrated in Table A.2, where the total FAA Operations and Maintenance Budget Appropriation from 1986 through 1996 is converted from current dollars to 1995 constant dollars. To convert constant dollars to current dollars requires that the procedure be reversed. First the deflator series must be divided by its value in the year in which the constant dollars are expressed and multiplied by the constant dollar series.

Another conversion likely to be encountered in practice is the transformation of a series from the constant dollars of one year to those of another. This is accomplished by multiplying the constant dollar series by the ratio of the price index term for the desired year to the price index term for the year in which it is currently expressed, where the base year of the price index is arbitrary. For example, to convert the 1995 constant dollar series in column (4) of Table A.2 from 1995 constant dollars to 1990 constant dollars requires that each number in column (4) be multiplied by 87.0/100 from column (2) or 93.6/107.6 from column (1).

A.2.2 Measuring Price Changes of Specific Goods and Services

A related but distinct situation arises when it is necessary to convert the price of a specific item, which is known in one time period, to what it was in the past or will be in the future. For past prices, this may be accomplished by using an historical price index defined for the particular class of item in question. For example, suppose it is known that a particular generic kind of aircraft was worth $2 million dollars in 1995. A price index defined for this general type of aircraft allows us to determine -- using the procedures described above in Section A.2.1 -- that the price of this aircraft has doubled since 1985. We can then estimate the price of this aircraft in 1985 as $1 million. Note that this price adjustment provides no information

TABLE A.2

CONVERSION of FAA OPERATIONS and MAINTENANCE APPROPRIATIONS from CURRENT DOLLARS to CONSTANT DOLLARS (Dollars in Millions)

Year	(1) GDP Deflator (1992 = 100)	(2) GDP Deflator (1995 = 100)[a]	(3) Total O&M Appropriations In Current Dollars	(4) Total O&M Appropriations In 1995 Constant Dollars[b]	(5) Total O&M Appropriations In 1990 Constant Dollars[c]
1986	80.6	74.9	2,808	3,749	3,262
1987	83.1	77.2	2,982	3,863	3,361
1988	86.1	80.0	3,184	3,980	3,463
1989	89.7	83.4	3,445	4,131	3,594
1990	93.6	87.0	3,824	4,395	3,824
1991	97.3	90.4	4,037	4,466	3,885
1992	100.0	92.9	4,360	4,693	4,083
1993	102.6	95.4	4,538	4,757	4,139
1994	104.9	97.5	4,580	4,697	4,086
1995	107.6	100.0	4,583	4,583	3,987
1996	109.7	102.0	4,643	4,552	3,960

Source: *Economic Report of the President*, published annually; *"Federal Aviation Administration Budget in Brief,"* Fiscal Year 1998.

a. Divide column (1) by 107.6 and multiply by 100.
b. Column (3) divided by column (2) and multiplied by 100.
c. Column (4) multiplied by 87.0 / 100.

as to whether this aircraft's price has increased faster than, slower than, or at a rate equal to the overall rate of inflation during this time period.

An estimate of the future price of an item may be made by using a forecast of a price index for the class of item to determine expected change in the price of the item and then adjusting the current price of the item. In the absence of a price index forecast defined for the class of item of interest, it may be necessary to use a broader index for a particular segment of the economy or in some circumstances a general measure of inflation such as the GDP deflator. While data limitations may require use of the broader measure, it must be recognized that in so doing information on changes in the price of the item relative to the general price level may not be totally or even partially captured.

Estimation of prices of items in the future is typically made for two reasons. The first is for budget purposes. It is necessary to know how much will actually be spent in the future so that it may be budgeted for and included in the appropriation process. The second occurs in the conduct of benefit-cost analysis where it is necessary to determine expected benefit or cost value changes relative to changes in the general price level. This can be particularly important when dealing with items which are a large component of the analysis and which have price changes that differ significantly from the overall change in the general price level. Of particular importance in FAA benefit-cost analysis is the decrease in the cost of electronics relative to the general price level. Suggested methods for dealing with this type of problem are presented in Section A.4.3 below.

A.3 Source of Price Indexes

Numerous different price indexes and forecasts of price indexes are published by governmental and private organizations. They are available for many narrowly defined commodities and services, as well as for broader classifications ranging in scope from selected 4-digit SIC[19] industries to the overall economy.

Available information and the specific situation should govern the selection of an index for any particular price adjustment problem. In general, broadly based measures which reflect the prices of all goods and services typically purchased by a specific buyer or class of buyer should be used to make adjustments for inflation -- changes in the general level of prices. Narrowly defined measures are appropriate for estimating past or future prices of specific goods or services. Special care should be taken not to use a narrowly defined index to make adjustments for the general level of inflation. For instance, if the objective is to determine the change in the real price of aircraft over time (as measured relative to other goods and services), it would not be appropriate to deflate an historical time series of aircraft prices by an aircraft price index. The aircraft price index is built from historical aircraft price changes, and its subsequent application to an historical series of aircraft prices would (by definition) give the impression that aircraft prices remained constant. In fact, prices of aircraft may have changed significantly relative to prices of other goods and services in the economy. It would be appropriate to use an index composed of a broad mix of goods and services (such as the implicit GDP deflator), of which aircraft prices are only a small part, to deflate aircraft prices. On the other hand, if the objective is to convert a known aircraft price from an earlier year to a current aircraft price in the study year, the use of an aircraft price index would be appropriate. The following section identifies several indexes that may be of use to agency analysts. They are organized by categories relevant to potential FAA economic analyses. These indexes are intended only as suggestions.

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[19] Industries are classified in the Standard Industrial Classification Manual 1987, Office of Management and Budget, 1987. The classification system operates in such a way that the definitions become progressively narrower with successive additions of numerical digits. The broadest classifications contain 2 digits and the narrowest 7 digits.

A.3.1 General Price Level

In January 1996 the Bureau of Economic Analysis, compelled by recent dramatic changes in the U.S. economy's structure (particularly the spectacular fall in computer prices), adopted a chain-weighted method of computing real GDP and aggregate growth.[20] Associated with this new approach is the GDP Chain-Type Price Index. Both the new GDP Chain-Type Price Index and the older GDP Implicit Price Deflator represent changes in the prices of all goods an services produced in the United States. Because of their broad coverage, they are widely regarded as the best single measure of changes in the general price level. Either may be used to adjust time series data on current dollar benefits and costs into constant dollars. These measures are compiled by the Bureau of Economic Analysis on a quarterly and annual basis. Data for the most recent three years are published in the *Survey of Current Business.*[21] Historical data are reprinted in the *Economic Indicators.*[22] Both series are also reprinted annually in the *Economic Report of the President.*[23]

Forecasts for the GDP Implicit Price Deflator and/or GDP Chain-Type Price Index are available from several sources. The Office of Management and Budget provides a projection of the GDP Implicit Price Deflator annually in conjunction with the preparation of the President's Budget. DRI/McGraw-Hill Data Resources provides forecasts of a wide range of deflators and indexes. The WEFA Group, another full service economic and information consulting firm, also provides a broad range of services including forecasts of deflators and indexes. OMB recommends that the GDP deflator projections prepared in conjunction with the President's Budget be used when it is necessary to forecast the rate of general inflation and that credible private sector forecasts be used to conduct sensitivity analysis.[24]

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[20]For a general discussion of the chain-type method, see Charles Steindel, "Chain-Weighting: The New Approach to Measuring GDP", *Current Issues in Economics and Finance*, Vol. 1, Number 9, Federal Reserve Bank of New York, December 1995, pp. 1-5. A more detailed description is given in Mark Lasky, "Forecasting with the New Data", *DRI/McGraw-Hill U.S. Review*, February 1996, pp. 38-50, and Mark Lasky "A Preview of the New Chain-Weighted GDP Measures", *DRI/McGraw-Hill U.S. Review*, September 1995, pp. 29-37.

