

FAA AIRPORT BENEFIT-COST ANALYSIS GUIDANCE

**Office of Aviation Policy and Plans
Federal Aviation Administration**

September 16, 2020

Table of Contents

Section 1: Introduction.....	1
1.1 Purpose of Guidance.....	1
1.2 Background.....	1
1.3 Application	2
1.4 Limitations of Guidance	2
Section 2: Role of BCA	3
2.1 General Objectives of BCA.....	3
2.2 Distinction between BCA and Financial Analysis	3
2.3 Treatment of Macro-Economic Impacts Associated with Airport Projects	4
2.4 Common Mistakes in Defining Benefits and Costs	5
Section 3: Overview of BCA Process	7
3.1 Define Project Objectives	7
3.2 Specify Assumptions	7
3.3 Identify the Base Case	8
3.4 Identify and Screen Reasonable Investment Alternatives:	8
3.5 Determine Appropriate Evaluation Period	8
3.6 Establish Reasonable Level of Effort	8
3.7 Identify, Quantify, and Evaluate Benefits and Costs	9
3.8 Measure Impact of Alternatives on Airport Usage.....	9
3.9 Compare Benefits and Costs of Alternatives.....	10
3.10 Perform Sensitivity Analysis	10
3.11 Make Recommendations	10
Section 4: Objectives.....	11
4.1 Statement of Objectives.....	11
4.2 Range of Possible Objectives	11
4.3 Treatment of Multiple Objectives.....	11
4.4 Designation of Principal Objective	12
Section 5: Assumptions.....	13
5.1 Future Airport Environment	13
5.2 Projected Growth in Airport Activity	13
5.2.1 Use of the TAF vs. Alternative Forecasts.....	13
5.2.2 Currency of Alternative Forecast	13
5.2.3 Developing an Alternative Forecast	14
5.3 Future Changes in Airport Facilities and Capacity	16
5.4 Binding Constraints on Airport Capacity	16
5.5 Air Traffic Management.....	17
5.6 Environmental Considerations	17
5.7 Need for New or Adjusted Assumptions.....	18
5.8 Economic Values.....	18

Section 6: Identification of the Base Case.....	19
6.1 Need for Correct Identification	19
6.2 Base Case Specification Requirements	19
Section 7: Specification of Alternatives	21
7.1 Importance of Complete Specification	21
7.2 Self-Contained Alternatives	21
7.3 Range of Alternatives	22
7.3.1 Investments in New Facilities	22
7.3.2 Reconstruction of Existing Facilities.....	23
7.3.3 Demand Management Strategies	23
7.3.4 Redistribution of Responsibility	24
7.4 Screening Alternatives.....	24
Section 8: Selection of Evaluation Period.....	26
8.1 Types of Evaluation Periods.....	26
8.1.1 Requirement Life.....	26
8.1.2 Physical Life.....	26
8.1.3 Economic Life	26
8.1.4 Selection of Appropriate Time Period.....	26
8.2 Augmentation of Evaluation Period to Assist in Project Timing Evaluation	28
Section 9: Level of Effort	29
9.1 Appropriate Level of Effort.....	29
9.2 Rationale.....	29
Section 10: Measurement of Benefits	31
10.1 Benefits of Capacity Projects	31
10.2 Identification and Measurement of Benefits	31
10.3 Step 1—Identification of Benefits.....	31
10.3.1 New Airside Capacity Projects.....	32
10.3.2 Rehabilitation of Airside Facilities.....	38
10.3.3 Acquisition of Airside Equipment Supporting Capacity.....	38
10.3.4 Airfield Safety, Security, and Design Standards Projects	39
10.3.5 Environmental Projects	39
10.3.6 Air Terminal Building Capacity Projects	39
10.3.7 ATB Security Projects.....	40
10.3.8 Inter-Terminal Transportation	40
10.3.9 Landside Access Projects	40
10.4 Step 2—Measurement of Benefits.....	40
10.4.1 Analysis of Airfield Delay Reductions	42
10.4.2 Analysis of Air Terminal Building Delay Reductions	49
10.4.3 Quantification of Landside Delay Reduction	50
10.4.4 Improved Schedule Predictability	51
10.4.5 More Efficient Traffic Flows.....	52
10.4.6 Use of Larger and/or More Capable or Efficient Aircraft	52

10.4.7	Safety, Security, and Design Standard Benefits Associated With Capacity Projects ..	55
10.4.8	Increased Safety Associated with Vertically Guided Approaches	56
10.4.9	Environmental Benefits Associated With Capacity Projects:	56
10.4.10	Lower Airport Operations and Maintenance (O&M) Costs	57
10.5	Step 3—Valuation of Benefits.....	57
10.5.1	Constant Dollars	57
10.5.2	Equal Valuation of Incremental Units.....	57
10.5.3	Valuation of Fractional Benefit Units	58
10.5.4	Summary of Unit Values for Benefits:.....	58
10.5.5	Valuation of Delay Reductions	59
10.5.6	Improved Schedule Predictability	64
10.5.7	More Efficient Traffic Flows:.....	64
10.5.8	Use of Larger, Faster, and/or More Efficient Aircraft.....	64
10.5.9	Safety, Security, and Design Standard Benefits Associated With Capacity Projects ..	65
10.5.10	Safety Benefits of Capacity Projects	65
10.5.11	Environmental Benefits of Capacity Projects	65
10.5.12	Airport Operating and Maintenance Benefits	65
10.6	Hard-To-Quantify Benefit and Impact Categories	65
10.6.1	Increased Passenger Comfort and Convenience.....	66
10.6.2	Non-Aviation Impacts	67
10.7	Special Case of New Airports	68
10.7.1	Regional Airports	69
10.7.2	Replacement Airports	70
10.7.3	Supplemental Airports.....	70
10.7.4	Uncertainties of Traffic Forecasts at New Airports	71
Section 11:	Cost Estimation	73
11.1	Costs of Capacity Projects.....	73
11.2	Cost Concepts	73
11.2.1	Opportunity Cost	73
11.2.2	Incremental Cost.....	74
11.2.3	Sunk Cost.....	74
11.2.4	Depreciation.....	74
11.2.5	Principal and Interest Expense	75
11.2.6	Inflation.....	75
11.3	Life Cycle Cost Model	75
11.3.1	Planning and Research and Development Cost.....	76
11.3.2	Investment Cost	76
11.3.3	Operations and Maintenance Cost (O&M).....	78
11.3.4	Termination Cost	79
11.3.5	Salvage Value	79
11.3.6	Relationship of Cost Components	80
11.4	Application of Life-Cycle Costing to Facility Replacement Decisions	80
11.4.1	Justification for Reconstruction Projects.....	80
11.4.2	Consideration of Degree of Reconstruction	81

Section 12: Multi-Period Economic Decision Criteria	83
12.1 Requirement for Multi-Period Analysis	83
12.2 Creation of Multi-Period Benefit Series	83
12.3 Creation of Multi-Period Cost Series	84
12.4 Conversion of Benefit and Cost Series to Present Value	84
12.4.1 Opportunity Cost of Capital	84
12.4.2 Inflation	84
12.4.3 Risk.....	85
12.5 Discount Rate	85
12.6 Basic Discounting Methodology	85
12.7 Alternative Evaluation Procedures:	87
12.7.1 Net Present Value (NPV)	87
12.7.2 Benefit-Cost Ratio	89
12.7.3 Internal Rate of Return	90
12.7.4 Payback Period	91
12.8 Evaluation of Optimal Project Timing	91
12.9 Selection of Best Alternative.....	92
Section 13: Uncertainty	93
13.1 Need to Address Uncertainty:	93
13.2 Characterizing Uncertainty:.....	93
13.3 Sensitivity Analysis:	93
13.3.1 Probability Distributions	93
13.3.2 Methods of Sensitivity Analysis	94
Section 14: Selection of Optimal Project	101
14.1 Consideration of All Information	101
14.2 Net Present Value	101
14.3 Hard-To-Quantify Benefits and Costs.....	101
14.4 Uncertainty	101
Appendix A: Treatment of Inflation	102
A.1 Introduction	102
A.2 Price Changes	102
A.2.1 Measuring Inflation	102
A.2.2 Measuring Price Changes of Specific Goods and Services.....	104
A.3 Source of Price Indexes	106
A.3.1 General Price Level	106
A.3.2 Economic Sector Price Levels.....	107
A.3.3 Construction	107
A.3.4 Energy.....	108
A.3.5 Electronics and Computers	108
A.3.6 Aircraft and Parts	108
A.4 Treatment of Inflation in Benefit-Cost Analysis.....	108
A.4.1 Constant or Nominal Dollars	109
A.4.2 Period between Analysis Date and Project Start Date	110

A.4.3	Inflation during Project Life	110
Appendix B: Official Guidance on Economic Analysis		112
B.1	Executive Order 12893 (January 26, 1994).....	112
B.2	OMB Circular A-94 (Revised) (October 2, 2012).....	112
B.3	Other References	112
B.3.1	Methodological.....	112
B.3.2	Data Sources	113
Appendix C: Adjustments of Benefits and Costs for Induced Demand		115
C.1	Consideration of Induced Demand.....	115
C.2	Economic Framework for Estimating Benefits	115
C.3	Methodology to Calculate Induced Demand.....	117
C.3.1	Total Trip Costs	118
C.3.2	Impact of Time Savings on Trip Time	120
C.3.3	Impact of Time Savings on Trip Fare	120
C.3.4	Impact of Change in Total Trip Cost on Final Demand.....	121
C.4	Induced Demand at Multiple Forecast Levels.....	122
C.5	Adjustments of Benefits and Costs to Reflect Induced Demand:	123
C.5.1	Benefits	123
C.5.2	Costs	124
Appendix D: Consumer Surplus and Economic Decision-Making		126
D.1	Overview	126
D.2	Authorities	126
D.3	Consumer and Producer Surplus	127
D.4	Consumer Surplus and Airport Infrastructure	129
D.5	The Full Price of Travel and Social Marginal Costs	131
D.6	Undertaking the Analysis	134
D.7	Money Elasticities of Demand	142
D.8	Assumptions about the Demand Curve	144
D.9	Induced Demand.....	144
Appendix E: Interpreting Simulation of Aircraft Operations at Airports for Use in Benefit-Cost Studies		146
E.1	Outcomes of Simulations for Benefit Cost Analysis.....	146
E.2	Description of the Simulation Process	147
E.3	Key Assumptions Made in Simulation Models.....	149
E.4	Hourly Operations by Aircraft Type for a Representative Day.....	150
E.4.1	Operations and Enplanements for a Current Model Day	153
E.4.2	Future Schedule Day	154
E.5	Wind, Ceiling, Visibility and Wet/Dry Runways.....	155
E.6	Airspace Structure by Airport Configuration	156
E.7	Airport Geometry (Runways, Taxiways, Ramps, Gates,)	157
E.8	Distribution of Aircraft to Runways.....	157
E.9	Terminal	158

E.10	Verification and Validation	158
E.11	Valuing Simulation Delays Using Estimated Marginal Costs.....	160
E-12	Simulation Models.....	163

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. In instances where unique circumstances require new methodologies be applied, these must be well documented and should be based on published authorities that reflect best practice.

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, and are now incorporated into FAA Order 5100.38. Capacity projects are defined in FAA Order 5090.5 as "...the minimum development or equipment that is required to reduce delay or improve an airport or system of airports for the primary purpose of maintaining access or accommodating more passengers, cargo, aircraft operations, or based aircraft, or allow access to a broader fleet mix."¹ 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 \$10 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 APP-500 which will consider the essential need of the project, its timing, and whether the estimated cost is reasonable and typical.

¹ Also see the AIP Handbook for discussion of project eligibility.
[AIP Handbook Chapter 3](#)

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 \$10 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 phases are in conjunction with environmental studies, or during project formulation. FAA will normally request a preliminary BCA from an airport sponsor before agreeing to begin an EIS for a capacity project. 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 economic 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 contact Jeffrey C. Wharff, Chief Economist, FAA Office of Aviation Policy and Plans, at (202) 267-7035.

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 them.

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 be 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. Models created by sponsors should be submitted to FAA with all features and variables available for FAA evaluation including allowing sensitivity studies that may lay outside boundaries investigated by the sponsor.

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, operator, users, and other stakeholders:

- 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 private producer will not be the same as the net benefits to the public.
- Airlines may be willing to pay for a certain amount of airport capacity expansion to reduce their own delay costs; however if consumers' willingness to pay to avoid delays is also taken into account, a project with more capacity may be justified in the public interest.
- 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 airfares 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.
- A sponsor may be tempted to propose a project that has features beyond what users would be willing to pay.

Consequently, it is appropriate that a full and objective accounting of aviation system user benefits and costs 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 all aviation system users nationwide 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.

2.4 Common Mistakes in Defining Benefits and Costs

One of the most common BCA mistakes is including monetary exchanges which are actually transfer payments. Transfer payments are transactions where money moves around the economy without anything of economic value being created or consumed. To avoid including transfer payments, focus on whether or not there is consumption or savings of real resources with economic value (time, land, materials, clean air, etc.). When resources are consumed or saved, that generally indicates a true cost or benefit. This applies whether or not there is an actual market for those resources. For example, while there is a market for land, there is no market for cleaner air. When money is merely moved around among members of the society on whose behalf a project is proposed or to/from their government(s), these movements are usually just transfer payments.

For example, an airport project in jurisdiction A may divert traffic from an airport in jurisdiction B.² When consumers save time accessing air services, then that is a real resource saving. Those savings would be counted in a benefit cost study.

But, an increase in economic activity (e.g., fuel sales) in A may come largely at the expense of fuel sales in B. From a society wide perspective, these are transfers and do not create economic value.

The viewpoint of the analysis may help the analyst correctly distinguish between transfers and real resource savings or costs. In our example, a local community or the fuel seller at the airport would count added fuel sales as a benefit to them. But, FAA's viewpoint is necessarily broader to include the national system and in effect the entire U.S. economy. If jurisdiction A gains \$1,001,000 in added fuel sales while jurisdiction B loses \$1,001,000 in fuel sales, there is no net resource cost savings to the national economy. But if consumers originally at B move to A and save time accessing air services, then the analyst would properly account for the value of the time saved as a real resource saving.³

Other examples of transfers would include:

² ARP does not normally support airport projects whose primary purpose is to divert traffic from another NPIAS airport.

³ [Benefit-Cost Analysis](#)

- An increase in tax revenues in jurisdiction A at the expense of jurisdiction B
- Savings in labor costs or utility costs in jurisdiction A at the expense of jurisdiction B

In both of these cases, it is possible that jurisdiction A is a more efficient producer of government services, labor or utility outputs; where this is the case, only these savings in resources would be counted in favor of a project. But the analyst would have to do a careful analysis to document these real resource savings. For example, if unemployment increased in jurisdiction B, the cost of supporting the unemployed would have to be counted against the savings in labor costs in jurisdiction A. In almost all cases, it is best to ignore the transfers and document only actual consumer gains or resource savings resulting directly from the project.

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.

Particularly important will be the use of an up-to-date and current forecast of operations in both the Base and Alternative Cases. Prior forecasts done for earlier analysis of a project (e.g. during the master plan or in an Environmental Assessment) must be revisited and updated with current trends, as needed. The investment decision being investigated should be based on the best information available at the time the BCA is undertaken. It may then be appropriate to run earlier forecast assumptions through the BCA model as a sensitivity analysis. It is important to stress that a forecast done for an Environmental Assessment is done for a very distinct purpose separate from comparing the economic benefits and costs of a proposed project and should not be used in a BCA analysis other than for sensitivity purposes.

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. In almost all cases, the Base Case would not be a “do nothing” scenario. Instead it would describe how the airport would develop if the subject project were not pursued.

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.

It is particularly important that the alternatives reflect current conditions as opposed to those that may have existed in an earlier time period when a project was first considered. For example, a project that was first evaluated in an EA might have been selected from a range of alternatives that were available at that time. If several years have passed, it would be important to revisit alternatives to see if better alternatives are now available at the time the BCA was conducted. This is just good economic practice. The costs and effort undertaken to do an EA may have been significant, but those are sunk costs. It is appropriate to make investment decisions with the best information available at the time of the decision.⁴

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.

⁴ In some cases, if the alternative chosen in a BCA was not considered in an EA, this may trigger additional environmental work.

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. At a minimum, the sponsor should distinguish benefits to existing users from benefits to new potential users. For example, in some cases where capacity is constrained in the Base Case, increased operations in the Scenario Case made possible by an improvement might trigger additional future delays for current users. But the improvement would also make possible new operations that create consumer surplus for new users. (Appendix C of this guidance addresses the issue of induced demand caused by airport improvements. The Consumer Surplus Appendix D provides details on how to estimate surplus.) Because of the uncertainty associated with the data used in an analysis of induced demand, advanced coordination is recommended with the FAA in order to decide whether or not to include this analysis in the BCA.

It is also important to carefully consider the economic benefits or costs of transferring operations from one airport to another. In some cases, an infrastructure program at airport A may cause some operators to transfer their base or some operations from airport B to airport A. From a national perspective, the only benefits created would be due to savings in resources at A versus B. Usually these would be savings in the value of passenger and crew time accessing A, if it is geographically advantaged relative to B. If airport A's improvements reduce taxi times, or avoid in air delays, valuing the difference in these variables between A and B may also be counted as

benefits. But transferring fuel sales, tie down fees or related expenses from B to A do not save society's resources; they are transfers from one place to another.

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. Benefits and costs expressed in constant dollars should be discounted to a single year using a 7% discount rate.⁵ 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.

When it is possible and the level of effort is appropriate, the sponsor should evaluate a full range of key drivers of benefits and costs, including appropriate statistical distributions of those drivers. These can be incorporated into a Monte Carlo model that tests the full range of potential outcomes given the range of inputs expressed by statistical distributions. The resulting Monte Carlo model outputs can be used to assess the probability that a project will produce net benefits, and may also be helpful in fine-tuning a project to reduce risks to the sponsor and FAA.⁶

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.

⁵ See page 9 of OMB Circular A-94: GUIDELINES AND DISCOUNT RATES FOR BENEFIT-COST ANALYSIS OF FEDERAL PROGRAMS (as updated): "Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years." [Circular A-94](#)

⁶ For a further discussion of Monte Carlo models, see section 13.3.2.3 Alternative Scenarios

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 prejudices 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;
- Increase the available range or payload for operators using the airport;
- Improve (maintain) airport safety and security;
- Mitigate environmental impacts of the airport on the surrounding community;
- Improve the resilience of the airport to variations in environmental conditions (e.g. severe weather or flooding)
- 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 extend an existing 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 potential capacity-related benefit. See Order 5100.38.

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
- Expected improvements in air traffic management procedures due to FAA plans for NAS modernization.
- Environmental considerations.

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 it is needed, causing scarce public 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.

5.2.1 *Use of the TAF vs. Alternative Forecasts*

Unless an alternative forecast is approved by FAA, the sponsor should utilize the most recent FAA Terminal Area Forecast (TAF) for the airport as the primary forecast in the BCA. It should be noted that the TAF is an unconstrained forecast and therefore may not be the best indicator of future activity and/or enplanements at an airport that is currently or projected to become capacity constrained. There may be other local circumstances that justify variations from the TAF. In those cases, the sponsor should formally present its alternative forecast to the FAA for approval prior to completion of the BCA. If the FAA approves an alternative forecast, the sponsor should run the BCA with the TAF forecast in at least one sensitivity case.

5.2.2 *Currency of Alternative Forecast*

Planning and gaining approval for major capacity and other capital improvements can take many years. In many cases, the sponsor will have to complete a NEPA evaluation of the project prior

to applying for a discretionary grant. NEPA typically will include one or more forecasts which are used to describe the need for the project and ultimately the changes in infrastructure and the implications for the environment. However, the forecast used in the NEPA review should not be the alternative forecast used in the BCA, if in the interim there have been changes in the local or national economy that would suggest the EA forecast is likely to be inaccurate. The alternative forecast applied in the BCA should be one that represents the sponsor's best estimate of future activity and enplanements. The forecast(s) from the NEPA review can then be used in sensitivity tests in the BCA.

5.2.3 Developing an Alternative Forecast

AC 150/5070-6B, Airport Master Plans, Chapter 7, 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. Exhibit 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 150/5070-6B is provided below:

Exhibit 5-1: Traffic Growth Assumptions

Required	Included Where Appropriate
Operations (annual) Itinerant Air Carrier Air Taxi and Commuter (Regional) General Aviation Military Local General Aviation Military	Domestic vs. International Annual Instrument Approaches IFR vs. VFR Operations Air Cargo Aircraft Operations Touch and Go Operations (Training) Helicopter Operations Average Load Factor Fuel Use
Passengers (annual) Enplanements Air Carrier Commuter Enplanements Originating Connecting	Passenger and Cargo Data Domestic vs. International General Aviation Passengers Helicopter Air Taxi Other: Number of Student Pilots Number of Hours Flown
Aircraft Based Aircraft Aircraft Mix Critical Aircraft	Average Seats/Aircraft

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.
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. Forecasts that vary from the TAF must be approved by FAA.
3. Make and document any adjustments to the aviation activity forecast to account for such conditions or factors—AC 150/5070-6B⁷(Chapter 7) 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 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 average 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

⁷ [AC 150/5070-6B](#)

See Chapter 7 *Aviation Forecasts*

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 database 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.

It is important to consult the section in the Simulation Appendix on forecasting for further details when highly detailed design day flight schedules are required to run simulations of airport activities.

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 150/5070-6B, Chapter 6⁸) 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, on-going benefits of a series of small-scale projects already approved at an airport should be properly attributed to them and included in the Base Case; any benefits attributed to the project under consideration in the BCA should be incremental to benefits due to projects already approved. 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

⁸ OP cit

constraint may yield benefits only to the point that some other constraint not addressed by the project becomes limiting.⁹¹⁰ However, the next constraint may also be in the far future and not relevant to the lifecycle of the project being considered.

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 gate capacity, for example. 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 gate capacity. However, caution must be exercised to not unduly group separate projects with distinct objections into megaprojects as is discussed in Section 4.3.

The BCA study should provide information on capacities and constraints of key airport system elements both before and after the subject project; realizing the full benefits of a project will depend on there being sufficient runway, airspace, taxiway, ramp, gate, terminal, and/or ground access capacity during peak demand periods. FAA capacity methodologies should be used to estimate these elements.

In cases where capacity calculations show that an airport either is (base case) or would be unbalanced (scenario case), additional simulation work may be necessary to properly identify when varying elements become constraints on airport operations.

5.5 Air Traffic Management

Scheduled improvements in air traffic automation equipment and procedures may accomplish some portion of the objectives that a particular infrastructure project is intended to accomplish. Such improvements may include the accommodation of reduced separation of aircraft, redesign of airspace, and applications of new technologies (e.g., GPS, PBN). The benefits attributed to air traffic improvements must be netted out of the benefits of the capacity project. APP-400 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 quieter aircraft. This may permit improvements in the utilization of current airport infrastructure and mitigate the need for the investment in question.

⁹ [AC 150/5060-5 Airport Capacity and Delay](#)

¹⁰ [AC 150/5060-5 Airport Capacity and Delay](#)

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 forecast would lead to average airside delays of more than 20 minutes per operation, the rate of growth in the baseline forecast would need to be adjusted downward to reflect a constrained growth scenario. This revision is necessary because approximately 20 minutes represents the highest level of average delay than can be tolerated for basic schedule integrity, albeit with a suboptimal level of service. 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," (as updated).¹¹

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.

For airport improvement BCAs the appropriate discount rate is 7 percent, which OMB judges to be the long-term opportunity cost of private capital. This discount rate should be applied to constant dollar benefits and costs estimated in constant dollars (excluding expected inflation).¹²

¹¹ [Benefit-Cost Analysis](#)

¹² [Circular No. A-94 Revised](#)

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.

It may be useful to state what the airport's policy is for accommodating additional operations and/or passengers in the Base Case. Airport sponsors have an obligation to accommodate all users under FAA Airport Sponsor Assurances:

“22. Economic Nondiscrimination. a. It will make the airport available as an airport for public use on reasonable terms and without unjust discrimination to all types, kinds and classes of aeronautical activities, including commercial aeronautical activities offering services to the public at the airport.”¹³

¹³ Grant Assurance 22 (please refer to the most current version at the time of analysis) [Assurances](#)

So for example, an airport with exclusive and preferential gates defined in their Use Agreements might in the Base Case establish a common gate policy to free up terminal capacity during off-peak times of the day.

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.

In some cases, alternatives may have been passed over in prior analysis (e.g. in a master plan); nevertheless, good practice dictates that the sponsor revisit all potentially economically viable alternatives when conducting the BCA to ensure that the best investment decision is reached. The sponsor should directly address all economically viable alternatives in the BCA. It is particularly important that sponsors document the cost to users of the subject airport and proposed (in the BCA) facility if instead these users accessed other airports nearby with required facilities and available capacity. The Net Benefits of the proposed investment should exceed these access costs. Otherwise, from a national perspective, society would be better off with users driving or otherwise accessing the nearby airports.

For example, suppose a runway extension produces benefits at airport A that are greater than costs on a discounted basis. (In other words, there are positive net benefits for the project at airport A.) If users benefiting from the proposed extension could access a nearby airport B with the required runway length at a cost that is less than the net benefits at A, the project at A would not be attractive. In making the comparison, care must be taken to identify all of the costs and benefits to users to make the appropriate comparison.

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; and
- Redistribution of responsibility
- In the Base Case, the sponsor should account for any existing projects or other improvements anticipated to be completed prior to the proposed project and projects that would be undertaken if the proposed project is not undertaken.

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 150/5070-6 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 of critical aircraft (e.g., RDC) 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. Again the access costs that users would pay to use equivalent nearby airports with sufficient capacity would have to exceed the Net Benefits (Benefits-Costs) for the proposed project to make economic sense.

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.

7.3.1.1 Consuming New Capacity

In some cases, new capacity may be quickly consumed by rapid increases in operations and/or passengers. There may be a period of time during which consumers and aircraft operators would experience reductions in delays versus the Base Case, but because an alternative case

makes additional capacity available, more operations occur and average delays across the airport rise again. The BCA should consider these impacts in defining the relative attractiveness of alternatives as well as binding constraints addressed in Section 5.4

Exhibit 7-1 shows a simple example that distinguishes between current users and new users made possible by a new project. In the Base Case, there are 100 operations that incur an average of 10 minutes. In the Scenario Case, there are 120 operations that also incur 10 minutes of delay. In this simple example, the new users have consumed the incremental capacity made possible by the project; the airport can now process 120 operations instead of 100, but all users still average a 10 minute delay. In this simple example, current users would get no benefits from the project, since they would incur the same delays in the Base and Scenario Cases. But, the project has made possible an additional 20 operations that otherwise would not be feasible. The benefits of the project in the simple example would equal the benefits to new users; they can be estimated using the concepts of consumer and producer surplus. For a discussion of how to estimate these benefits, please refer to the Consumer Surplus Appendix D.

Exhibit 7-1: Distinguishing Current and New User Benefits

Cases	Current Users Operations	Current Users Average Delay (minutes)	New User Operations	New Users Average Delays (minutes)
Base Case Delay	100	10	NA	NA
Scenario Case	100	10	20	10

7.3.2 Reconstruction of Existing Facilities

An obvious course of action when delay or other costs are caused by facilities in an advanced state 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. For this reason, facilities are sized to the average peak demand rather than the absolute peak. One alternative for consideration would be to encourage users of a facility to spread peak usage over a longer period (i.e., smooth peaks) 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) for certain users, or price incentives (e.g., lower landing fees at off-peak hours). A useful role of the airport sponsor maybe 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.

In 2008, FAA amended its Rates and Charges Policy (5190.6b) to allow airports to charge two-part tariff landing fees (separate charges for weight and operations). The per-operation charge may discourage marginal services during peaks and/or the use of small aircraft during those times. A key requirement is that the new tariffs be revenue neutral (that is they would collect no more than a conventional landing fee which in turn is designed to collect fees to offset the costs of operating the airfield (the rate base)).¹⁴

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.

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 unique 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.

There have been important recent changes in the potential framework for public and private partnerships that may affect how projects and/or entire airports are owned and managed.¹⁵ The Airport Investment Partnership Program removed the restriction on the number and type of public airports that may be privatized. The 2018 Reauthorization Act also permits public sponsors and private operators to manage an airport jointly. Sponsors may wish to consult up to date FAA guidance on these matters.

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

¹⁴ [Policy Regarding Establishment of Airport Rates and Charges](#)

¹⁵ Section 160 of the FAA Reauthorization Act of 2018 (Pub. L. No. 115-254 (October 4, 2018)) amended 49 U.S.C. § 47134.

- 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.

Comparable Time Periods for All Alternatives: Most transportation projects including those at airports are in service for a very long time. Equipment and infrastructure may wear out, be refurbished, or be replaced, but the project does not end. In such cases, "end of project" costs are not important because the project does not end and therefore does not have salvage or close-out costs. The residual values of alternate investments are closely related to their values during the period of analysis so that including them would not affect the relative attractiveness of alternate proposals. So in most cases there is no need to include end of life costs in the BCA of what is expected to be a perpetually operated facility.

However, when alternatives have different economic lives, it may be necessary to adjust all project alternatives to the longest lived alternative. To be clear, regardless of the length 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.

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.

Residual value is defined as the estimated value of project assets at the end of the period of analysis, representing their expected value in continuing use. So, when an alternative has X years of residual economic life (prior to replacement or reconstruction), the benefits and costs for this remaining time would be discounted to present value and included in the evaluation of that alternative. For example, a BCA might in a Base Case assume a runway would be rehabilitated with an expected additional life of 20 years, while a completely rebuilt runway might last 30 years. To make the two alternatives comparable, the analyst could estimate the additional benefits and costs due to extending the life of the rehabilitated runway for another 10 years. This eliminates the issue of salvage value, which for a government project is difficult to evaluate.

Care should be taken in developing residual values because of the potential for growth assumptions to distort outcomes in the far future. At least one scenario should be presented where the annual residual benefit stream is frozen at the last year prior to the beginning of residual life and discounted to the beginning of the analysis period. In most cases, no benefits in the residual period should be assumed to grow faster than average real economic growth in the economy – on the order of 1-2% annually.

In some cases, there may be a need to estimate termination (close-out) costs and salvage values. When a facility is being replaced by another one, there may be termination costs including

restoring the physical environment to a suitable state. These costs are properly included in the BCA.

Finally in some limited cases it may be appropriate to estimate a salvage value for assets that may be sold at the end of a project. Salvage value is defined as the estimated value of an asset in cases where there exists a market for selling the asset. So for example if a project is designed to use temporary equipment to help accommodate operations during construction of a project, and the airport plans to dispose of the equipment, then in the BCA the sale would be assumed to occur at the end of the project with the proceeds deducted from costs. The salvage value could be based on the remaining (undepreciated) life of the assets.

8.2 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 Rationale

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 travel or block 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 have a primary purpose of maintaining access or accommodating more passengers, cargo, aircraft operations, or based aircraft, or allow access to a broader fleet mix. Capacity projects may include those that increase efficiency but not hourly capacity. For example, a runway extension may be needed to support aircraft operations with a larger aircraft and higher payload. The runway extension could increase the range or payload capacity of the aircraft, but it may not increase the hourly capacity of the airport.

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. See Order 5100.38 for further information and guidance.

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	
<ul style="list-style-type: none"> New or extended runway, taxiway, apron, or hold pad 	<ul style="list-style-type: none"> Reduced access time for passengers now closer to an airport with more capabilities Increased throughput of aircraft, passenger, and cargo operations and/or reduced delay during normal airport operations Reduced aircraft, passenger, and cargo delay during reconstruction of other airport facilities Greater schedule predictability and integrity: Aircraft operator able to make more efficient use of equipment and personnel 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 For runway extensions, a higher operating payload or range for departing aircraft; as well as improved safety and reduced diversions when the runway is contaminated Bringing pre-existing infrastructure into compliance with FAA safety and security standards
<ul style="list-style-type: none"> Reconstruction of runway, taxiway, apron, or hold pad 	<ul style="list-style-type: none"> Lower facility maintenance costs Avoided added time accessing a more distant airport Avoided loss of capacity benefits associated with facility failure
<ul style="list-style-type: none"> Acquisition of airside equipment to support capacity objectives (navigational aids, snow removal and maintenance equipment) 	<ul style="list-style-type: none"> Reduced aircraft , passenger, and cargo delay during normal airport operations Greater schedule predict ability Improved safety Lower facility maintenance costs Avoided added time accessing a more distant airport
Airside Safety, Security, and Design Standards Projects	
<ul style="list-style-type: none"> Installation of signage and lighting Expansion of runway safety areas Removal of obstructions from existing 	<ul style="list-style-type: none"> Compliance with Advisory Circular safety, security, and design standards is not subject to BCA. Installation must be done in most cost-

Project Type	Typical Benefit Type
<ul style="list-style-type: none"> approaches Fencing Acquisition of rescue and fire-fight 	effective manner acceptable to FAA.
Airside Environmental Projects	
<ul style="list-style-type: none"> Noise mitigation for pre-existing infrastructure (noise insulation, structure removal) Fuel and chemical containment for pre-existing infrastructure 	<ul style="list-style-type: none"> Not subject to BCA, but must be done in most cost-effective manner acceptable to FAA.
AIRPORT TERMINAL BUILDING (ATB)	
ATB Capacity Projects	
<ul style="list-style-type: none"> Reconstruction, expansion, and/or modernization of ATBs (excluding concession areas which are not eligible for AIP funding) 	<ul style="list-style-type: none"> Reduced aircraft, passenger, cargo, and meeter/greeter delay (attributable to more gates and faster passenger transfers to connecting flights) Improved passenger schedule Shorter aircraft turn times predictability (ability to allow less time for potential delays at ATB) More efficient traffic flows (shortened pedestrian traffic distances) Improved passenger comfort
<ul style="list-style-type: none"> Baggage Handling Systems 	<ul style="list-style-type: none"> Reduced passenger and cargo delay More efficient baggage distribution Lower operating and maintenance costs
ATB Security Projects	
<ul style="list-style-type: none"> Passenger, baggage, and freight security systems 	<ul style="list-style-type: none"> Compliance with FAA and TSA standards—not subject to BCA if primary objective of project
<ul style="list-style-type: none"> Security fencing and gates 	<ul style="list-style-type: none"> Compliance with FAA and TSA standards—not subject to BCA if primary objective of project
Inter-Terminal Transportation	
<ul style="list-style-type: none"> Fixed rail Bus 	<ul style="list-style-type: none"> Reduced aircraft, passenger, and cargo delay (attributable to faster passenger transfers to connecting flights) Improved passenger comfort Lower operating and maintenance costs\ Reduced passenger time accessing airport
LANDSIDE	
Landside Access Projects	
<ul style="list-style-type: none"> Airport access roads Passenger pick-up/drop-off areas Transit areas 	<ul style="list-style-type: none"> Reduced passenger, cargo, and airport and airline employee delay in getting to and from 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 (increased transit time), and (to a limited extent) persons at the airport for purposes other than their own air transportation needs. For a discussion of using simulation models to estimate delays and cancellations, see the Simulation Appendix E.).