[21]*Survey of Current Business*, Bureau of Economic Analysis, Department of Commerce, Washington, D.C., published monthly.

[22]*Economic Indicators*, prepared for the Joint Economic Committee by the Council of Economic Advisers, U.S. Government Printing Office, Washington, 1996, published monthly.

[23]*Economic Report of the President*, Council of Economic Advisors, Washington, D.C., published annually in January.

[24]OMB Circular A-94 (Revised -- October 29, 1992) p. 8.

A.3.2 Economic Sector Price Levels

Price levels of sectors of the economy represented by the various components of Gross Domestic Product are measured by either the respective deflator for each component of the respective chain-weighted index. Component deflators or component chain-weighted indexes likely to be of interest to agency analysts are those for total personal consumption expenditures, fixed investment, nonresidential structures, and government purchases of goods and services. They are published in the same sources as the GDP Deflator and Chain-Type Price Index. Historical data on a chain-weighted basis are available back to 1959. Forecasts of these series are available from the same sources as the GDP Deflator and Chain-Type Price Index. (Section A.3.1).

A.3.3 Construction

Several widely known indexes of construction costs are available in addition to the implicit deflator. The Boeckh Building Cost Index is compiled monthly by E.H. Boeckh Company, the property division of Mitchell International (internet address: http://www.mitchell.com/boeckh/bcontact.html). It represents construction costs for three types of buildings: (1) apartments, hotels, and office buildings, (2) commercial and factory buildings, and (3) residential buildings. *The Engineering-News Record* (ENR) publishes monthly its Construction Cost, Common Labor, Skilled Labor, Building Cost and Material Cost (comprised of cement, steel and lumber) Indexes. These indexes are available separately for 20 U.S. cities. In addition, the ENR uses the Department of Commerce fixed-weighted Construction Cost index to deflate the value of New Construction Put-In-Place to constant 1992 dollars. On a quarterly basis, the ENR compiles various construction cost indexes: general-purpose cost, valuation, and special purpose indexes. Each December the ENR forecasts these indexes for the next 12 months.[25]

The Federal Highway Administration publishes a quarterly index of highway construction costs in "Price Trends for Federal-Aid Highway Construction."[26] It is based on pricing of six components of highway construction: common excavation, to indicate the price trend for all roadway excavation; Portland cement concrete pavement and bituminous concrete pavement, to Indicate the price trend for all surfacing types; and reinforcing steel, structural steel, and structural concrete, to indicate the price trend for structures.

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[25]For detailed description of the index, see "Materials and Labor Cost Trends in the U.S.," *Engineering News-Record*, (March 9, 1981); pp. 132-137. Also see fourth quarterly Cost Report in ENR for December 23, 1996, and Forecast' 97 in ENR for January 27, 1997.

[26]"Price Trends for Federal-Aid Highway Construction," Office of Engineering, Federal-Aid and Design Division, Federal Highway Administration, publication number FHWA-PD-95-006.

A.3.4 Energy

As a component of the Producer Price Index (PPI), the Bureau of Labor Statistics compiles monthly indexes for the prices of coal, coke, gas fuels, electric power, crude petroleum, and refined petroleum products -- gasoline, kerosene and jet fuels, light fuel oils, residual fuels -- as well as a composite of them. These are published in the *PPI Detailed Report*[27] or in *The Monthly Labor Review*.[28] The PPI indexes are also available on the BLS web site at http://stats.bls.gov.

In addition, the Energy Information Administration of the U.S. Department of Energy publishes the *Annual Energy Review* and *Annual Energy Outlook*. For most series historical energy statistics are given from 1949 through the current year. The *Annual Energy Outlook* contains projections to 2015. Most of the data are also available electronically at http:/www/eia.doe.gov.

A.3.5 Electronics and Computers

Also contained in the Producer Price Indexes are several components representing electric and electronic devices. The broadest category is for electrical machinery and equipment. It represents such items as wiring devices, instruments, motors, transformers, switching gear, electric lamps, and electric components and accessories. An index for each of these subcomponents is also available. The electric and electronic devices index is published in the *Monthly Labor Review* and the subcomponent indexes in the monthly *PPI Detailed Report*.[29] In addition, the *PPI Detailed Report* provides indexes for specific SIC electronics industries—electron tubes (SIC 3671), printed circuit boards (SIC 3672), semiconductors (SIC 3674), electronic capacitors (SIC 3675), electronic resistors (SIC 3676), electronic coils and transformers (SIC 3677) and electronic connectors (SIC 3578). Computers are aggregated under a broad category -- Office, Computing, and Accounting Machines (SIC 357). At the four-digit level, the computer industry is represented in the PPI by electronic computers (SIC 3571), computer storage devices (SIC 3572), computer terminals (SIC 3575), and computer peripheral equipment, n.e.c. (SIC 3578).

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[27] *The PPI Detailed Report*, Bureau of Labor Statistics, Department f Labor, published monthly.

[28] *The Monthly Labor Review*, Bureau of Labor Statistics, Department of Labor, published monthly.

[29] *The PPI Detailed Report*, Bureau of Labor Statistics, Department of Labor, published monthly.

A.3.6 Aircraft and Parts

In addition, BLS publishes the PPI indexes for aircraft and parts. These consist of an aggregate index for aircraft and parts (SIC 372) and more detailed indexes: aircraft (SIC 3721), aircraft engine and engine parts (SIC 3724), and aircraft parts auxiliary equipment, n.e.c. (SIC 3728). DRI provides a forecast of these indexes upon customer request.

A.4 Treatment of Inflation in Benefit-Cost Analysis

As a general rule, inflation should not be permitted to affect the outcome of benefit-cost analyses. Such studies are concerned with real quantities -- resources consumed and benefits provided. The dollar is used only as the yardstick of value measurement. Because changes in the unit of measurement cannot affect the relationship between the real quantities, allowing price changes to affect the analysis will distort the results. This section presents methodology for ensuring that inflation does not impact benefit-cost analysis and produce such distortions.

A.4.1 Constant or Nominal Dollars

OMB now permits benefit-cost analyses to be conducted in either nominal or current dollars or in constant dollars of a particular year.[30] Effects of inflation are excluded by choosing *either* nominal dollars *or* constant dollars and avoiding mixing-up both in the same analysis and by using a nominal discount rate if the analysis is conducted in nominal dollars and a real discount rate if the analysis is conducted in constant dollars. (See Chapter 5, 11.C. of *"Economic Analysis of Investment and Regulatory Decisions -- Revised Guide,"* FAA-APO-98-4, dated January 1998.) OMB implies a preference for the use of constant dollars unless most of the underlying values are initially available in nominal dollars. Although some conversions from nominal to constant or vice-versa may be necessary to get all values into one form or the other, the choice of nominal or constant dollars should be made so as to minimize the conversions required.

Another consideration in selecting nominal or constant dollars is whether or not private sector optimizing behavior is endogenous within the analysis to be undertaken. If it is, the analyst must recognize that private sector actions are based on after tax impacts and that taxes are typically a function of nominal values. (For example, an analysis of alternative policies designed to influence aircraft operations to replace older aircraft with newer, quieter ones would need to incorporate tax impacts of replacement.) Where the outcome of an analysis depends significantly on such behavior, the analyst should seriously consider use of nominal

[30] "OMB Circular A-94" (Revised -- October 29, 1992) p. 8. The previous version of Circular A-94 (March 27, 1972) p. 3, had required that all analyses be conducted in constant dollars.

values when designing the study.Current FAA practice is to conduct benefit-cost analyses in constant dollars. Although use of nominal values may be advantageous in certain cases, FAA analyses should continue the use of constant dollars as normal practice unless there is good reason to do otherwise. The following guidance presumes the use of constant dollars.

A.4.2 Period Between Analysis Date and Project Start Date

The selection of the yardstick of value measurement is arbitrary. The constant dollars of one year are as good as the constant dollars of any other year as far as the economics of the analysis goes. However, for practical considerations it is recommended that the constant dollars of the year of the analysis be selected as the unit of measurement. This procedure is a natural approach because it permits benefits and costs to be valued at their current prices. Moreover, it avoids the need to transform current prices into past or future year dollars and, with respect to future years, the need to forecast inflation. Note that this recommendation is not a hard and fast rule and should not be followed when other circumstances so indicate.

A.4.3 Inflation During Project Life

During the projected life of the proposed investment of regulation, changes in the general level of prices should not be allowed to impact the analysis. Benefits and costs are real quantities; they consist of the goods and services provided by a project and the resources consumed in providing them. Dollars enter the analysis only as the yardstick of value. To allow the unit of measurement to vary would assign different valuation to the same benefits or costs depending on the variation in the unit of measurement over the project's lifetime.[31] With the typical investment or regulation during times of increasing prices, large costs occurring early in the project's life would be assigned less value than benefits stretching out over the years. This could lead to projects being undertaken which are not worthwhile because inflation had been allowed to increase benefit values relative to cost values. To avoid such distortions, all benefits and costs associated with an investment or regulation must be measured in the constant dollars of a particular year -- preferably the year of the analysis for reasons noted in Section A.4.2 of this appendix.

There is an important qualification (not exception) to the general rule of expressing all quantities in the constant dollars of a particular year. Quantities that increase or decrease in value more or less than the general price level should have their values adjusted by the difference between changes in their value and the general price level. This must be done to

[31] This statement assumes use of a real discount rate such as the OMB specified 7 percent rate. It would not hold if a nominal discount rate were used because the inflation premium built into the nominal rate should remove, at least approximately, the impacts of inflation.

reflect that their real values relative to the real values of other goods a services have changed apart from any changes in the general level of prices.

Adjustment for real price changes requires that the difference between forecast general price level changes and prices of the items in question be computed. This be accomplished by taking the ratio of the specific item price index to the GDP Deflator (or GDP Chain-Type Price Index). The resultant index will show how much the specific item is forecast to increase or decrease in price once the impact of overall price level changes is removed. The resultant index may then be multiplied by the constant dollar estimate of the item in question in each year to adjust it for real changes in value. This procedure is demonstrated by equations (A-1) and (A-2):

$$RI_t = \frac{SPI_t}{GDPI_t} \qquad (A-1)$$

$$XA_t = XO_t(RI_t) \qquad (A-2)$$

where: SPI_t = specific item price index in year t,
$GDPI_t$ = implicit GDP deflator in year t,
RI_t = resultant index in year t,
XO_t = unadjusted value, and
XA_t = value adjusted for real price changes.

In practice, another procedure is often used. If a particular item is known to be changing in real value at an approximately constant rate, its value may be projected by equation (A-3):

$$XA_t = XO_t(1+f)^m \qquad (A-3)$$

where: m = the number of years between year t and the year in which the constant dollars of measurement are stated; and
f = the annual rate of real relative price change.

This adjustment can be combined with the discounting procedure developed in Chapter 5 (of *Economic Analysis of Investment and Regulatory Decisions -- Revised Guide*) and defined in equation (5-6). Combination is possible because two ratios are being applied similarly to the same benefit or cost figure. This is indicated in equation (A-4):

$$NPV = \sum_{t=0}^{k} \frac{(B-C)^t}{(1+r)^t} + \sum_{t=0}^{k} X_t \left[\frac{1+f}{1+r}\right]^t \qquad (A-4)$$

where: X_t = the quantity in year t being adjusted expressed in constant dollars of the year of initial project implementation,
$(B\text{-}C)_{t'}$ = all benefits and costs other than those contained in Xt,
r = the discount rate, and
k = the total number of periods in the evaluation period of the project or regulation.

A typical situation where real cost changes must be considered arises with respect to replacement projects. One advantage of the proposed new system over the old often is that it replaces an old technology with a new one. In cases where the real cost of the old technology is projected to increase with time, the absolute amount of the new system's advantage continually increases. While it is proper to include such an ever-increasing advantage in an evaluation, the burden of establishing an appropriate rate of increase rests squarely on the shoulders of the analyst. Conclusions which result solely from assuming large real cost increases in the existing system which are not thoroughly justified are not convincing and are easily contested.

Appendix B: OFFICIAL GUIDANCE ON ECONOMIC ANALYSIS

Official guidance on the need to conduct economic analyses of investment projects and appropriate methodologies for doing so are documented in the following Executive Order and Office of Management and Budget (OMB) Circular.

B.1 Executive Order 12893 (January 26, 1994): "Principles of Federal Infrastructure Investment"--Requires Federal agencies to develop and implement plans for infrastructure investment and management consistent with the following principles: systematic analysis of transportation infrastructure project benefits and costs; efficient management of infrastructure; greater private sector participation in infrastructure investment and management; and project decisionmaking at the appropriate level of government. The Executive Order requires agencies to evaluate infrastructure investment at both the program-level (e.g., AIP-level) and individual project level.

B.2 OMB CIRCULAR A-94 (Revised) (October 29, 1992): "Guidelines and Discount Rates For Benefit-Cost Analysis of Federal Programs"--Prescribes the methodology to be used in evaluating time-distributed benefits and costs. The circular requires that present values for benefits and costs of projects such as airport infrastructure projects be calculated using a 7 percent real discount rate. It also establishes policy for the treatment of inflation and changes in real costs. The circular applies to the evaluation of U.S. Government programs and projects.