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 specific weather conditions. Aircraft flights are less likely to be delayed (or in scenarios with excessive delay, 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.

It is important to distinguish between delays that occur in the air by phase of flight versus those that occur on the ground. Aircraft operating costs are generally higher during takeoff than during the cruise or descent phases of flight. If a capacity project reduces the elapsed time or flight miles during takeoff phase it would save more costs than one that shortened final descent time, holding all else equal.

Aircraft operating costs when taking a delay at the gate (when an aircraft is not under its own power) will be less expensive than delays while under power in a runway queue which in turn are less expensive than while an aircraft is taxiing.¹⁶ Please see the Simulation Appendix E. which includes a section on estimating marginal costs by phase of flight based on average variable costs published by DOT for airlines and by private companies (e.g. Conklin & de Decker) for GA aircraft. (See the Simulation Appendix E. for a discussion of how to modify Form 41 and GA aircraft costs to reflect phase of flight).

In some cases, an airfield capacity project may yield only modest delay benefits during routine airport operations, but may have added benefits to the airport's efficient operation during the reconstruction and temporary closure of some other infrastructure. 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. This is an example where the benefits of the secondary runway can be counted in the BCA, even though a backup runway is not supported as a primary rationale for AIP or PFC funding.

¹⁶ Aircraft manufacturers and private firms have models to estimate fuel consumption by phase of flight. There are also academic studies on the subject. For example, see the following: Ryerson, et al: *Fuel Burn Impacts of Taxi-out Delay and their Implications for Gate-hold Benefits*, *Transportation Research Part C Emerging Technologies* · January 2015

10.3.1.2 Improved Schedule Predictability

Aircraft operators, passengers, and shippers may tie- up resources and/or pad schedules (block times) 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 excessive 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. In some cases, perishable commodities might be transferred from aircraft to ground transportation for on-ward distribution more reliably which may contribute to fresher commodities being received by the final consumer.

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. An important factor in claiming such benefits would be airline or other operator written support demonstrating how aircraft operations would be more efficiently accommodated with the project; airline support should explicitly take account of the implications of schedule changes including accommodation of rescheduled flights at hubs or other airports.

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. See the above caution regarding properly accounting for costs during different phases of flight.

10.3.1.4 Use of Larger and/or More Capable or Efficient Aircraft

Some capacity projects are intended primarily to accommodate larger and/or more efficient or capable 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 with larger payloads, or current aircraft types carrying heavier fuel loads, can then fly directly to more distant locations (reducing route circuitry and stopovers) or carry more people at lower cost on existing routes. Runway extensions can also improve safety and reduce diversions when the runway is contaminated. In the case of a capacity project that allows an airport to accommodate jet service for the first time, passengers may also experience shorter flight times to more distant destinations to be served by jet aircraft.

It is appropriate to estimate the benefits of these projects by accounting for available alternatives, for example by assessing the costs to users of accessing an alternative nearby airport with the appropriate infrastructure and available capacity. If it is less expensive for users (especially inbound itinerant passengers) to drive to and from an alternative airport with the needed facilities, that would argue against building additional capacity at the subject airport.

10.3.1.5 Compliance with FAA Safety, Security, and Design Standards

Airport capacity projects must conform to safety and security standards, including 14 CFR 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,"¹⁷ and AC 150/5370-10, "Standards for Specifying Construction of Airports."¹⁸ 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 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. See AC 150/5000-17. Rather, the guidance simply presents the safety and design guidance to which the airport is expected to provide 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. In addition, the analysis should account for the possibility that some users may be able to utilize an alternate airport.¹⁹

¹⁷ [AC 150/5300-13A Airport Design](#)

¹⁸ [AC 150/5370-10H Standard Specifications for Construction of Airports](#)

¹⁹ The net benefits of the projects should exceed the out of pocket and time related costs to users of accessing nearby airports (with appropriate infrastructure and capacity).

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 vertically-guided and/or reduced-obstacle approaches and applies only to airports experiencing an overall upgrade in IFR capabilities. 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, net environmental benefits may be claimed for the noise reduction to the formerly impacted area.

Another benefit that is sometimes advanced is the idea that new capacity will reduce delay such that nighttime flights are instead available in daytime hours, as defined by the DNL metric. While this can be true in theory, it also depends on airline decisions on how to run their network – which may include flowing more traffic through uncongested hubs in order to avoid excessive delays at the subject airports. Most simulation models do not consider this feedback loop to changes in airline networks. Consequently, FAA will treat claimed benefits from reduced nighttime noise due to delay savings with caution.

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 aircraft engines. Such reductions in emissions should be counted as qualitative project benefits in areas not in attainment of Clean Air Act standards. They may also be counted in cases where the airport project makes a significant contribution to maintaining attainment in areas currently in compliance with EPA

standards. When there are large reductions in emissions at an airport, it may effectively reduce the cost of compliance in the attainment area.

FAA's AEDT model is the official model used to estimate aviation emissions and noise.²⁰

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 capacity, 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 AIP-eligible 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.

But there may be instances where a facility should be closed or where only part of it should be rebuilt. For example, there may be cases where activity at an airport or runway system is very low and there are nearby alternative airports with at least equivalent infrastructure suitable to serve the same traffic. There may also be several viable ways to reconstruct a runway or piece of infrastructure with wide differences in costs. It will usually make sense to judge rehabilitation projects against an alternative where users drive to the closest alternate airport with appropriate infrastructure and capacity. In cases where the out-of-pocket and time-related costs to access the alternate airport are less than the cost of rehabilitation, it may make sense to recalibrate the size of the project or not do it all.

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. AIP funds may be used to acquire specific NAVAIDs as identified in Order 5100.38. FAA retains 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

²⁰ [Environmental Analysis Tools and Guidance](#)

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.²¹ 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.

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.²²

²¹ 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.

²² 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.

10.3.7 *ATB Security Projects*

FAA does not require that ATB investments or actions undertaken to comply with TSA 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.

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	
<ul style="list-style-type: none"> Reduced aircraft delay 	<ul style="list-style-type: none"> Reduced aircraft delay hours by airborne, taxi, or gate status/phase of flight for each aircraft class (air carrier, commuter, GA, military)
<ul style="list-style-type: none"> Reduced passenger delay 	<ul style="list-style-type: none"> Reduced passenger delay hours by airside, ATB, and landside status Reduced passenger vehicle delay hours in landside access. Reduced passenger schedule delay (see discussion of Full Price of Travel in the Consumer Surplus Appendix D)
<ul style="list-style-type: none"> Reduced cargo delay 	<ul style="list-style-type: none"> 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 Value of longer post-delivery life for perishables
Improved Predictability	
<ul style="list-style-type: none"> 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
<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> 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) Reduced schedule padding/block times²³
More Efficient Traffic Flows	
<ul style="list-style-type: none"> Reduced aircraft vectoring and taxiing 	<ul style="list-style-type: none"> Reduced aircraft hours by phase of flight and reduced passenger hours due to more efficient layout of runways, taxiways, hold pads, and aprons
<ul style="list-style-type: none"> Shortened pedestrian traffic distances 	<ul style="list-style-type: none"> Reduced passenger time required to walk within ATB (not attributable to reduced ATB congestion)
Use of Larger and/or More Capable or Efficient Aircraft	
<ul style="list-style-type: none"> Reduced aircraft operation costs and shorter passenger travel times due to service by larger, faster, and/or more efficient aircraft 	<ul style="list-style-type: none"> 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 Reduced passenger access time associated with new airport capabilities
Safety, Security, and Design Standard Benefits Associated with Capacity Projects	

²³ In many cases, schedule padding (to avoid reportable delays) can be estimated by comparing scheduled times for flights during low activity periods (e.g. first flight out) with those during busier periods of the day.

Benefit Type	Measurement Unit
<ul style="list-style-type: none"> • New capacity project complies with FAA safety, security, and design standards 	<ul style="list-style-type: none"> • No benefits applicable. All new capacity projects must be built to FAA safety, security, and design standards to quality for AIP funds.
<ul style="list-style-type: none"> • New capacity project enables compliance of pre-existing infrastructure within FAA safety, security, and design standards 	<ul style="list-style-type: none"> • 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)
<ul style="list-style-type: none"> • Increased safety associated with vertically guided approaches 	<ul style="list-style-type: none"> • Number of vertical approaches flown with new NAVAIDs and reduced accident probability (will be calculated by FAA)
Environmental Benefits	
<ul style="list-style-type: none"> • New capacity project complies with Federal environmental requirements 	<ul style="list-style-type: none"> • No benefits applicable. All new projects must be built to Federal environmental requirements
<ul style="list-style-type: none"> • New capacity project brings pre-existing infrastructure into compliance with Federal environmental requirements 	<ul style="list-style-type: none"> • Value of most cost-effective alternative means to accommodate Federal environmental requirements (if new project were not built)
Airport Operating and Maintenance Benefits	
<ul style="list-style-type: none"> • Lower operating and maintenance costs 	<ul style="list-style-type: none"> • 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. Consult with APP-400 in advance on model selection and expectations. Some older models and methods may no longer be acceptable. Simpler, analytical models and methods described in Chapter 2 or 3 of FAA AC 150/5060-5, "Airport Capacity and Delay") are rarely acceptable for use in a BCA.

For further discussion of the use and interpretation of capacity simulation models in BCA's, please see Appendix E.

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 (e.g., runway capacity). For more information on how to interpret simulation models in an airport BCA, please consult the Simulation Appendix E.

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). Several proprietary models are also available for airport and consultant use. Coordination with APP-400 is advised before selecting a model to ensure the choice made will be acceptable to FAA. See the Simulation Appendix E. for more information on these proprietary models.

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:

- Validation of baseline model results against actual runway capacity (e.g., ATC called rates) and actual taxi times.
- Demonstrated involvement of local ATC and operators (airlines) in the development of the simulation analysis.
- Configuration use that is annualized in reference to both actual weather and weighted capacity²⁴
- Estimation of realistic values for performance rates and trends 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
- 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. See the Simulation Appendix E for more information on demand forecasting for simulations. 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

²⁴ See A. Chow and J. Gulding: Capacity Variation Algorithms for Simulation Modeling and Performance Analysis 2013 Aviation Technology, Integration, and Operations Conference ; August 12-14, 2013, Los Angeles, CA A (AIAA-2013-4355)

all project analysis. Intermediate years are generally approximated by interpolation and/or extrapolation.²⁵⁴

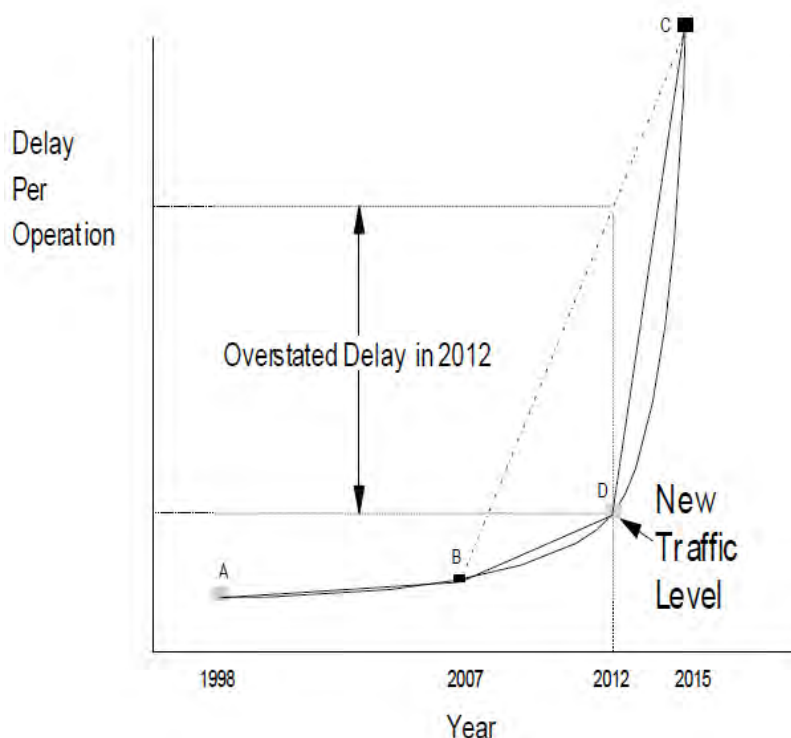
Simulation runs at each demand level should be conducted for representative weather conditions and runway configurations, and then annualized to yield average delay per operation over the course of a year (i.e., average annual day, not the average day peak month). After completion of simulation analysis 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, normally at the same traffic levels (unless a constrained scenario exists due to specific capacity limitations). 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. See the Simulation Appendix E. for more information on distinguishing between delay savings for different phases of flights.

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 Exhibit 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.

²⁵ Due to the expense involved in simulation modeling, it is generally not practical to model every year of the project's operating life.

Exhibit 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.

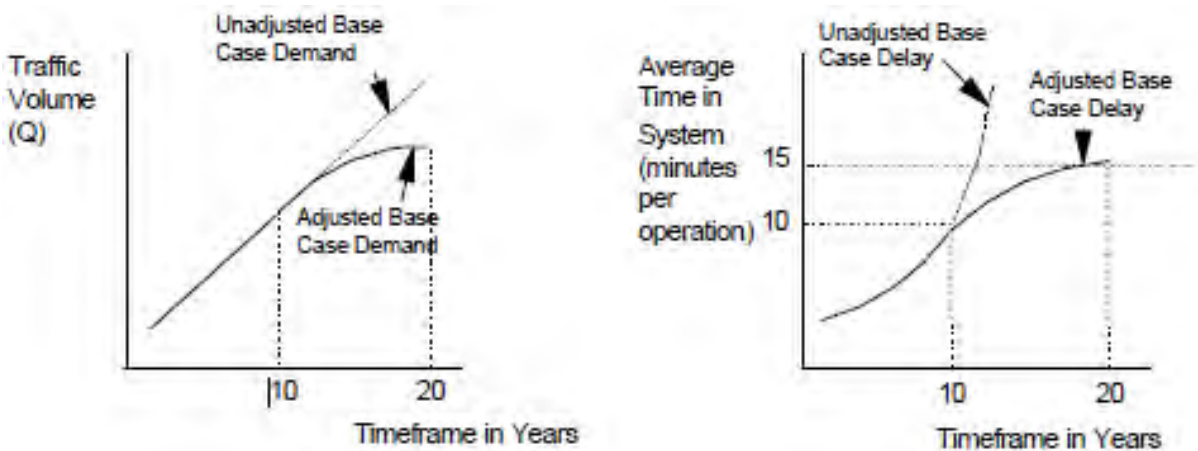
Airports experiencing severe delay due to congestion will not be able to accommodate rising demand for air service. Average delay per operation of 15 minutes or more may be considered excessive at a hub airport. **Sustained** delays in excess of 20 minutes are seldomly observed. As delays approach this level, airlines tend to adjust schedules including cancelling or consolidating flights during peak delay periods. Airlines may also opt to flow traffic through other, less congested hubs in their networks. Airlines could also begin to use larger aircraft, if available in their fleet. Passengers would make use of alternative airports, seek other means of transportation (e.g., automobile or train), or simply avoid making some [trips](#).²⁶

²⁶ 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.