B.3 Other References: The following references may also prove to be useful.

B.3.1 Methodological:

Airport Capacity and Delay, FAA Advisory Circular 150/5060-5, September 9, 1983.

Airport Capacity and Delay, Change 2, December 1, 1995.

Airport Design, FAA Advisory Circular 150/5300-13, September 29, 1989.

Lyon, Randolph M., "Federal Discount Rate Policy, The Shadow Price of Capital, and Challenges for Reforms," *Journal of Environmental Economics and Management*, 18, no. 2, part 2 (March 1990), S29-S50.

OMB BULLETIN No. 94-16, "Guidance on Executive Order No. 12893, Principles for Federal Infrastructure Investments," March 7, 1994.

"Policy Guidance Regarding Benefit-Cost Analysis for Airport Capacity Projects Requesting Discretionary Airport Improvement Program Grant Awards and Letters of Intent," *Federal Register*, Vol. 62, No. 121, June 24, 1997.

"Policy Regarding Revisions of Selection Criteria for Discretionary Airport Improvement Program Grant Awards," *Federal Register*, Vol. 59, No. 209, October 31, 1994.

"Policy for Letter of Intent Approvals under the Airport Improvement Program, " *Federal Register*, Vol.59, No. 209, October 31, 1994.

Staffing Standards System—Air Traffic, FAA Order 1380.33B, Federal Aviation Administration, Washington D.C. March 10, 1980.

Staffing Standards System—Airways Facilities Sector Level, FAA Order 1380.40C, Federal Aviation Administration, Washington D.C., December, 21, 1992.

Staffing Standards—Regional Logistics Division, FAA Order 1380.42A, Federal Aviation Administration, Washington D.C.

A Study of the High Density Rule, DOT Report to Congress, Department of Transportation, Washington D.C., May 1995.

"Treatment of Value of Life and Injuries in Preparing Economic Evaluations," Office of the Secretary of Transportation Memorandum January 6, 1993, and subsequent annual updates.

"The Value of Saving Travel Time: Departmental Guidance for Conducting Economics Evaluations," Office of the Secretary of Transportation Memorandum, April 9, 1997.

B.3.2. Data Sources:

Air Carrier Traffic Statistics, Bureau of Transportation Statistics, U.S. Department of Transportation, published monthly.

Economic Indicators, prepared for the Joint Economic Committee by the Council of Economic Advisers, U.S. Government Printing Office, Washington D.C., 1996, published monthly.

Economic Report of the President, Council of Economic Advisers, Washington, D.C., published annually in January.

FAA Air Traffic Activity, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington D.C., Published annually.

FAA Aviation Forecasts, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington, D.C., published annually.

FAA Statistical Handbook of Aviation, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington D.C., published annually.

"Materials and Labor Cost Trends in the U.S., "*Engineering News Record*, March 9, 1981, pp. 132-137.

Monthly Labor Review, Bureau of Labor Statistics, Department of Labor, published monthly.

OMB CIRCULAR No. A-76 (Revised Handbook), *Performance of Commercial Activities*, March 1996.

PPI Detailed Report, Bureau of Labor Statistics, Department of Labor, published monthly.

"Price Trends for Federal-Aid Highway Construction," publication number FHWA-PD-95-006, Office of Engineering, Federal-Aid and Design Division, Federal Highway Administration, Washington D.C.

Standard Industrial Classification Manual, Office of Management and Budget, 1987.

Standard Abstract of the United States, Department of Commerce, Washington D.C., 1996.

Survey of Current Business, Bureau of Economic Analysis, Department of Commerce, published monthly.

Appendix C: ADJUSTMENTS OF BENEFITS AND COSTS FOR INDUCED DEMAND

C.1 Consideration of Induced Demand: Sections 10 and 11 of this guidance described methods that can be used to quantify benefits and costs associated with airport projects at specified levels of capacity and usage. However, a complete BCA should address the dynamic interaction of project benefits and costs and level of airport usage. Specifically, the net benefits generated by an investment for current users of the airport will induce new users to come. These new users will also benefit from the project but, at the same time, they will impose demands on the airport's capacity that may reduce the net benefits of the project to current users. Although it is desirable that induced demand be included in a BCA, because of the uncertainty associated with the data required for this analysis, the FAA leaves it to the option of the airport sponsor whether to include it or not in the BCA submission.

C.2 Economic Framework for Estimating Benefits: Economic theory provides the essential framework for understanding and measuring the dynamic interaction of project net benefits and demand for the project. A simplified version of this framework, known as consumer surplus, is illustrated in Figure C.1 for air transportation services.

Figure C.1 is premised on the following assumptions:

- Passengers and cargo shippers are the ultimate users of air transportation services provided by or from the airport;
- Passengers and cargo shippers consume airport services largely through the intermediary of air carriers and other aircraft operators;
- In a competitive environment, air carriers will pass on net operating cost savings associated with improved infrastructure to their passengers in the form of lower fares and charges;
- Passengers will also realize benefits from infrastructure improvements in the form of reduced travel times;
- The air transportation supply curve, which represents the total cost (price) of air service to passengers (air fare and the value of passenger time spent in travel), is upward sloping due to growing per operation delay as the volume of air service increases under congested airport conditions; and
- The demand curve for airline services is downward sloping, meaning that more air transportation service is demanded when fares/travel times are lower than when they are higher.

The intersection of the supply curve S and the demand curve D in Figure C.1 (point "a") represents the equilibrium demand for and supply of air services at a given point in time assuming no significant investment in airside infrastructure (i.e., the base case scenario). Total price "P" and demand "Q" correspond to this non-investment equilibrium point.

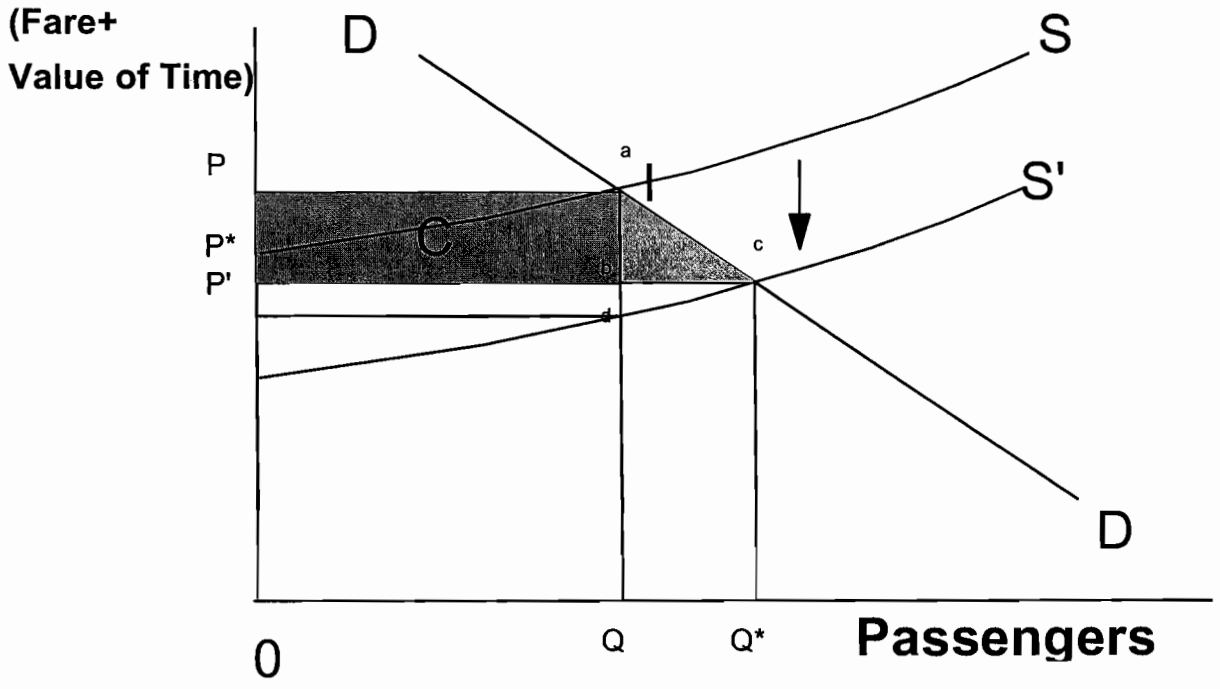

Figure C.1: Consumer Surplus and Role of Induced Demand

Now assume that an infrastructure capacity investment would reduce airside congestion and therefore reduce delay per aircraft operation and passenger. Although traffic demand with respect to a given total price does not change with the investment (curve D does not shift), the investment would permit a higher volume of air service to be provided at the same total price per passenger, or (alternatively) would allow a lower total price per passenger for the same traffic level. This effect is represented by a shift in the air travel supply curve downward, from S to S'. The supply and demand equilibrium is altered from point "a" to point "c", indicating that a reduction in the total price of air travel would lead to an increase in demand for air travel services by passengers.

The net effect of the project is to increase total benefits by an amount equal to the areas C plus I. C is the product of the decrease in total price ($P-P^*$) multiplied by the number of passengers (Q) who would have used the airport even without the investment (pre-existing passengers). The benefit to induced or incremental traffic (those passengers who would not have used the airport except for the benefits of the investment) is the product of the decrease in total price ($P-P^*$) multiplied by the increase in the number of users (Q^*-Q) multiplied by one-half. Multiplication by one-half is required because the demand curve bisects the area that would be formed by the product of ($Q-Q^*$) and ($P-P^*$).[32]

The consideration of induced demand and consumer surplus is necessary for a correct quantification of benefits.[33] Failure to consider induced demand in Figure C.1 would lead the analyst to conclude that total price per passenger would fall to P' rather than P* and that total benefits would equal the rectangle PadP', rather than the polygon PacP^* (areas C plus I). In some cases, this error could become severe. Figure C.2 illustrates a case where average delay costs are rising steeply as operations increase at a congested airport. The assumption that

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[32]In economic terms, the adjustment by one-half represents the difference between the marginal valuation, read from the demand function, and the new total price P^* at each quantity above Q.

[33]Air carriers could also experience a benefit known as producer surplus, provided that air carrier operating expenses are subject to rising marginal costs. However, this discussion assumes that air carrier operating costs in an uncongested airport environment experience constant returns to scale (i.e., the price of providing an additional unit of service does not change with the volume of service). Delay attributable to increases of air service at congested airports would lead to higher per operation air carrier costs. However, assuming the airport is served by multiple carriers, it is likely that carriers will increase service in response to the prevailing average delay per operation rather than the marginal delay per operation. Under the condition of a supply curve defined by rising average cost, there would be no producer surplus associated with an expansion of air transportation service.

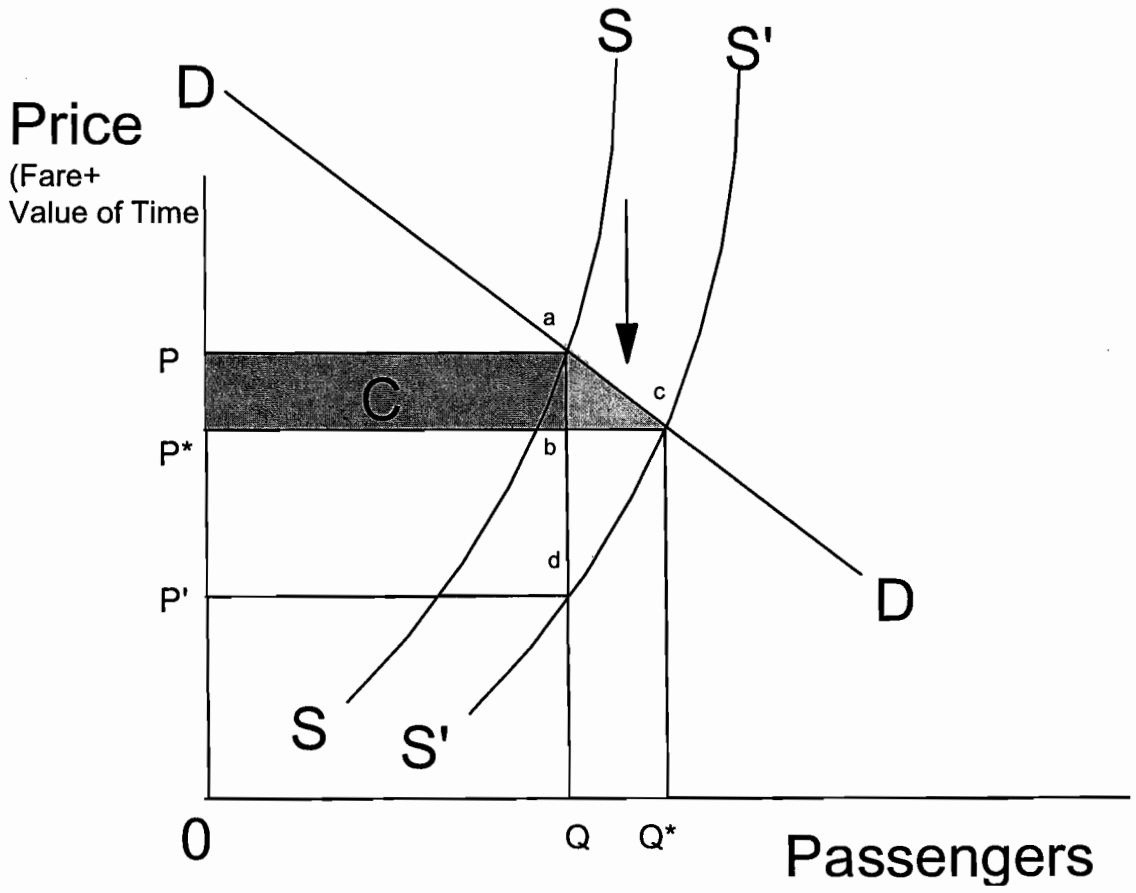

Figure C.2: Consumer Surplus With Radical Delay

airport activity would remain unchanged in response to the investment resulting in supply curve S' would lead to an overestimation of future average passenger delay savings equal to the difference between the area PadP' and PacP*.