Thus, it would be unrealistic to conclude that an investment 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](#).²⁷

Exhibit 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 is realistic given how the system will respond and prevents the measurement of excessively high apparent delay savings that ignore the availability to airport users of alternative actions to simply waiting in line.

Exhibit 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.²⁸

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

²⁷ Capping delay in excess of 20 minutes should be applied to the base case as well as the alternatives

²⁸ There may be limited instances where a large aviation infrastructure project may stimulate regional economic demand. However, regional growth does not necessarily constitute an economic benefit if it is due to a diversion of activity from other regions of the country or other sectors of the economy. Benefits of infrastructure will usually be due to savings in resources – time, fuel, passenger and crew time, inventory time of goods, etc.

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.

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 Benefit Passengers (D+G)	Total Benefit without Correction for Induced Demand
Passenger Time	\$2.00	2,000,000	\$4,005,000	50%	-	\$0	\$4,005,000	\$0
Aircraft Operating Cost	\$1.08	2,000,000	\$2,160,000	50%	-	\$0	\$2,160,000	\$0
Total Benefit	\$3.08	2,000,000	\$6,165,000	50%	-	\$0	\$6,165,000	\$0

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 Traffic Flow Management System (TFMS), which includes individual flight information on arrival (AZ), departure (DZ), and other Z messages for operations conducted under IFR flight plans.

Another relevant data source is FAA's Aviation System Performance Metrics (ASPM) data that provides information on arrival and departure rates, airport runway configurations, weather conditions, and taxi times for individual days of the year. A sample of an hourly efficiency report for Hartsfield-Jackson Atlanta International Airport (ATL) is shown in Exhibit 10-3.

Exhibit 10-3: ASPM Daily Configuration by Hour Report

ASPM : Airport Efficiency : Daily Configuration By Hour Report

From 1/1/2014 To 1/4/2014 ; Airport=ATL, BOS, BWI, CLT, DCA, DEN, DFW, DTW, EWR, FLL, HNL, IAD, IAH, JFK, LAS, LAX, LGA, MCO, MDW, MEM, MIA, MSP, ORD, PHL, PHX, SAN, SEA, SFO, SLC, TPA

Airport	Scheduled Departure Date	Local Hour	Scheduled Departures	Scheduled Arrivals	Actual Departures	Actual Arrivals	Actual Total	ADR* Runway Cap Configuration AAR (Arr Dep)	Approach Condition	Average Taxi Out Time	Average Taxi In Time	Temp (F)	Wind Dir	Wind Speed (Knots)	Ceiling (100ft)	Visibility (Stat Miles)	Airport Weather	Weather Impact
ATL	01/01/2014	0	0	3	1	2	3	230 26R, 27L, 28 26L, 27R	VAC	12.00	7.00	35	320	3	200	10.00		None
ATL	01/01/2014	1	0	0	1	0	1	230 26R, 27L, 28 26L, 27R	VAC	13.00	0.00	37	000	0	200	10.00		None
ATL	01/01/2014	2	0	1	1	1	2	230 26R, 27L, 28 26L, 27R	VAC	0.00	5.00	35	180	3	200	10.00		None
ATL	01/01/2014	3	0	0	0	1	1	230 26R, 27L, 28 26L, 27R	VAC	0.00	7.00	36	000	0	150	10.00		None
ATL	01/01/2014	4	0	0	0	0	0	230 26R, 27L, 28 26L, 27R	VAC	0.00	0.00	36	000	0	150	10.00		None
ATL	01/01/2014	5	1	10	2	13	15	230 26R, 27L, 28 26L, 27R	VAC	12.00	7.00	36	110	3	200	10.00		None
ATL	01/01/2014	6	5	13	5	10	15	234 8L, 9R, 10 8R, 9L	VAC	11.50	6.91	36	080	5	200	10.00		None
ATL	01/01/2014	7	15	19	15	22	37	238 8L, 9R, 10 8R, 9L	VAC	12.19	7.47	36	070	5	200	10.00		None

Source: [ASPM Help](#)

Detailed weather data can be downloaded from the National Oceanic and Atmospheric Administration (NOAA) for weather stations near or on most U.S. airports.²⁹ The Global Climate Station Summaries are simple indicators of observational normals which include climatic data summarizations and frequency distributions. These typically are statistical analyses of station data over 5-, 10-, 20-, 30-year or longer time periods. If available for the airport station, the 30-year periods are preferred as a measure of long-term trends. Summaries for the following weather elements are available: Ceiling-visibility, dew point statistics, flying conditions, relative humidity, sky cover, sea-level pressure, station pressure, temperature, wind speed / direction, and present weather. Data are derived from stations collecting hourly data.).

The analyst may also find it advantageous to use ASDE-X OOOI data on the movement of aircraft on the airport surface. These data provide valuable information on the time aircraft spend in the ramp, taxiway and runway areas under different airport configurations. These data are available at 44 large US airports as of mid-year 2020.

Additional details on these data sources can be found in the Simulation Appendix E.

10.4.1.5 Description of Delay

Delay savings should be presented by class of aircraft and by where the delay would have occurred—in the air (by phase of flight), on the ground (in queue vs taxiing), 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. See the Simulation Appendix E. on modeling and outputs and how to value delays by phase of flight using marginal costs.

²⁹ [WMO Resolution 40 NOAA Policy](#)

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. An alternate source for commercial operations is DOT T-100³⁰ data, from which passenger and cargo load factors can be computed. For general aviation aircraft, FAA Economic Values should be employed.³¹

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 can be obtained from DOT T-100 data. 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 can be 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. A recent ACRP project provided a general overview of simulation and spreadsheet models that are available to evaluate terminal congestion.³²

³⁰ [BTS TranStats](#)

³¹ [Benefit-Cost Analysis](#)

³² [ACRP 07-04 Spreadsheet Models for Terminal Planning & Design](#)

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.

Care should be taken to identify the location of time savings. With a few exceptions, only passengers, crew, concession, security and airport personnel are able to access facilities beyond TSA security checkpoints.

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. 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. See the ACRP report cited just above for further information on available landside delay models.³³

³³ [ACRP 07-04 Spreadsheet Models for Terminal Planning & Design](#)

10.4.4 Improved Schedule Predictability

Measurement of the time and resources allocated by aircraft operators specifically to accommodate potential airport delays is complex and difficult. Delay 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. The operator surveys should take account of the ability or willingness to adjust schedules given the need to meet hub banks (schedule integrity) or other commitments in an airline's route system. These responses can then be matched to the estimated delays associated with the base case and investment alternatives.

Another way to evaluate potential savings is to assess whether airport improvements are likely to reduce airline schedule padding (adding time to schedules to account for expected delays).³⁴ One way to estimate schedule padding is to compare actual scheduled block times to minimum block times by airport pairs. Minimum feasible block times between airport pairs can be inferred using the Department of Transportation's Bureau of Transportation Statistics (BTS) Airline Service Quality Performance System (ASQP) data or FAA ASPM or TFMS data. The BCA would then have to provide evidence that carriers would actually reduce schedule padding as a result of the proposed project. Because carriers have to account for marketing and logistical factors (e.g. meeting hub banks), the amount of avoidable schedule padding may be only a portion of total schedule padding. Caution is warranted here, as the degree of historical schedule padding will also vary by the same operator as they try different methods of scheduling their operations (including peaking and de-peaking) in line with their current business strategy.

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.

³⁴ [NEXTOR Total Delay Impact Study](#)

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, more direct aircraft traffic flows (as distinct from delay reductions associated with decreased congestion) should be quantified and presented separately in the BCA. Certain airports have detailed FAA surface surveillance data available (via installed ASDE-X or ASSC systems) data which can be used to inform modeling of alternative routings and the resulting time and money savings. ASDE-X is a surveillance system that tracks the surface movement of aircraft and vehicles. As of 2020, the system was installed at 44 major airports.

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 and/or More Capable or 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, longer 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, or enabling a higher payload), 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 following are initial steps that the sponsor should undertake before proposing an improvement to accommodate larger aircraft:

1. Consider the proximate airports with comparable service patterns that have the required facilities to accommodate larger aircraft and in fact do accommodate those aircraft; then estimate the access cost savings to passengers and other users if the subject airport were improved. If the life cycle cost of the proposed project exceeds the access cost savings of using alternative airports, the project may not be justified because it does not make a large enough improvement in the national system of airports to justify the cost.
 - a. In making this analysis, it is appropriate to consider whether the alternative airports are subject to more delay to passengers and aircraft than the subject airport would be if the project were constructed. When this is the case, these resource savings should also be counted in favor of the subject project.
2. If the outcome in Step 1 is positive for the subject project, the sponsor should assemble information on operator interest in increasing operations of larger, faster and/or more efficient aircraft at the subject airport. Ideally the sponsor would be able to show that

incremental operations by these aircraft are highly likely. For example, if an operator has signed agreement or LOI to operate incremental flights at the airport subject to the completion of the subject project, that would be good evidence of operator intentions.

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.
- Contracts with carriers that commit them to operate larger aircraft when facilities are completed or carrier commitments to complementary facilities already available to accommodate larger aircraft.

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. Ideally the sponsor or surveyed carriers would demonstrate that the market size for new service is sufficient to support it. Carriers may not increase aircraft size if it is more profitable to operate smaller aircraft on a route.

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. Ideally, operators will have signed agreements that commit them to use proposed facilities, although FAA recognizes that sometimes carriers may not be willing to commit to contractual obligations. Letters of intent from operators on their expected use of the proposed facility are also useful. Nevertheless, FAA expects that sponsors will present FAA with information comparable to what they would otherwise have to present to lenders or other financial intermediaries to obtain funding for such projects. 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, 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 O&D traffic levels to the study airport;
- Similar airport infrastructure, both before and after the investment being studied; and
- Location in communities with demographic and other characteristics (population, per capita income, businesses with extensive operations in the region, existence of an airline connecting hub, or presence of LCCs) similar to those of the study airport.
- Existence of operations at the destination airport by a carrier promising the new service

As many comparison airports as possible should be studied. 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, and trip times, between the comparison and study airports. Data of this type are available from commercial vendors of aviation data provided by air carriers to BTS.³⁵ 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.

³⁵ Unfortunately, aircraft cost information is typically not available on an airport specific basis.

Of particular interest to a benefits analysis are differences between the airports with regard to average trip times. Shorter trip times may be the result of faster aircraft (jets rather than turboprops) and more direct flights or may reflect carrier strategies to minimize trip time to more efficiently use aircraft and personnel

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

10.4.6.4 Other Methods

FAA will consider additional methodologies for measuring the potential impact of infrastructure that accommodates larger, faster, or more efficient aircraft. Advance coordination is recommended before expending resources on such alternative methodologies. 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 delay at the airport can be measured using capacity simulation models.³⁶

³⁶ 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 Increased Safety Associated with Vertically Guided 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 or LNAV system), there also may be safety benefits. FAA will provide information on potential safety benefits consistent with then existing investment and establishment criteria.

10.4.9 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). Both noise and emissions modeling should be conducted using FAA's Aviation Environmental Design Tool (AEDT) which simultaneously computes noise, fuel burn and emissions using detailed information on commercial aircraft and engines. AEDT is designed to model various scales ranging in scope from a single flight at an airport to scenarios at the regional, national and global levels.

10.4.9.1 Noise Benefits

Another benefit that is sometimes advanced is the idea that new capacity will reduce delay such that nighttime flights are instead available in daytime hours, as defined by the DNL metric. While this can be true in theory, it also depends on airline decisions on how to run their network – which may include flowing more traffic through uncongested hubs in order to avoid excessive delays at the subject airports. Most simulation models do not consider this feedback loop to changes in airline networks. Consequently, FAA will treat claimed benefits from reduced nighttime noise due to delay savings with caution.

AEDT is the noise model employed by FAA. AEDT reveals the extent of aircraft noise impacts by mapping regions that are unacceptably impacted. It indicates the number of residences or structures that must either be purchased or modified to mitigate impacts under various scenarios.

AEDT 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).

Air Emissions. To model emissions, AEDT estimates fuel burn using very specific information on the combinations of aircraft, engines and takeoff procedures, while accounting for payload. Fuel consumption is then translated into emissions. A new airport infrastructure project may

reduce airport emissions or may make it feasible for them to increase (perhaps through the use of larger aircraft). These issues should be documented in the BCA.

10.4.10 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 2019, 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 2019 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 time 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, should 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 assumed to equal the aircraft's variable operating cost at the stage of flight when the delay occurs. Commercial aircraft delayed at the gate incur few variable costs at the gate prior to the doors being closed. Once doors are closed, crew costs usually begin to be incurred. Once an aircraft begins taxiing (in or out), it incurs variable costs but fuel and engine maintenance costs are significantly lower than during flight. One study suggests that fuel burn during taxiing is about 1/3 of in-flight fuel usage.³⁷ Full variable operating costs include crew costs, maintenance, and fuel and oil costs that would be incurred during takeoff, enroute and landing phases of flight. But 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 an air traffic control delay management program at another airport. For more information on how to convert average variable operating costs to marginal costs by stage of flight, consult the Simulation Appendix E.

Table 10-4: Valuation of Airport Project Benefits

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
Reduced Aircraft Delay Hours		
<ul style="list-style-type: none"> 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 including by phase of flight and whether moving under power on the airport surface. 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 Economic Values ³⁸ or 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 Economic Values which also contains lease values.)
Reduced Passenger Delay Hours		
<ul style="list-style-type: none"> 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	DOT publishes guidance on valuation of travel time in economic analysis which OST

³⁷ Ryerson, Hao, Kang & Hansen Fuel Burn Impacts of Taxi-out Delay and their Implications for Gate-hold Benefits (Nextor Presentation June 30, 2015); also see the Simulation Appendix for a method for estimating marginal operating costs by phase of flight.

³⁸ [Benefit-Cost Analysis](#)

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
		has developed and requires FAA to use. ³⁹
<ul style="list-style-type: none"> Reduced passenger vehicle hours in landside access 	Passenger vehicle operating costs	Current IRS estimates of variable cost per mile = “standard mileage rate” for business less depreciation. ⁴⁰
Reduced Air Cargo Delay Hours		
<ul style="list-style-type: none"> 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% real opportunity cost (annual basis) to value of cargo for period delayed.
<ul style="list-style-type: none"> 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
<ul style="list-style-type: none"> Reduced trucking hours in landside access 	Cargo vehicle operating costs	Current IRS estimates for light trucks (including driver costs).
Reduced Meeter/Greeter Delay Hours		
<ul style="list-style-type: none"> Reduced meter/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 meter/greeter time. Sensitivity analysis should assume half the values applied to passenger time in per DOT guidance.
Improved Schedule Predictability		•
Reduced Aircraft Delay Hours		
<ul style="list-style-type: none"> Reduced resources needed to meet flight schedules 	Cost of resources allocated to accommodate potential delays	Documented cost data provided by operators (if available).
<ul style="list-style-type: none"> 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 per DOT guidance.
More Efficient Traffic Flows		
<ul style="list-style-type: none"> 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	See Reduced Aircraft Delay
<ul style="list-style-type: none"> 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		

³⁹ [Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis](#)

⁴⁰ [IRS Standard Mileage Rates](#)

Look for the publication entitled “Standard Mileage Rates” on the above site. Take the standard mileage rate (see Section 3; in 2020, this was 57.5 cents) and subtract estimated depreciation (Section 4; for 2020, this was 27 cents); thus the appropriate mile rate would be 27.5 cents.

BENEFIT UNIT	VALUATION	SOURCE OF VALUE DATA
<ul style="list-style-type: none"> Lower cost due to more efficient aircraft 	Cost or fare reduction per passenger/cargo unit	Information provided by aircraft operators (if available). Commercially available/DOT Form 41 (cost) or DB1B data on average RASM, destinations, and trip distance at subject airport.
<ul style="list-style-type: none"> 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.
<ul style="list-style-type: none"> 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		
<ul style="list-style-type: none"> 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.
Safety Benefits of Capacity Projects		
<ul style="list-style-type: none"> Vertically guided approaches enabled by new landing system 	Reduced fatalities, injuries and property damage per precision approach	Benefits calculated by FAA-
Environmental Benefits of Capacity Projects		
<ul style="list-style-type: none"> 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		
<ul style="list-style-type: none"> 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 and staffing records and management cost estimates

Variable operating costs used to value aircraft delay reductions at an airport will depend on the type of aircraft affected by the investment. 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.

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 (Economic Values)"⁴¹ 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 Economic Values.⁴² (Also see Appendix A of this guide for more information on use of price indexes). Analysts are also advised to consult the Simulation Appendix E. for information on identifying and adjusting operating costs by phase of flight.

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 Economic Values 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. IRS provides annual estimates of average automobile variable operating costs.⁴³ To calculate them, take the "business" standard mileage rate from IRS (57.5 cents in 2020) and deduct depreciation—termed "basis reduction amount"⁴⁴—(24 cents in 2020) to estimate the variable cost of operating an automobile (23.5 cents per mile in 2020).

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.

⁴¹ [Benefit-Cost Analysis](#)

⁴² [Benefit-Cost Analysis](#)

⁴³ [IRS Standard Mileage Rates](#)

⁴⁴ [IRS 2020 Standard Mileage Rates](#)

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.⁴⁵¹⁰ 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 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. A separate analysis will be necessary based on neutral authorities demonstrating the contribution of delays to spoilage for specific commodities; an important factor in evaluating impacts on perishables is whether the temperature-controlled supply chain ("cold chain") is broken; delays without breaks in the cold chain can usually be evaluated in the same way as conventional cargo

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. It is unlikely that avoiding these types of delay would be a consistent source of benefits for an airport infrastructure project. Instead the logistics network would be adjusted to take account of expected delays.

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. The analyst should also rely on independent third party models or methodologies wherever feasible including consulting academic literature.

10.5.5.4 Valuation of Meeter/Greeter Delay Reductions

FAA has not settled on a general methodology for recognizing or valuing 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. Furthermore, because meeter/greeters are normally unable to enter secure ATB areas, they usually drop off departing passengers or wait in cell phone lots to pick up arriving passengers. With easy access to flight information via the internet, most meeter/greeters

⁴⁵ See Section 12 for a discussion of the time value of money.

can avoid incurring long delays by simply keeping updated on potential delays via airline websites. They can then apply the time to alternative activities, thereby minimizing any losses. For this reason, it is recommended that these costs not be counted in a BCA unless it can be shown that an infrastructure project would allow meter/greeters to avoid unexpected delays. 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.⁴⁶

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 10.5.5.⁴⁷¹¹

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 including airport access time. The latter would be computed based on savings in access time versus using the closest airports with the capacity and facilities needed to service the subject aircraft.

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

⁴⁶ In cases where meter greeter time is valued, consult the FAA Benefit Cost website for the latest guidance on the value of time. Usually local personal time is valued at 50% of per hour median household income.

[Treatment of Time](#)

⁴⁷ 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.

transit should be valued at the value per hour of passenger time or cargo time (see Section 10.5.5). In cases where passengers or cargo can reduce access time to the airport capable of accommodating larger, faster or more efficient aircraft, these time savings should also be valued using the appropriate standard values.

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 system wide delay caused by local airport delay;
- Passenger comfort and convenience; and
- Non-aviation macroeconomic and productivity impacts.

System-wide 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. FAA has published guidance on follow-on delays focused primarily on larger commercial airports.⁴⁸ The factors developed in the guidance can be multiplied by the estimated delays savings yielding a result that accounts for system-wide delays. In addition, FAA does use proprietary models for evaluation of system wide flows across the NAS, including benefits with infrastructure or NAS modernization projects. Coordinate with FAA to ascertain if it is possible to apply these models to the proposed airport project. .

10.6.1 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. 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. 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.

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.

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. In theory, the incremental benefit would be included in the consumer and producer surplus created by the new ATB facility. Consumers and producers should be willing to pay for the improvements and it may be possible to carefully distinguish comfort and convenience benefits from others created by the project.

⁴⁸ [Delay Propagation Multipliers](#)

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 may be useful, particularly in contexts in which good market data are not available.

10.6.2 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 land banking.

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. Extreme care should be taken to ensure that any claimed benefits are net of any losses or transfers from other U.S. locations. Furthermore, such benefits should be incremental to the next best alternative – e.g. use of an alternative airport.

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.

10.6.2.1 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.

10.6.2.2 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.⁴⁹¹³ 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.

Other studies include airport investments into larger evaluations of the output elasticities due to transport investments. These studies use econometric techniques to evaluate the increase in output due to such investments. See Melo et al for a meta-analysis of such studies.⁵⁰

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. Many productivity gains would already be captured in the BCA – e.g. more efficient use of aircraft and people and other factors of production; any additional gains would be due to a different way of doing business which would have to be documented. 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 possibly lower fares;
- Construction of an airport to replace an obsolete or poorly-situated airport that is subject to excessive delays or service limitations; and
- Construction of an airport to supplement or relieve a nearby congested airport.

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

⁴⁹ 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.

⁵⁰ Melo et al: *The productivity of transport infrastructure investment: A meta-analysis of empirical evidence*; Regional Science and Urban Economics 43 (2013) 695–706.

relevant to investments at existing airports, such as additional commuting distance to the airport, must be specifically addressed.

The Net Benefits of a new airport usually will not exceed the costs that passengers (and other customers) would avoid if they otherwise had to access alternative airports which together or alone can produce the same set of services. So for example, the benefits of a new general aviation airport cannot exceed the benefits users gain by avoiding accessing other existing general aviation and/or commercial airports with the same capabilities (runway length, lighting and approach capabilities, capacity, and other facilities.) Any benefits beyond these access related savings would have to be due to unique productivity gains (in the production of aviation services) or macroeconomic gains that would otherwise not occur nationally, both of which would have to be separately reported. For example, an airport capacity project that stimulated net national⁵¹ demand for aviation services might produce consumer benefits that otherwise would not exist by lowering the full cost of travel by a substantial amount. But this would be highly unusual in a mature aviation market where annual growth rates are typically in the low single digits.

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, better IFR weather access, 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 (if enabled by competition at the new airport). 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

⁵¹ To stimulate demand in a meaningful way, any gains at the subject airport would have to more than offset losses at other airports in the U.S.

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 TAAM or AirTOP or other simulation models that can account for multi-airport airspace management. See the Simulation Appendix E. for more information on simulation models.

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. In fact, if a new airport is located further from population centers, the incremental access costs to users should be

accounted for in the BCA as an offset to other benefits. 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. The gains to society from a new airport would in most cases be reduced ground access costs versus existing airports. In some cases, a new airport may create opportunities for new commercial services, which otherwise might not exist. These benefits have to be carefully evaluated versus existing alternatives.

New airport forecasts are subject to major uncertainties. 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 or an uncertain customer base;
- Poor location of the new airport relative to regional population centers; and
- Proximity of a hub airport within reasonable driving distance (e.g., 90-120 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 and usage 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 passenger 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 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 and/or nonstop service 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. Sponsors can consult with FAA-ARP headquarters staff on modeling access costs. The full price of travel would include the 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. See the Consumer Surplus Appendix for further discussion of the full price of travel and how it might be applied to new airports.

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 decision-making and should not be included in the BCA.

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.⁵² 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. Depreciation should be measured over the economic life of the asset.⁵³

⁵² See section 8.1.4 for the limited circumstances where salvage values and residual values should be used in a BCA.

⁵³ See section 8.1.4.

As noted earlier in Section 8.1.4, salvage values are best applied to assets that have a known market value and can easily be sold. An example would be equipment acquired for a project that would be sold at the end of the project. In that case, the salvage value would offset costs in the year the project was completed.

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. The BCA should provide evidence of increasing or decreasing real costs and why the trend is expected to continue. 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. Incurred costs are sunk and are not relevant for decision-making 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 equiptage 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 offsite)
Storm water system (including water treatment)
Electric, gas and telephone
Perimeter and security fencing

Project and Project Components
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.

Transition costs also include resources expended moving from one facility to a new or refurbished facility.

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.

For FAA-owned NAVAIDS and equipment, airports should consult the FAA for recurring O&M costs rather than estimate them independently.

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

Please see Section 8.1.4 for a discussion of when salvage and residual values may be applied in airport BCA's.

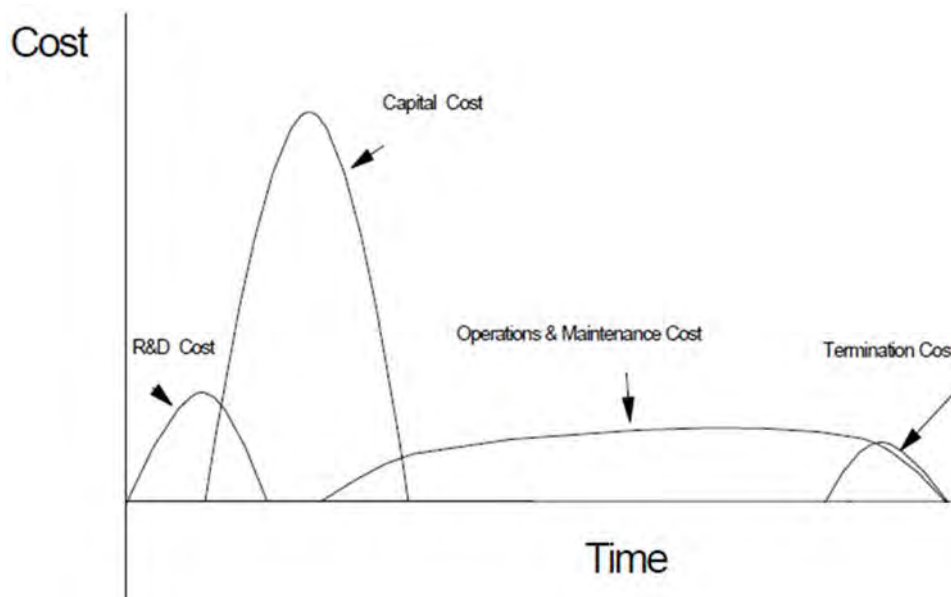
11.3.6 Relationship of Cost Components

Exhibit 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. Salvage values would be estimated for any equipment for which there is an established market where it can be readily sold. (See Section 8.1.4.)

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.

Exhibit 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, closing the facility and having users use a nearby alternative airport 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.⁵⁴ Both extremes (with appropriate intermediate levels) should be evaluated and costed.

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

⁵⁴ 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.

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.

In general, the cost of reconstruction (including intermediate delays or other costs to users) should not exceed the cost to users of accessing nearby airports with sufficient capacity and appropriate infrastructure to provide the same services.

11.4.2.4 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 requires 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-94.⁵⁵ The real discount rate relevant to all airport projects to be funded with Federal grant funds is 7 percent, as described in the latest version of OMB Circular No. A-94, (Section 8.0):

“Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. Significant changes in this rate will be reflected in future updates of this Circular.”

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:

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

where:

V = future value in year n in constant dollars
r = annual real discount rate

⁵⁵ See the following for the latest OMB guidance applicable to USDOT projects:
[OMB Circular A-94](#)

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., $n = \frac{1}{2}, 1\frac{1}{2}, 2\frac{1}{2}$, etc.). Finally, a discounting formula can be applied which assumes continuous accrual of costs and benefits over the course of a year.⁵⁶¹⁵

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.

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 2016), with costs and benefits expressed in real 1996 dollars and discounted back to December 31, 2016. The project life span (discussed in Section 8) would reflect the expected economic life of the project.

⁵⁶ Present value tables, located in various financial text books, can also be used.

Table 12-1: Discounting of Project Costs and Benefits

Project	Cost	Benefit	Discount Rate	PV	PV
2017	\$50,000	\$0	$(1+.07)^1 = 1.07000$	\$46,729	\$0
2018	\$5,000	\$15,000	$(1+.07)^2 = 1.14490$	\$4,367	\$13,102
2019	\$5,000	\$15,000	$(1+.07)^3 = 1.22504$	\$4,081	\$12,244
2020	\$6,000	\$17,000	$(1+.07)^4 = 1.31080$	\$4,577	\$12,969
2021	\$6,000	\$17,000	$(1+.07)^5 = 1.40255$	\$4,278	\$12,121
2022	\$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:

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

where:

B = future annual benefits in constant dollars C = future annual costs in constant 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
2017	\$46,729	\$0	\$28,037	\$0	\$65,421	\$0
2018	\$4,367	\$13,102	\$4,367	\$10,481	\$5,241	\$20,089
2019	\$4,081	\$12,244	\$4,081	\$9,796	\$4,898	\$18,775
2020	\$4,577	\$12,969	\$3,814	\$9,155	\$4,577	\$19,072
2021	\$4,278	\$12,121	\$4,278	\$10,695	\$4,991	\$17,825
2022	\$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:

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

where:

B_t = future annual benefits in constant dollars

C_t = future annual costs in constant 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 12-3.⁵⁷

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	\$1,641,000	\$4,595,000
Total Costs (Discounted at 7%)	\$1,263,000	\$4,217,000
Benefit-Cost Ratio	1.3	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

⁵⁷ Adapted from De Neufville.

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:

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

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

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.⁵⁸ 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.

⁵⁸ This assumes that it is not feasible to do Alternative C in Year t=1 and extend its life by 5 years, assuming $B_i > C_i$ for $i=1, \dots, 5$.

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.

Analysts may find it convenient to use a spreadsheet plug in program to implement risk and uncertainty simulation analysis.⁵⁹ These programs provide ready-made processes for selecting and sampling probability distributions and incorporate easy to read graphical and text outputs of Monte Carlo experiments (where the probability distributions are sampled thousands of times).

⁵⁹ Many of these programs are compared in the following Wikipedia article:
[Comparison of Risk Analysis Microsoft Excel add-ins](#)

The result is a range of outcomes which then can be expressed in confidence intervals. For example, one could conclude that given the range of assumptions for key input variables and how they are distributed, the benefit-cost ratio of a project would exceed 1.0 about X% of the time. The same type of output can be generated for net present values. This kind of analysis gives decision-makers the opportunity to decide how much risk they are willing to accept when undertaking a project. Care should be taken to document in the BCA report the assumptions concerning the range and distribution of key variables and the rationale for such assumption.

Simpler sensitivity studies such as those described immediately below should also be reported in the BCA report.

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.

13.3.3 One Variable Test

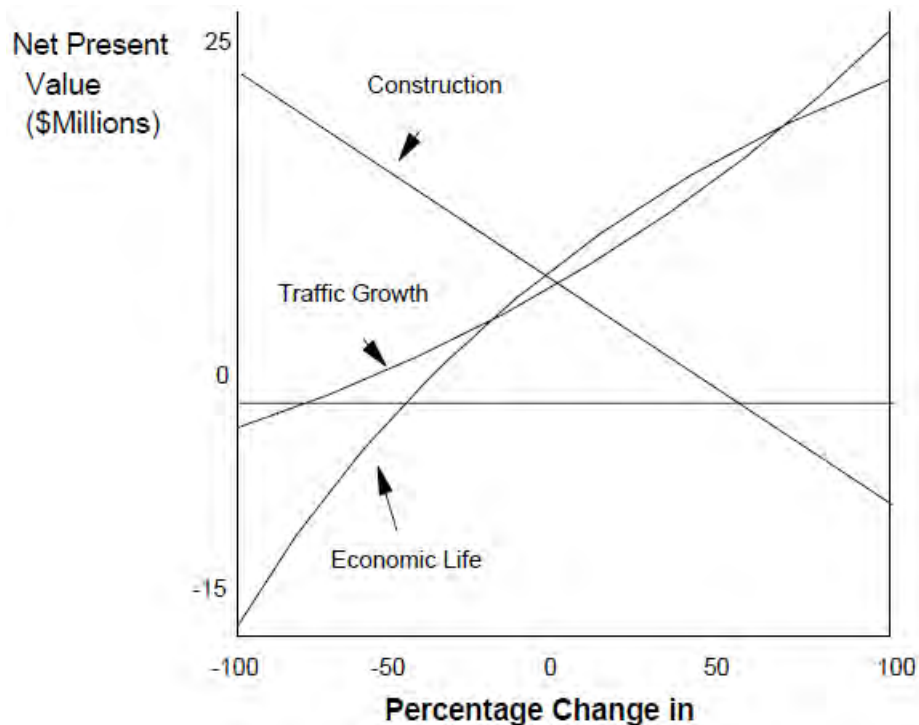
This procedure should be applied to the major cost and benefit components of each alternative. Its primary purpose is to identify the sensitivity of the NPV of each alternative to changes in value of each component. This permits additional effort to be devoted to improving the reliability of estimates 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 be 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. Exhibit 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.

Exhibit 13-1: One Variable Uncertainty Test



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.