C.3 Methodology to Calculate Induced Demand: The guidance for doing simulation analysis of airport capacity projects in Section 10.4.1 recommended that a series of simulations be conducted at passenger demand levels escalating in 2 percent increments from the base case demand levels simulated. Estimated delay reductions per operation at each demand level should then be recorded in a tabular format (see Table 10.3).

The data in Table 10.3 can be used to determine the impact of the investment on the final demand for air transportation services (as measured by the number of passengers). By calculating the net impact of delay reductions and other project benefits on passenger trip time and fare, and by making a reasonable estimate of the total elasticity of demand for air travel at the study airport, the induced demand scenario in Table 10.3 that best represents an equilibrium demand/supply solution can be determined. In particular, the scenario with the induced demand level (e.g., 2 percent, 4 percent) that most closely conforms to the expected change in demand (passenger response to the actual delay reduction for that scenario as estimated using the total elasticity of demand) will be the equilibrium scenario. This process is explained in detail in the following subsection.

C.3.1 Total Trip Costs: The first step to reaching an equilibrium demand/supply solution is to determine the total one-way trip cost for an average passenger currently using the airport. This cost consists of two principal components: the average value of one-way passenger transit time (e.g., the time from entering the departure airport to the time of leaving the arrival airport) and the average one-way ticket fare (which will reflect the cost of providing air service to that passenger in a competitive market).

The current total one-way trip cost estimates (time and fare) serve as the basis for evaluating the relative impact of delay reductions and other benefits associated with an investment. Table C.1 represents an expansion of the type of data contained in Table 10.3 to include the impact of travel time and fare associated with a particular investment option in year X. Table C.1 should include any other quantifiable benefits realized by air travelers, whether or not these benefits are themselves sensitive to changes in passenger demand. Airlines and passenger service providers are assumed to increase their level of service (subject to constant returns to scale) to meet the changed demand for air service by passengers.

Table C.1 is presented in a stacked format, but as a spreadsheet would represent a continuous table extending over 33 columns. For purpose of reference within the table, the columns are labeled by their alphabetic spreadsheet column headings from A through Z and AA through AG. Five scenarios, representing induced demand levels equal to 0, 2, 4, 6, 8 percent of base case demand, are identified and developed. Enplanements in the base case are identified in column C and passengers per enplanement in column D. Total passengers, consisting of base

TABLE C. 1: CALCULATION OF REDUCED DEMAND

A	B	C	D	E	F	G
SCENARIO INDUCED PASSENGER LEVELS						
	Additional Percentage Induced Over Base Case Demand	Base Case Demand (Explanements)	Passengers Per Enplanement	Base Case Demand (Passengers) (C*D)	Induced Demand (Passengers) (B*E)	Total Demand (Passengers) (E*F)
Scenario A	0%	1,000,000	2	2,000,000	0	2,000,000
Scenario B	2%	1,000,000	2	2,000,000	40,000	2,040,000
Scenario C	4%	1,000,000	2	2,000,000	80,000	2,080,000
Scenario D	6%	1,000,000	2	2,000,000	120,000	2,120,000
Scenario E	8%	1,000,000	2	2,000,000	160,000	2,160,000

A	H	I	J	K	L	M
SCENARIO VALUE OF REDUCED TRIP TIME						
	One-Way Base Case Trip Time (Minutes)	Value of Passenger Time	Value of Base Case Trip Time ((H/60)*I)	Time Saving of Investment Option (Minutes)	Value of Time Saving of Investment Option ((K/60)*I)	Value of Investment Case Trip Time (J-L)
Scenario A	150	$26.70	$111.25	2.9	$1.29	$109.96
Scenario B	150	$26.70	$111.25	2.7	$1.20	$110.05
Scenario C	150	$26.70	$111.25	2.5	$1.11	$110.14
Scenario D	150	$26.70	$111.25	2	$0.89	$110.36
Scenario E	150	$26.70	$111.25	1.5	$0.67	$110.58

A	N	O	P	Q	R	S	T	U	V	W	X
SCENARIO VALUE OF REDUCED AIR FARE											
	One-Way Base Case Trip Fare	Average Aircraft Operating Cost/Hour	Average Passengers Per Operation	Aircraft Operating Cost Savings Per Pass. (K/60*O)/P	Annual Financing Cost From Invest. in Year X	Annual Operating & Maintenance Cost From Invest, in Year X	Higher Landing Fee & O&M Costs From Invest. Per Pass. ((R+S)/G)	Net Aircraft Operating Cost Savings Per Pass. (Q-T)	Percent Cost Savings Passed On To Passenger	Net Fare Savings Per Pass. (U*V)	One-Way Trip Fare After Invest. (N-W)
Scenario A	$130.00	$1,200.00	50	$1.16	$500,000	$100,000	$0.30	$0.86	100%	$0.86	$129.14
Scenario B	$130.00	$1,200.00	50	$1.08	$500,000	$102,000	$0.30	$0.78	100%	$0.78	$129.22
Scenario C	$130.00	$1,200.00	50	$1.00	$500,000	$104,000	$0.29	$0.71	100%	$0.71	$129.29
Scenario D	$130.00	$1,200.00	50	$0.80	$500,000	$106,000	$0.29	$0.51	100%	$0.51	$129.49
Scenario E	$130.00	$1,200.00	50	$0.60	$500,000	$108,000	$0.28	$0.32	100%	$0.32	$129.68

A	Y	Z	AA	AB	AC	AD	AE	AF	AG
SCENARIO TOTAL TRIP COST REDUCTION (TIME AND FARE)							BEST INDUCED DEMAND ESTIMATE		
	One-Way Base Case Total Cost (N+J)	Total One-Way Cost Reduction Realized Per Passenger (L+W)	One-Way Investment Total Cost (Y-Z)	Percent Change in rip Cost Due to Investment (-Z/Y)	Price Elasticity of Demand	Estimated Percentage Induced Demand (AB*AC)	Discrepancy Estimated Induced Relative to Assumed (AD-B)	Closet Match	Actual Invest. Case Time Saving Per Operation (Minutes)
Scenario A	$241.25	$2.15	$239.10	-0.89%	-1.20	1.07%	1.07%		
Scenario B	$241.25	$1.99	$239.26	-0.82%	-1.20	0.99%	-1.01%	*	2.7
Scenario C	$241.25	$1.82	$239.43	-0.76%	-1.20	0.91%	-3.09%		
Scenario D	$241.25	$1.40	$239.85	-0.58%	-1.20	0.70%	-5.30%		
Scenario E	$241.25	$0.99	$240.26	-0.41%	-1.20	0.49%	-7.51%		

case (column E) and induced passengers (column F) are summarized in column G. All data in Table C.1 are illustrative and do not reflect an actual airport analysis.