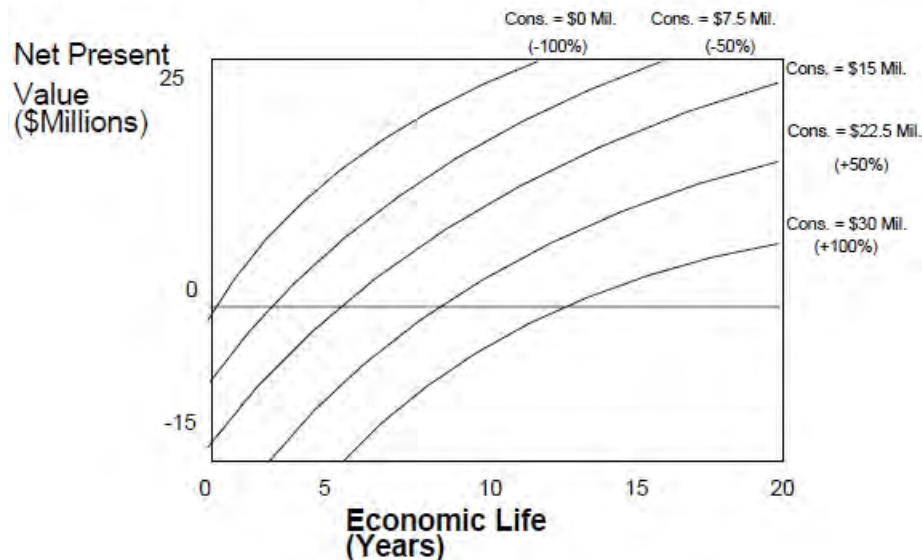
13.3.3.1 Two Variable Test

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 Exhibit 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 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.

Exhibit 13-2: Two Variable Uncertainty Test



13.3.3.2 Alternative Scenarios

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

$$NPV = f(X_1, X_2, X_3, \dots, X_n) \quad 13-1$$

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.

When it is appropriate to evaluate outcomes by varying input assumptions across several key variables, it may be appropriate to use spreadsheet plug-in programs mentioned above.

Value at Risk

Decision-makers can benefit from knowing the full range of possible outcomes of a complex investment. Because of risk and uncertainty, it is useful to understand the probability that a project will produce positive Net Benefits (how often the project will payoff). It is also useful to

understand how big net costs could be, especially when one is considering a new, large scale investment like a new airport. In finance, answering these questions is critical and the standard approach is called “value at risk.”

Value at Risk (VaR) is a concept that originated in the financial industry in the late 1980’s. The idea was to estimate the probability a financial firm’s maximum loss in a relatively short period of time. Because these institutions managed large and highly diverse portfolios, it was difficult to fully understand all of the risks they were exposed to. An example of the VaR for the portfolio of a large financial institution might show that it has a one percent chance of losing \$100 million in a day, given its portfolio and the historic price movements in the underlying individual stocks and bonds it held. This is a highly useful metric because it gives managers and regulators a way to assess how much capital a firm should have on hand to cover maximum daily losses. The Securities and Exchange Commission instituted capital requirements for financial firms (based on what came to be known as VaR) in 1980 sufficient to cover with 95% confidence the losses that might be incurred during the time it would take to liquidate a securities firm (30 days).⁶⁰

One can think of an airport as a portfolio of current and future assets that produce cash flows for the enterprise and benefits to passengers and airlines. A benefit-cost analysis tests how likely it is that society will be better off with a specific project (Scenario Case) versus without it (Base Case). If the analyst is able to specify the distributions of critical assumptions in the BCA (typically using one of the plug in programs for risk analysis mentioned above), then BCA simulations can be run thousands of times using the random number generator imbedded in the programs (these are called Monte Carlo simulations) to select values of the input distributions to produce a range of possible outcomes. In each simulation, the Net Benefits (discounted net present value) of the project are computed, these results are placed in order from lowest to highest, and the final result is a distribution of outcomes.

A traditional BCA compares the discounted benefits of the project against the discounted costs (including construction, maintenance, operation, etc.) For purposes of a VaR analysis, rather than focusing on the benefit-cost ratio of a project, one can look at the results in a slightly different way and consider the “net impacts” for both the Base Case and the Scenario.

Consider the following simplified example: suppose an airport is considering building a runway extension to handle the extra takeoff length required on days when the temperature exceeds 110°F. As with any benefit-cost analysis, the goal is to evaluate the present value of benefits and costs over time. Presumably, the costs of the runway extension can be accurately projected (say \$X) based on construction and maintenance estimates.

The harder part is to identify and quantify the benefits. For simplicity, suppose that without the runway extension, carriers will experience schedule delays and/or weight restrictions estimated to cost \$Y per day if the temperature exceeds 110°F. With the extension, flights can operate normally as scheduled without any service disruptions. Thus, this can be thought of as a mitigation project – without it, the airport and its users may incur delays due to high

⁶⁰ See Holton, G. History of Value-at Risk 1922-1998 (Working Paper 2002). (Retrieved from [History of Value-at-Risk: 1922-1998](#))

temperatures, but there is a great deal of uncertainty regarding when and how often those delays may occur.

A useful approach here would be to run Monte Carlo simulations of the maximum daily temperature projections; these may be available from a number of different climate models, but the essential point is that these projections are not known with certainty. Rather, the analyst has a *distribution* of projections over future years. Suppose the analysis decides to do 5,000 simulations to cover a 30-year analysis period. For each simulation, the analyst will make random draws from this distribution to cover the entire 30-year period. So for Simulation #1, it may turn out that the Year 1 projection is for 5 days in excess of 110°F; in Year 2, there are 12 such days; in Year 3, there are none, etc. After going through all 30 years, one can then compute the Base Case damages that would occur without the project (appropriately discounting each year's results), the Scenario damages (if any) that would occur with the project, and the construction, maintenance and operation costs of the project. From these numbers, one can also compute the net present value of the project and a benefit-cost ratio.

The entire process would be repeated 5,000 times, each time generating a new set of results that will vary depending on the number and timing of high-temperature days in the future. Some of the runs will have much lower than average high-temperature days; others will be just the opposite. But collectively, the results should accurately reflect the range and likelihood of high temperatures as projected across the different available climate models.

One could then compute a mean value and standard deviation across the 5,000 net present values and/or benefit-cost ratios. This is valuable information for decision makers and provides estimates of not only the average expected NPV or benefit-cost ratio, but also the likely range of outcomes as measured by the standard deviation.

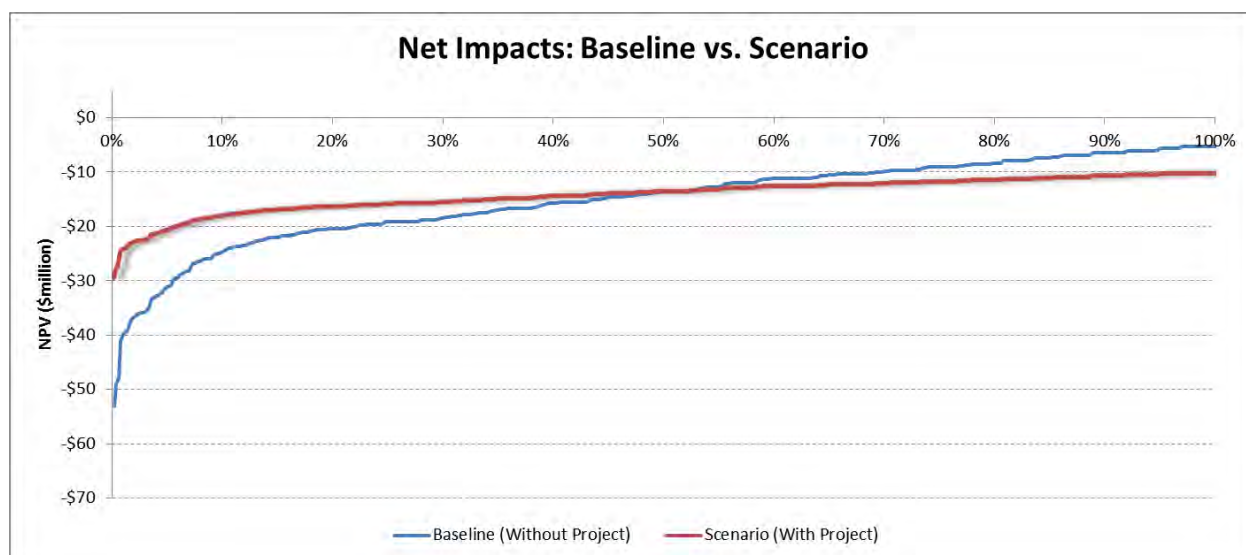
But in addition, the output from the Monte Carlo simulations can be transformed into a VaR analysis in a straightforward way. For purposes of a VaR analysis, rather than focusing on the benefit-cost ratio of a project, one can look at the results in a slightly different way and consider the “net impacts” for both the Base Case and the Scenario.

For the Base Case, net impacts for this mitigation project are simply the present value of the dollar damages incurred if the project is not undertaken. For the Scenario, net impacts are the present value of the remaining damages not mitigated by the project (if any) plus the present value of the investment costs (including construction, maintenance and any other relevant costs) for the project. For VaR purposes, each of these impacts will be represented as negative dollar quantities.

One could then plot these two quantities on a graph; if the Scenario value is more negative than the Base Case value, this indicates that the project did not pay off. This would be repeated for each Monte Carlo simulation, resulting in a new pair of net impacts under the Base Case and Scenario. To assess these results across all the simulations, they can be sorted based on the *difference* between the two values, and then plotted along a percentage scale.

The result is a VaR graph such as the one shown below in Exhibit 13-3.

Exhibit 13-3: Value-at-Risk Comparison



Based on the varying net benefit results from the Monte Carlo simulations, the blue line in the chart shows that if the airport does nothing, it faces a 10 percent chance of incurring damages (in the form of delay costs) of at least around \$25 million (where the blue line passes the 10% point on the horizontal axis), and could incur damages worth as much as \$50+ million. On the other hand, if it does undertake the mitigation project, it must pay the investment costs plus incur any remaining delay impacts; these two factors combined could total as much as about \$30 million (left extremity of chart for the red line). But also note that the range of potential net impacts is much larger under the Baseline (from about \$5-50 million in damages) than under the Scenario (\$10-30 million in damages and project costs). The chart also shows that there is about a 50 percent chance that the project would pay off (indicated by the point at which the two curves intersect).

It is important to properly interpret the meaning of these results. Facing a 10 percent chance of incurring damages of at least \$25 million means that in 10 percent of the simulations, the present value of damages was \$25 million or worse. Remembering that each simulation represents a set of future outcomes over 30 years, these will include many different specific outcomes that vary across the years. In some simulations, there may be a small number of unusually hot years early on, resulting in a few highly-valued delays (because they are discounted less when occurring early). In many others, the high temperatures will have been estimated to occur in later years, but they are likely to occur more often, resulting in more lower-valued delays. So it is important to recognize that the 10 percent chance of damages includes many different potential outcomes; it does not refer to an annual probability of occurrence, but rather the overall likelihood (over the entire analysis period) that the airport's users would face \$25 million or more of delay costs (in present value terms) under the Base Case.

This provides a different perspective than the more traditional focus on average NPV or average benefit-cost ratio from the simulations. With VaR a decision maker can better assess how much risk he or she is willing to accept. An airport and its operators may or may not be willing to

accept \$25 million in losses with a 10% probability. But at least they would have a better idea of the risk they are accepting if they choose not to do the project.

A recent ACRP report provides more information on setting up value at risk models for airport investments.⁶¹

⁶¹ [The National Academies Press Log In](#)

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 based on **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 affect 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 GDP Chain-Type Price Index. Both measures are currently published by the Bureau of Economic Analysis of the Department of Commerce. Because the two series usually differ only slightly, and in this time period are identical, 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 (2008 – 2018)

Year	GDP Chain-Type Price Index	GDP Implicit Price Deflator
2008	94.3	94.3
2009	95.0	95.0
2010	96.1	96.1
2011	98.1	98.1
2012	100.0	100.0
2013	101.8	101.8
2014	103.7	103.7
2015	104.8	104.8
2016	105.9	105.9
2017	107.9	107.9
2018	110.4	110.4

Source: *National Accounts*, 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 2012 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 2012 being equal to 100.

For example, the 2015 value of the GDP implicit price deflator of 104.8 means that the price level for a given basket of goods and services in 2015 was 4.8 percent higher than it was in 2012, which is readily apparent from inspection. Given the 2012 base, it is not readily apparent, how much greater the price level was in 2015 than in 2008. This can be easily computed as 11.1 percent by dividing the 2015 value by the 2008 value and subtracting 1: $(104.8 / 94.3) - 1 = 11.1\%$. 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.⁶² Annual changes may be computed by dividing each value by that of the previous year and subtracting 1.

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

⁶² 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.

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 Budget Appropriation from 2008 through 2018 is converted from current dollars to 2018 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 2018 constant dollar series in column (4) of Table A-2 from 2018 constant dollars to 2010 constant dollars requires that each number in column (4) be multiplied by $100/87$ from column (2) or $110.4/96.1$ 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 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.

Table A-2: Conversion of Total FAA Appropriations from Current Dollars to Constant Dollars

(\$millions)

Year	(1) GDP Deflator (2012 = 100)	(2) GDP Deflator (2018 = 100)^a	(3) Total FAA Appropriations in Current Dollars	(4) Total FAA Appropriations in 2018 Constant Dollars^b	(5) Total FAA Appropriations In 2010 Constant Dollars^c
2008	94.3	85.4	\$14.9	\$17.4	\$20.1
2009	95.0	86.1	\$16.8	\$19.5	\$22.4
2010	96.1	87.0	\$15.6	\$17.9	\$20.6
2011	98.1	88.9	\$15.9	\$17.9	\$20.6
2012	100.0	90.6	\$15.9	\$17.5	\$20.2
2013	101.8	92.2	\$16.0	\$17.4	\$19.9
2014	103.7	93.9	\$15.9	\$16.9	\$19.5
2015	104.8	94.9	\$15.8	\$16.6	\$19.1
2016	105.9	95.9	\$16.3	\$17.0	\$19.5
2017	107.9	97.7	\$16.4	\$16.8	\$19.3
2018	110.4	100.0	\$16.1 ^d	\$16.1	\$18.5

Source: *Budget*, Federal Aviation Administration

a. Column (1) divided by 110.4 and multiplied by 100.

b. Column (3) divided by column (2) and multiplied by 100.

c. Column (4) multiplied by 87.0 / 100.

d. Requested amount (actuals not yet available)

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 SIC⁶³19 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.⁶⁴

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.

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.⁶⁵ Associated with this new

⁶³ 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.

⁶⁴ Bureau of Economic Analysis (BEA) publishes the GDP deflator: See [BEA Prices & Inflation](#)
Bureau of Labor publishes 535 industry price indexes in combination with over 4,000 specific product line and product category sub-indexes and more than 3,700 commodity price indexes for goods and about 800 for services (seasonally adjusted and not seasonally adjusted), organized by product, service, and end use. See: [BLS Producer Price Indexes](#)

⁶⁵ 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.

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 and 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

Forecasts for the GDP Implicit Price Deflator and/or GDP Chain-Type Price Index are available from several sources. 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.⁶⁶

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.⁶⁷

The Federal Highway Administration publishes a quarterly index of highway construction costs in "Price Trends for Federal-Aid Highway Construction."⁶⁸ 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

⁶⁶ OMB Circular A-94 (Revised—October 29, 1992) p. 8.

⁶⁷ [ENR Report Market Still Remains Strong](#)

⁶⁸ [Archived Price Trends for Federal-Aid Highway Construction](#)

Indicate the price trend for all surfacing types; and reinforcing steel, structural steel, and structural concrete, to indicate the price trend for structures.

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. The PPI indexes are available on the BLS web site at [US Bureau of Labor Statistics](https://www.bls.gov/labor).

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.. Most of the data are also available electronically at <https://www.energy.gov/energy-economy/prices-trends>. .

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*. 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).

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).

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 prefers that analysis be conducted in constant dollars:

*Base-Case Analysis. Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. Significant changes in this rate will be reflected in future updates of this Circular.*⁶⁹

OMB does permit benefit-cost analyses to be conducted in either nominal or current dollars or in constant dollars of a particular year.⁷⁰ 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 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.

⁶⁹ OMB A-94 section 8

⁷⁰ "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.

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 or 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.⁷¹ 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 reflect that their real values relative to the real values of other goods and 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):

⁷¹ 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.

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

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

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):

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

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):

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

where: X_t = the quantity in year t being adjusted expressed in constant dollars of the year of initial project implementation,
 $(B-C)^t$ = all benefits and costs other than those contained in X_t ,
 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 decision-making 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 2, 2012)

"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.⁷²

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 23, 1983.⁷³

Airport Design, FAA Advisory Circular 150/5300-13A, September 28, 2012.⁷⁴

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.

⁷² [OMB Circular A-94](#)

⁷³ [AC 150-5060.5 - Airport Delay and Capacity](#); includes changes 1 and 2.

⁷⁴ [AC 150/5300-13A - Airport Design](#)

OMB BULLETIN No. 94-16, “Guidance on Executive Order No. 12893, Principles for Federal Infrastructure Investments,” March 7, 1994.⁷⁵

“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, 1997.⁷⁶

“Policy Regarding Revisions of Selection Criteria for Discretionary Airport Improvement Program Grant Awards,” *Federal Register*, Vol. 59, No. 209, October 31, 1994.⁷⁷

“Policy for Letter of Intent Approvals under the Airport Improvement Program,” *Federal Register*, Vol. 59, No. 209, October 31, 1994.⁷⁸

Air Traffic Controller Workforce Plan, Published Annually.⁷⁹

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.⁸⁰

“The Value of Saving Travel Time: Departmental Guidance for Conducting Economics Evaluations,” Office of the Secretary of Transportation Memorandum, April 9, 1997, and updates.⁸¹

B.3.2. Data Sources

Air Carrier Traffic Statistics, Bureau of Transportation Statistics, U.S. Department of Transportation, published monthly.⁸²

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.⁸³

Economic Report of the President, Council of Economic Advisers, Washington, D.C., published annually in January.⁸⁴

⁷⁵ [Selected OMB Guidance Regarding Capital Assets](#)

⁷⁶ [FR Vol. 62 No. 121 Notices](#)

⁷⁷ [Airport Improvement Program \(AIP\)](#)

⁷⁸ [Letter of Intent \(LOI\) Program Overview](#)

⁷⁹ [Air Traffic Controller Workforce Plan 2020/2029](#)

⁸⁰ [Revised Departmental Guidance on Valuation of a Statistical Life in Economic Analysis](#)

⁸¹ [Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis](#)

⁸² [U.S. Air Carrier Traffic Statistics through May 2020](#)

⁸³ [Economic Indicators](#)

⁸⁴ [Economic Report of the President February 2020](#)

FAA Air Traffic Activity, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington D.C., Published annually.⁸⁵

FAA Aviation Forecasts, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington, D.C., published annually.⁸⁶

FAA Statistical Handbook of Aviation, Office of Aviation Policy and Plans, Federal Aviation Administration, Washington D.C., published annually.⁸⁷

“Materials and Labor Cost Trends in the U.S.,” *Engineering News Record*, published monthly⁸⁸

Monthly Labor Review, Bureau of Labor Statistics, Department of Labor, published monthly.⁸⁹

OMB CIRCULAR No. A-76 (Revised Handbook), *Performance of Commercial Activities*, March 1996.⁹⁰

PPI Detailed Report, Bureau of Labor Statistics, Department of Labor, published monthly.⁹¹
“National Highway Construction Cost Index,” Federal Highway Administration, Washington D.C.⁹²

Standard Industrial Classification Manual, Office of Management and Budget, 1987.⁹³ SIC’s were replaced by the North American Industry Classification System (NAICS) in 1997.⁹⁴

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.⁹⁵

⁸⁵ [Air Traffic Activity System \(ATADS\)](#)

⁸⁶ [Aviation Forecasts](#)

⁸⁷ [Aviation Data & Statistics](#)

⁸⁸ [ENR: Material and Labor Cost Index Falls in July](#)

⁸⁹ [BLS: Monthly Labor Review](#)

⁹⁰ [Circular No. A-76 Performance of Commercial Activities](#)

⁹¹ [BLS: Producer Price Indexes](#)

⁹² [National Highway Construction Cost Index \(NHCCI\)](#)

⁹³ [U.S. Standard Industrial Classification \(SIC\)](#)

⁹⁴ [North American Industry Classification System \(NAICS\)](#)

⁹⁵ [Statistical Abstracts Series](#)

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.

Please refer to Appendix D for a more complete discussion of consumer and producer surplus and their application to benefit-cost analysis.

C.2 Economic Framework for Estimating Benefits

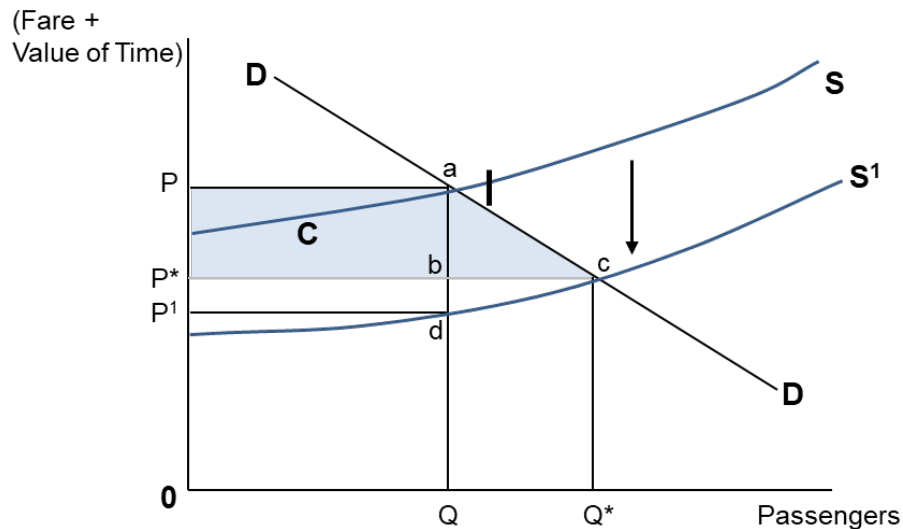
Economic theory provides the essential framework for understanding and measuring the dynamic interaction of project net benefits and demand for the project. A simplified version of this framework, known as consumer surplus, is illustrated in Exhibit C-1 for air transportation services.

Exhibit 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 Exhibit 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.

Exhibit 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.

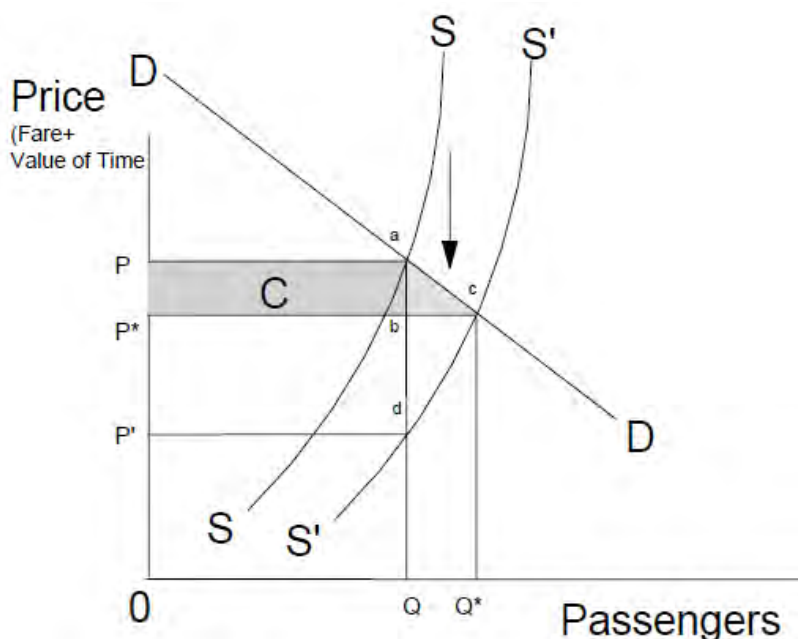
The net effect of the project is to increase total benefits by an amount equal to the areas C plus I . C is the product of the decrease in total price ($P - P^*$) multiplied by the number of passengers (Q) who would have used the airport even without the investment (pre-existing passengers). The benefit 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 $(P - P^*)$.⁹⁶

⁹⁶ 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 .

The consideration of induced demand and consumer surplus is necessary for a correct quantification of benefits.⁹⁷ Failure to consider induced demand in Exhibit 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. Exhibit C-2 illustrates a case where average delay costs are rising steeply as operations increase at a congested airport. The assumption that 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 $PacP^*$.

Exhibit C-2: Consumer Surplus with Radical Delay



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).

⁹⁷ 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.

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 full price of travel (FPT) 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 FPT elasticity of demand) will be the equilibrium scenario. This process is explained in detail in the following subsection.

Details on estimating the FPT elasticity of demand are contained in the Consumer Surplus Appendix D to this document. First assume in this case that most service at the airport is short haul domestic travel; for this kind of travel, Table 9 in the Appendix show consensus money demand elasticity (the change in quantity due to a change in fares) is -1.53. To estimate the FPT elasticity, assume this money elasticity and the price and value of time information in Table C-1. Using Formula 7 from the Appendix, the full price of travel elasticity is:

$$E_{fpt} = E_d \left(\left(\frac{P}{P + vT} \right) + \left(\frac{vT}{P} \right) \left(\frac{vT}{P + vT} \right) \right),$$

Where E_d is the money elasticity, P is the fare, v is the value of time and T is trip time, delay and schedule delay. In this example, the full price of travel elasticity is -1.51.

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 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.

Table C-1: Calculation of Induced Demand

SCENARIO INDUCED PASSENGER LEVELS						
A	B	C	D	E	F	G
Scenario	Additional Percentage Induced Over Base Case Demand	Base Case Demand (Enplanements)	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

SCENARIO VALUE OF REDUCED TRIP TIME								
A	H	I	J	J'	J''	K	L	M
Scenario	One-Way Base Case Trip Time (Minutes)	Value of Passenger Time	Value of Base Case Trip Time ((H/60) * I)	Value of Base Case Schedule Delay*	Total Value of Trip Time	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	\$47.10	\$117.75	\$9.59	\$127.34	2.9	\$2.28	\$125.06
Scenario B	150	\$47.10	\$117.75	\$9.59	\$127.34	2.7	\$2.12	\$125.22
Scenario C	150	\$47.10	\$117.75	\$9.59	\$127.34	2.5	\$1.96	\$125.37
Scenario D	150	\$47.10	\$117.75	\$9.59	\$127.34	2.0	\$1.57	\$125.77
Scenario E	150	\$47.10	\$117.75	\$9.59	\$127.34	1.5	\$1.18	\$126.16

SCENARIO VALUE OF REDUCED AIR FARE											
A	N	O	P	Q	R	S	T	U	V	W	X
Scenario	One-Way Base Case Trip Fare	Average Aircraft Operating Cost per Hour	Average Passengers per Operation	Aircraft Operating Cost Savings per Passenger ((K/60 * O) / P)	Annual Financing Cost from Investment in Year X	Annual Operating & Maintenance Cost from Investment in Year X	Higher Landing Fee and O&M Costs from Investment per Passenger ((R + S) / G)	Net Aircraft Operating Cost Savings per Passenger (Q - T)	Percent Cost Savings Passed on to Passenger	Net Fare Savings per Passenger (U * V)	One-Way Trip Fare After Investment (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

SCENARIO TOTAL TRIP COST REDUCTION (TIME AND FARE)							BEST INDUCED DEMAND ESTIMATE		
A	Y	Z	AA	AB	AC	AD	AE	AF	AG
Scenario	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 Trip Cost Due to Investment (-Z / Y)	Price Elasticity of Demand	Estimated Percentage Induced Demand (AB * AC)	Discrepancy Estimated Induced Relative to Assumed (AD - B)	Closest Match	Actual Investment Case Time Saving per Operation (minutes)
Scenario A	\$247.75	\$3.14	\$244.61	-1.27%	-1.51	1.92%	1.92%		
Scenario B	\$247.75	\$2.90	\$244.85	-1.17%	-1.51	1.78%	-0.22%	*	2.7
Scenario C	\$247.75	\$2.67	\$245.08	-1.08%	-1.51	1.63%	-2.37%		
Scenario D	\$247.75	\$2.08	\$245.67	-0.84%	-1.51	1.27%	-4.73%		
Scenario E	\$247.75	\$1.50	\$246.25	-0.60%	-1.51	0.91%	-7.09%		

* Average seat size is 50 and average frequency per day is 4. See table 6 in the Consumer Surplus Appendix for details.

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.⁹⁸ Column J is the product of columns I and H and represents the time value of the total base case trip. Column J' is estimated schedule delay (the value consumers assign to frequency of service and the number of seats available to them). The total trip time including schedule delay is shown in Column J''. 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 2019 dollars. Average trip fare can be calculated from DB1B data, while average actual trip time (schedule plus actual delay) is available from ASPM data... Column O is the variable operating cost for the average aircraft using the airport (see Section 10.5.5.1 and the Simulation Appendix E. for methods to estimate these cost savings based on where they occur). 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.⁹⁹ 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

⁹⁸ [Benefit-Cost Analysis](#)

⁹⁹ 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).

column Q (aircraft operating cost savings per passenger) to yield a net cost savings to the aircraft operator per passenger.

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).¹⁰⁰ 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 Full Price of Travel Elasticity of Demand

Column AC introduces the full price of travel (FPT) elasticity of demand for air travel—a key parameter for determining which of the simulated induced demand levels is the correct equilibrium demand level. FPT elasticity of demand for air travel is a measure of air travelers' response to variations in the cost of air travel including the value of time. 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 Exhibit C-1). For more information full price of travel elasticities, please see Appendix D. on Consumer Surplus.

C.3.4.2 Application of Full Price of Travel 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

¹⁰⁰ 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.

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 an 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.

Table C-2: 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 without 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	\$45,630	\$4,608,630	\$4,901,000

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 Consumer Surplus which is the product of the decrease in price ($P-P^*$) multiplied by the increase in the number of users (Q^*-Q) multiplied by one-half.¹⁰¹ From the context of Exhibit 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-2. Column B of Table C-2 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-2 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-2. Benefits in column B of Table C-2 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-2. 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-2.

As can be seen when comparing columns G and I of Table C-2, 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 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-3.

¹⁰¹ See the Consumer Surplus Appendix for further details on this concept.

Table C-3: Impact of Induced Demand on Costs

A	B
Capital Cost	Does not vary with passenger volume
O&M	\$102,000

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.

Appendix D: Consumer Surplus and Economic Decision-Making

D.1 Overview

This appendix reviews key authorities providing guidance on the evaluation of federal government programs including AIP grants to airports using benefit-cost analysis. It then describes concepts and methods to undertake the analysis, including the key concepts of consumer and producer surplus and the full price of travel.

D.2 Authorities

The Office of Management and Budget (OMB) uses Circulars to communicate relevant information and instructions to executive departments, including the Department of Transportation and FAA. The key document concerning how to evaluate whether a program or project makes sense is OMB Circular A-94 (amended in 1992)¹⁰² Key instructions include the following:

*Benefit-cost analysis is recommended as the technique to use in a formal economic analysis of government programs or projects. Cost-effectiveness analysis is a less comprehensive technique, but it can be appropriate when the benefits from competing alternatives are the same or where a policy decision has been made that the benefits must be provided.*¹⁰³

Net present value is the preferred tool for making the evaluation.

*The standard criterion for deciding whether a government program can be justified on economic principles is net present value—the discounted monetized value of expected net benefits (i.e., benefits minus costs). Net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Programs with positive net present value increase social resources and are generally preferred. Programs with negative net present value should generally be avoided*¹⁰⁴

For federal programs social benefits and costs are the appropriate measures for the analysis. Analyses should include comprehensive estimates of the expected benefits and costs to society based on established definitions and practices for program and policy evaluation. Social net benefits, and not the benefits and costs to the Federal Government, should be the basis for evaluating government programs or policies that have effects on private citizens or other levels of government. Social benefits and costs can differ from private benefits and costs as measured in the marketplace because of imperfections arising from: (i) external economies or diseconomies where actions by one party impose benefits or costs on other groups that are not

¹⁰² [Circular No. A-94 Revised](#)

¹⁰³ Ibid page 3

¹⁰⁴ Ibid page 3

compensated in the market place; (ii) monopoly power that distorts the relationship between marginal costs and market prices; and (iii) taxes or subsidies.¹⁰⁵

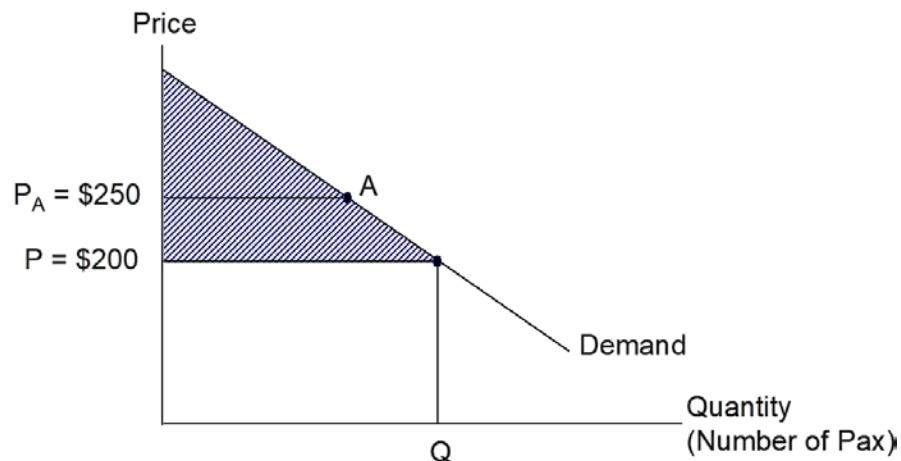
The OMB goes on to suggest that benefits be measured using economic principles based on the consumer's willingness to pay versus the market price, which is the definition of consumer surplus.