C.3.2 Impact of Time Savings on Trip Time: Column H of Table C.1 reflects the unadjusted average passenger one-way trip time in minutes. Passenger trip time can be determined from passenger and/or operator surveys, consultations with operators, and/or data provided by commercial data vendors. Estimation of total trip time should make allowances for passenger check in, transfers to connecting flights, check out, and delay encountered. It is also critical that trip time be considered for a whole one-way trip, and not simply a segment of a multi-segment flight. Column I represents the official DOT value of passenger time (see Section 10.5.5.2, FAA-APO-98-8, and APO issued updates to the value of passenger time). Column J is the product of columns I and H and represents the time value of the total base case trip. Column K is the average savings in trip minutes attributable to the investment for different possible levels of demand (base plus induced demand), taken from column E of Table 10.3. Column L represents the value in passenger time of this delay saving, and M represents the average amount and value of the trip time in column J less the time savings in column L.

C.3.3 Impact of Time Savings on Trip Fare: Column N of Table C.1 is the average trip fare in 1996 dollars. Average trip fare can be calculated from the same sources--surveys, consultations with operators, and/or commercial data vendors--used to determine average trip time. Column O is the variable operating cost for the average aircraft using the airport (see Section 10.5.5.1). Column P represents the average number of passengers on each flight operation that experiences the delay saving noted in column K. Column Q is the value of the delay reduction in terms of reduced variable aircraft operating costs, calculated by valuing minutes of delay saving from column K at the aircraft operating cost in column O.

Column Q represents the unadjusted benefit of the investment with regard to its impact on aircraft operating costs on a one-way trip. However, the aircraft operator may or may not pass on this saving to passengers in the form of lower trip fares--some will be diverted to the airport (in the form of airport user fees) or may be retained by the carrier itself. In column R of Table C.1, it is assumed that $500,000 in airport user fees must be raised from aircraft operators to cover the project financing cost in year X[34]. In addition, column S summarizes the annual O&M costs in Year X associated with the investment at different levels of demand. Column T shows the sum of columns R and S, divided by total passengers (column G). In column U, column T (total airport user fees and O&M costs per passenger) is subtracted from column Q (aircraft operating cost savings per passenger) to yield a net cost savings to the aircraft operator per passenger.

[34]In the case of an AIP-funded project, the amount raised through higher rates and charges to air carriers will be the residual portion of the project not covered by AIP or payments from airport reserve funds. It should be noted that airport user fees are considered here because they affect the net gain to the aircraft operator, and thus the average cost savings that may be passed along to passengers. User fees to cover capital costs are not otherwise considered in the BCA, however, in that the costs of financing the investment are already captured in the discounted value of the capital and operating costs of the investment (see Section 11).

In a competitive market, it may be assumed that air carriers will pass along some portion of their net cost savings to passengers in the form of lower fares. In column V of Table C.1, it is assumed that aircraft operators pass on 100 percent of these cost savings to their passengers as lower fares (shown in column W).[35] Column X represents the one-way base case fare of column N less the full value of the net per passenger aircraft operating cost savings in column W for each assumed demand level.

C.3.4 Impact of Change in Total Trip Cost on Final Demand: Columns Y, Z, and AA summarize the total trip cost before and after the investment for each level of simulated demand, with column Z summing the total time and fare savings realized by each passenger. Column AB represents the percentage reduction in total per passenger trip cost attributable to the new investment at each of the five simulated demand levels.

C.3.4.1 Total Elasticity of Demand. Column AC introduces the total elasticity of demand for air travel--a key parameter for determining which of the simulated induced demand levels is the correct equilibrium demand level. Total elasticity of demand for air travel is a measure of air travelers' response to variations in the cost of air travel. This parameter measures the percentage change in air passenger trips resulting from a one percent change in trip prices. Total elasticities are negative because price and quantity demanded are inversely proportional (see Figure C.1).

Total elasticities are highly specific to the characteristics and location of the particular airport (e.g., the carriers serving the airport, local ground access congestion, the proximity of competing airports, and availability of other transportation modes). Estimation of total elasticities specific to an airport may be possible, particularly if carriers at the airport engage in limited fare wars (especially when the fare war is limited to the airport in question). In such cases, changes in airport usage can be measured. Alternatively, surveys of passengers to determine demand responses must rely on contingent valuation methodologies which are expensive to administer and may yield inaccurate results.

As part of a major study on child restraint systems, FAA sponsored an extensive review of the economic literature regarding total elasticity of demand for air travel at a national level. The findings of this review are summarized in Chapter 2 and Appendix G of Report to Congress: Child Restraint Systems, Volume 1 and 2, May 1995. The elasticity values found in the academic literature range from -0.6 to -4.5. Representative values for business and non-business travelers are presented in Table C.2. Values in Table C.2 can be tailored to the mix of passengers at an airport. Overall weighted values are -0.79 and -1.59 for business and non-business travelers, respectively, with an overall average (assuming the 50/50 mix typical of the nation at large) of -1.2.

[35] Technically, (1) 100% of the cost savings should always be passed on in order to attract new customers and (2) only the marginal customers are the recipients of the cost savings.

TABLE C.2: TOTAL ELASTICITY OF DEMAND

Travel Distance (One Way)	Non-Business Travelers	Business Travelers
Less than 500 miles	-2.0 (8.9% of NB Travelers	-1.0 (4.7% of Business Travelers)
Greater than or equal to 500 miles	-1.6 (91.1% of NB Travelers	-0.8 (95% of Business Travelers)
All distances	-1.6 (100% of NB Travelers	-0.8 (100% of Business Travelers)

C.3.4.2 Application of Total Elasticity. As already noted, column AB of Table C.1 provides the percentage changes in total trip cost (value of time and fare) that would result from the investment at different levels of simulated demand (consisting of base case and induced demand). These percentage changes in cost will be negative if trip cost is reduced by the investment for a specified demand level. Multiplication of the negative total elasticity of demand coefficient in column AC by the negative cost change estimate in column AB yields the positive percentage change in demand (induced demand) that would actually be associated with the time and fare savings of each demand scenario (e.g., base case demand, base case demand plus 2 percent, etc.). The estimated induced demand associated with each scenario is listed in column AD of Table C.1.

The analyst must compare the estimated induced demand associated with each scenario (column AD) to the assumed level of induced demand used to simulate the scenario (column B). This comparison is shown in column AE. The estimated induced demand level that most closely approximates the simulated demand level (the lowest absolute difference between column AD and B as shown in column AE) represents the equilibrium demand level for the investment.

In Table C.1, the best match between estimated and simulated demand is the 2 percent induced demand level described in scenario B (the 2.8 minute delay reduction associated with a 1.4 percent induced demand level). This match is indicated in columns AF and AG. In other words, the resulting delay reduction (and any other net benefits realized by passengers) associated with the demand levels simulated in scenario B most closely matches the predicted demand response associated with the realized delay reductions (2 percent versus 1.4 percent). In all other tested scenarios, the spread between the simulated and predicted demand levels is greater. Thus, once the investment is in place and passengers (existing and new) have responded to the benefits attributable to the investment in year X, it would be expected that approximately 2 percent more passengers will be using the airport than would have been the case under the base case. Given a base case demand level of 1 million passenger enplanements, this would correspond to 20,000 new enplanements, or 40,000 new passengers.

Although the induced demand effect illustrated in the above example is not large, in some cases (e.g., airports in close regional proximity) total elasticity of demand may be high (4 or above). Given a elasticity coefficient of -6, the induced demand effect in the above example would have been 6 percent. Similarly, a project generating major delay savings would also have a magnified induced demand effect.

C.4 Induced Demand at Multiple Forecast Levels: Table C.1 was developed for one point in time, corresponding to that point when demand at the airport would reach 1 million enplanements under the base case demand forecast. Depending on the expected growth in enplanements under the base case, two or more higher demand levels will have been simulated for the investment (see Section 10.4.1), each of which will have its own level of induced demand. Consequently, Table C.1 should be repeated for each present and future demand level simulated.

Travel time and fare estimates for the current period should be adjusted to each of the future forecast years based on expected growth in delay as measured in the base case scenario. Future travel times will be equal to the current travel time plus new delay associated with future traffic. Delay will also increase operator costs by the value of aircraft operating costs associated with the new delay. This added cost should be converted to a per passenger basis and added to the current average fare to calculate a future base fare for base case (this assumes the cost increase is passed on to customers).

Because an investment may have greater benefits relative to the base case at higher overall demand levels, it does not follow that the percentage of induced demand associated with one demand level (year X) will apply to higher demand levels (year X+10). Thus, induced demand which was 3 percent in Table C.1 (associated with 1 million base case enplanements in year X) could be 4 or 6 percent when base case enplanements reach 2 million in year X+20.

C.5 Adjustments of Benefits and Costs to Reflect Induced Demand: Table C.1 was developed to determine the response of users to the airport following the implementation of a new project. Demand response was measured according to the cost savings realized by the ultimate user of the system--the passenger. The information contained or developed in the Table C.1 is also critical to the development of total project benefits and costs, although some further processing is required.

C.5.1 Benefits: Benefits from Table C.1 must reflect those to the overall project rather than simply to passengers. In addition, benefits must be counted differently for pre-existing and induced passengers.

C.5.1.1 Project Versus Passenger Benefits. Table C.1 measured travel time and fare reductions realized by passengers as a means of gauging the change in final demand for airport services that may result from an investment. Fare reductions, made possible by lower airline operating costs, were adjusted downward to reflect user charges paid by airlines to the airport sponsor to cover financing and O&M costs associated with the investment.

However, the full cost savings to airlines (whether distributed to the sponsor through user charges or to the passenger through lower fares or retained by the airline) must be measured as benefits of the project. In the case of Table C.1, these are measured on a per passenger basis in column Q. Project financing and O&M costs are already considered by the BCA process in the total capital and O&M cost of the project (adjusted in the discount rate).

C.5.1.2 Benefits To Pre-Existing and Induced Traffic. Benefit information contained in Table C.1 must be interpreted differently for passengers who would have used the airport even without the investment (pre-existing passengers) and those who are induced to use it due to the benefits of the investment. As noted in Appendix C.1, the benefit to induced passenger traffic is equal to the product of the decrease in price ($P-P^*$) multiplied by the increase in the number of users (Q^*-Q) multiplied by one-half. From the context of Figure C.1, multiplication by one-half is required because the demand curve bisects the area that would be formed by the product of ($Q-Q^*$) and ($P-P^*$).

The values in these columns for scenario B would represent the total benefits per pre-existing passenger, which are summarized in Table C.3. Column B of Table C.3 contains the per passenger benefits of columns L and Q of Table C.1. These benefits are multiplied by the number of pre-existing passengers (column E of Table C.2) to generate total benefits to pre-existing traffic.

Column E of Table C.3 contains the 50 percent factor to scale benefits down by one-half for induced passengers. The total number of induced passengers for scenario B is listed in column F of Table C.3. Benefits in column B of Table C.3 are multiplied by the 50 percent factor in column E and then by the induced passenger total in column F, yielding total benefits to induced passengers in column G. Total benefits for pre-existing and induced passengers are summed in column H of Table C.3. An alternate calculation, based solely on the savings per passenger in scenario A of Table C.1 (no induced demand), is provided in column I of Table C.3.

As can be seen when comparing columns G and I of Table C.3, consideration of induced demand leads to an overall reduction in benefits relative to what would have been measured were induced demand not considered. This result will occur in situations where delay is highly

TABLE C.3: IMPACT OF INDUCED DEMAND ON BENEFITS

A	B	C	D	E	F	G	H	I
BENEFIT	BASE CASE DEMAND PASSENGERS (PRE-EXISTING)			INDUCED PASSENGERS			TOTAL PASSENGERS	
	Saving Per Pre-Existing Passenger	Total Pre-Existing Passengers	Saving for Existing Passengers in Year X Due to Investment (B*C)	Percent Pre-Existing Passenger Saving Applying To Induced Passenger	Total Induced Passengers	Total Benefits Induced Passengers (B*E)	Total Benefit Passengers (D+G)	Total Benefit W/O Correction For Induced Demand
Passenger Time	$1.2015	2,000,000	$2,403,000	50%	40,000	$24,030	$2,427,030	$2,581,000
Aircraft Operating Cost	$1.08	2,000,000	$2,160,000	50%	40,000	$21,600	$2,181,600	$2,320,000
Total Benefit	$3.2815	2,000,000	$4,563,000	50%	40,000	445,630	$4,608,630	$4,901,000

TABLE C.4: IMPACT OF INDUCED DEMAND ON COSTS

A	B
VARIABLE COST	Annual Cost in Year X
Capital Cost	Does not vary with passenger volume
O&M	$102,000

sensitive to increased traffic in both the base and investment cases. Alternatively, in examples where the additional traffic induced by the investment has little or no impact on delay relative to the base case demand levels (e.g., if the values in column K of Table C.1 did not fall with higher passenger levels), consideration of induced demand would lead to higher total benefits than would be measured were induced demand not considered.

C.5.2 Costs: Relevant cost data found in Table C.1 is associated with O&M expenses listed in column S. In this case, O&M is influenced by the amount of traffic using the airport and is assumed to have a constant per passenger value. Thus, O&M totals developed in Section 11 for the base case are adjusted upwards by the amount of induced passengers associated with scenario B. O&M costs (adjusted for induced demand) are summarized in Table C.4.

Alternatively, the overall capital costs of the project are not subject to variations in passenger demand. Financing charges, which reflect the payments needed to pay off loans and bonds issued for project costs not covered by AIP or other grants, are reflected in column R of Table C.1. As noted above, these amounts are considered in Table C.1 only to measure their impact on passenger demand. The financing cost of project capital, along with the opportunity cost of grant funds, is captured in the discount rate applied to all project costs and benefits.