*The principle of willingness-to-pay provides an aggregate measure of what individuals are willing to forego to obtain a given benefit. Market prices provide an invaluable starting point for measuring willingness-to-pay... When it can be determined, consumer surplus provides the best measure of the total benefit to society from a government program or project.*¹⁰⁶

D.3 Consumer and Producer Surplus

In this section the concepts of consumer and producer surplus are introduced conceptually. The next sections discuss how the concepts can be applied to airport infrastructure projects. Consumer surplus is the measure of the net benefits consumers gain by buying a product or service in a market. Consider the market demand curve shown in Exhibit D-1, which is made up of many passengers and traces out their willingness to pay. At a price of \$200, passenger A is willing to pay \$250 but only has to pay the market price of \$200 and so receives consumer surplus of \$50 from taking one flight (i.e., \$250 minus \$200).

Exhibit D-1



At a price of \$200, the shaded triangle in the Exhibit D-1 is the total consumer surplus earned by all consumers in the market. This area is the sum of surplus gained by individual consumers. Some may have been willing to pay \$300 but only had to pay \$200, realizing a gain of \$100, while others may only have been willing to pay \$205, gaining only \$5. So consumer surplus captures the distribution of the maximum amounts individual consumers would be willing to pay for an airline seat.

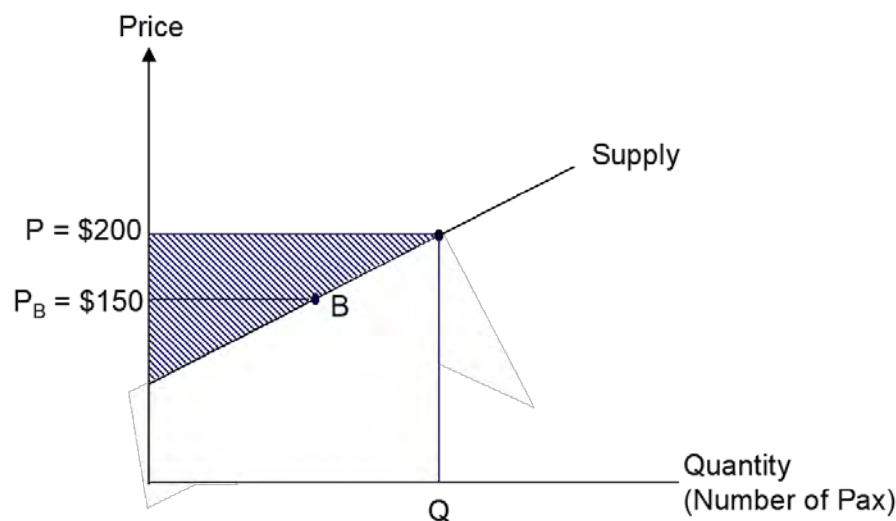
¹⁰⁵ Ibid page 5

¹⁰⁶ Ibid page 6

Producer surplus is a measure of the gain to producers in a market when they supply products or services. In Exhibit D-2, at a price of \$200, a carrier can provide a seat for \$150 but receives a market price of \$200 and so receives producer surplus of \$50 from providing one passenger a flight (i.e., \$200 minus 150).

At a price of \$200, total producer surplus in the market is the shaded area in the exhibit. Again, some airlines may be willing to supply a seat for less than \$150. For example, if a low cost carrier can supply a seat for \$100, it will gain \$100 when the market price is \$200 (\$200-\$100). Other airlines may have higher costs and be willing to offer a seat at a much higher price – say \$195, in which case their gain is only \$5. Producer surplus represents the sum of producers' willingness to supply seats in the market.¹⁰⁷

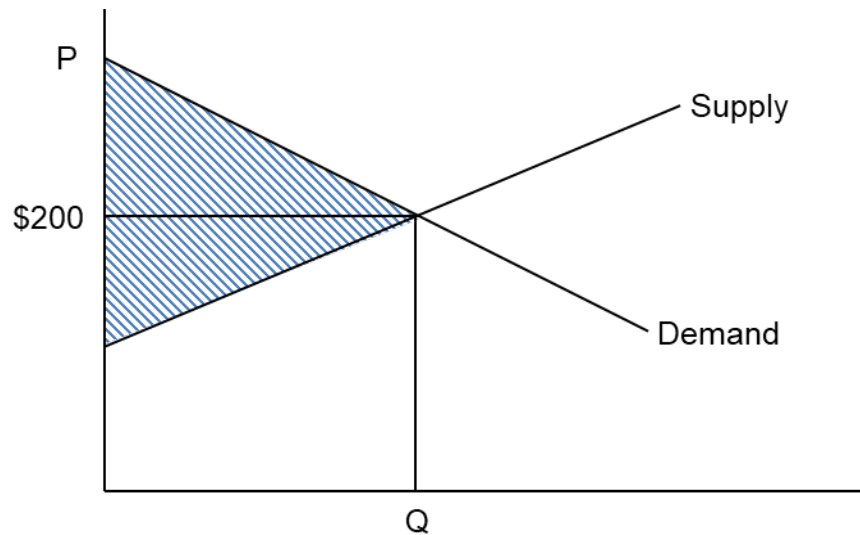
Exhibit D-2



The sum of consumer and producer surplus is total surplus or the total gain to society from the service or product. The shaded area in Exhibit D-3 represents total surplus. Both consumers and producers are better off because there is a market in airline seats. The maximum possible total surplus (highest possible gain to society) is achieved at market equilibrium. In the market equilibrium there is no way to make some people better off without making others worse off. This is what economists mean when they say markets are economically efficient.

¹⁰⁷ It is important to observe that the standard analysis presented above assumes a single market-clearing price of \$200. But a more sophisticated analysis, based on the same principles, could be developed that recognizes differentiated products with different prices. For example, the market price of a ticket from a low-cost carrier who does not offer advanced seat selection or who provides a tighter seating configuration may well be different from the market price from a traditional network carrier.

Exhibit D-3



D.4 Consumer Surplus and Airport Infrastructure

In undertaking a benefit cost analysis of an investment in airport infrastructure that may be paid at least in part by an AIP grant, the analyst is trying to answer an important question:

- Would consumer and producer benefits society-wide made possible by the infrastructure exceed all of society's costs?

This is a different question than would be asked by a private company or a consumer buying a new product or service. An individual consumer (or company) only cares whether his or her benefits exceed the costs he or she has to pay. But once federal public money is potentially part of the investment, purview of the analysis extends out to all of benefits and costs to all of society's participants because at the federal level all taxpayers are theoretically involved in paying for the project.

So, for example, suppose an airline is considering adding a flight into an airport that is congested at the scheduled time of arrival. Adding the flight will create additional delay at the airport.

D.4.1 Private Decision

- The airline would look only at its own profit opportunity: would revenues exceed variable costs (including the landing fee) sufficiently to make a larger contribution to the airline's fixed costs than any other alternative flight it might fly? It would consider its own expected delays and its costs imposed on its own existing and new flights (crew, disruption costs, and impacts on its reputation for reliability) in its calculations.
- The consumers or passengers that would take that proposed flight would consider how well it satisfied their travel needs – they would compare the price (fare), the time of day, available seats, schedule time, potential delays, and other characteristics of the flight against available alternative flights or other modes of transportation. The

- consumer would pick the proposed flight if it maximizes his or her net benefit. In effect, each consumer's willingness to pay minus the price they pay is his or her consumer surplus. The consumer will be interested in buying the service as long as the consumer surplus is positive.
- Neither the airline nor the passengers would consider the fact that the new flight might impose delay costs on other airlines or passengers. Acting privately, they would not consider any other impacts either – like increased emissions or noise in the immediate area. They would only be concerned about their own delay experience at the airport and how that impacts their own decision to fly.

D.4.2 Public Decision

Now consider the same flight from FAA's perspective. FAA is interested in projects that improve the aviation system overall by saving resources including passenger time and operator operating costs. Suppose an airport is considering building new infrastructure capacity to handle increasing traffic which is causing delays. In undertaking a Benefit-Cost Analysis for an AIP grant, FAA would want to see a BCA that considers whether the benefits to everyone in society exceed the costs to society over the life of the project. How would it do the analysis? To illustrate the differences between a Private and Public Decision, let's consider just the one additional flight mentioned above.

- The airport first would consider a Base Case without the new infrastructure where the new flight is introduced and results in added delays; the Base Case would account for all of the costs and benefits in the Private Decision plus "external effects" such as delays, noise and emissions impacts imposed on other operators, passengers and the community. The airport would calculate the net benefits (benefits minus costs) of the flight assuming no change in infrastructure.
- It would also consider a Scenario Case, where the additional infrastructure is built, and thus delays for both the new flight and all other flights would be lower. Again, the airport would consider all impacts on all market participants and the community and calculate net benefits in the scenario case.
- The analysis would then consider whether the change in net benefits (Scenario Case - Base Case) exceeds the cost of paying for the infrastructure (including both local and federal contributions) and the costs of operating and maintaining it. This analysis would be done over the life of the infrastructure, with all calculations discounted to a single year's dollars.

So the Public Decision is much broader. It accounts for all benefits and all costs, regardless of who gains the benefits or who pays the costs. Airport sponsors submitting a BCA for a discretionary grant will want to produce these broader studies.

There are two important differences between Private and Public Decisions that should be highlighted:

- The Public Decision has to account for the impacts of the proposed infrastructure project on all flights (both current and new) to properly complete the analysis. The proposed infrastructure may reduce the delays incurred by some or all current flights just as it would reduce the delays incurred as a result of the new flight.

- Building the infrastructure may effectively lower the costs to both operators and consumers. Operators may save money if they incur fewer delays at the airport. Consumers may save valuable time if there are fewer delays. So building the infrastructure may “induce” additional operations or demand at the airport. If only private benefits of new infrastructure are considered, the airport may underinvest in capacity enhancements and an optimal level of delays (taking account of effects on all consumers and operators) will not be attained.

D.5 The Full Price of Travel and Social Marginal Costs

For many AIP capacity projects, a proper benefit cost analysis will implement estimates of both the full price of travel and social marginal costs to account for changes in total surplus that may result.

- **Full Price of Travel** is a measure of the money cost (fare) plus the value of time consumed in a flight. It recognizes that consumers consider both the money price of a service offer as well as the amount of time it consumes, including whether the flight is scheduled at a convenient time and whether it is subject to potential delays.
- **Social Marginal Costs** measure the external costs of an individual action on other members of society; in capacity projects, an additional flight may cause added delays to other flights and passengers, and cause additional noise and emissions. All of these costs are relevant in a federal benefit-cost study.

D.5.1 Full Price of Travel

The full price of travel includes:

- The money fare that a consumer must pay
- The value of his or her time in transit (including both the scheduled time and any expected delays including access time delays) and the value of “schedule delay” (which is defined as the difference between the ideal time of departure/arrival for the consumer versus the actual schedule offered weighted by the probability of being accommodated on the desired flight).

The common sense interpretation of the full price of travel model is that consumers prefer to fly at a time closest to their desired departure (or arrival) time, at the lowest possible price, and in a manner that minimizes the expected time in transit, including the risk of delays and cancellations. Consumer surplus is the value of air transportation in excess of the full price of travel.

These concepts have direct relevance to evaluating airport infrastructure projects. In some cases, runway or other projects may expand capacity and flights at an airport which can reduce fares and delays, and thus the full price of travel. As a result, there will be an increase in consumer surplus from the project, which would be computed as the difference between Base Case and Scenario Case consumer surplus.

D.5.1.1 Social Marginal Cost

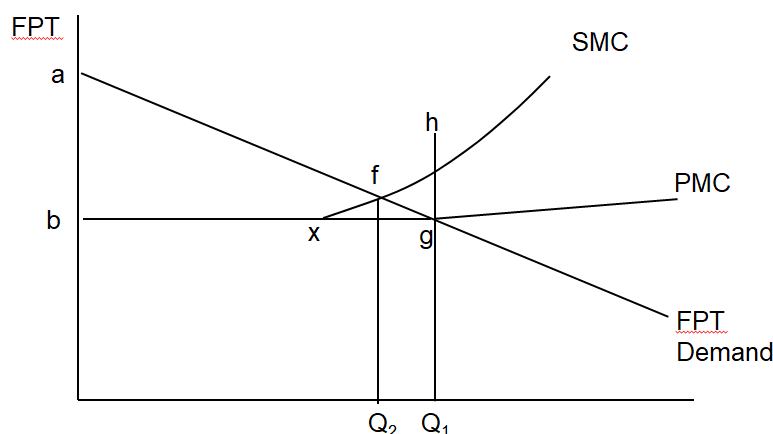
At low levels of activity, there may be no difference between private and social marginal costs of flight operations at an airport. When there are no delays, and no meaningful noise or emissions issues, the two cost measures will be identical. But for capacity projects it will often be the case that current operations are near to the capacity of the airport, which results in delays, cancellations and a general reduction in reliability of flights. In such cases, private and social costs will diverge.

So for example, a project may be planned to enhance the capacity of the airport in order to meet expected future demand. In the Base Case, delays would be increasing as new flights are added. In the Scenario Case (with the new capacity) the level of delays would be less than in the Base Case. Each individual operator will take account of its own expected delays in both cases, but will not take account of the delays they impose on other operators and passengers. For a benefit cost analysis, it is appropriate to add up all of the delay costs on all operators. As was noted above, the delay impacts on passengers are accounted for in the full price of travel.

D.5.1.2 Surplus with the Full Price of Travel and Social Marginal Costs

Exhibit D-4 puts all of the preceding concepts into play in a benefit cost analysis framework. This exhibit represents the Base Case for a capacity project. The full price of travel is shown on the vertical axis. The demand curve reflects the full price of travel (including consumer time). Also shown on the graph are the private and social marginal cost curves (PMC and SMC). These curves are identical at lower levels of output when there is no congestion at the airport. But, beyond some level of output, both PMC and SMC increase as output increases due to delays. The PMC and SMC curves diverge at point x because operators ignore the delay costs they impose on others.

Exhibit D-4



In the Base Case in Exhibit D-4, the observed number of operations (which can be translated into passengers) is at Q1, where the private marginal cost curve intersects the full price of travel. At this level of output, consumer surplus under the full price of travel demand curve is represented by the area abg.

In this example, we have made some additional assumptions about the supply curve which will often be convenient in these studies. We have assumed the industry is competitive, which means the private supply curve is equal to the private marginal cost curve. That is, operators offer their services at marginal costs which include their own delay costs but none of the costs they impose on other operators.¹⁰⁸ In effect, we have assumed that because the industry is competitive, producer surplus has been competed away and realized by consumers.

Notice however that the private and social marginal costs curves diverge, and at equilibrium output of Q1 social marginal costs are much higher than private marginal costs, and also far exceed consumers' willingness to pay as measured by the full price of travel demand curve. The size of these external costs is equal to the area fhg.

If this market were perfectly regulated, output would be set at Q2, where the social marginal cost curve intersects the full price of travel demand curve. At this level of output, the price would just equal the social costs including external delays.

But in a market economy, the external delay costs would not be accounted for by private actors. So in the Base Case, net total surplus would equal consumer surplus minus the external delay costs at Q1, calculated as abk-fhg.

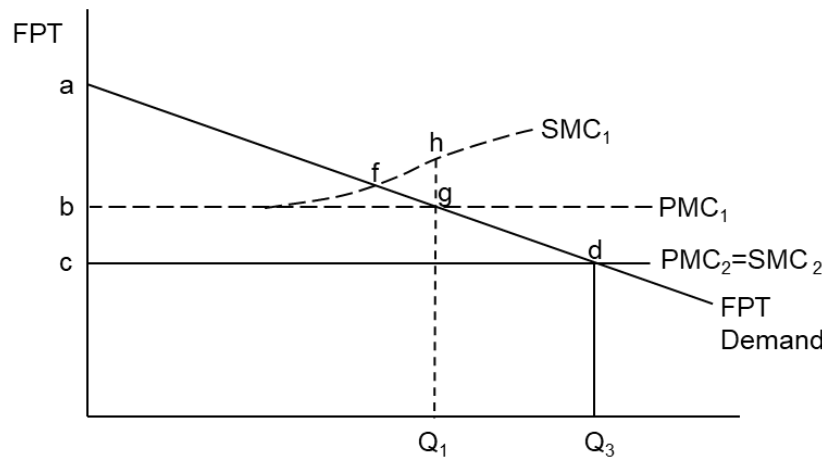
Exhibit D-5 shows an example of a Scenario Case which includes a project to enhance capacity at the airport.

The project causes both the private and social marginal cost curves to shift down to PMC2 and SMC2, reflecting a decrease in delays at the airport. This exhibit is drawn to entirely eliminate the external delays so that private marginal costs PMC equal social marginal costs SMC at the market-clearing price c.¹⁰⁹ The new equilibrium quantity is Q3. Scenario consumer surplus is the area acd, and there are no external costs at the Q3 equilibrium. We have assumed the producer surplus has been competed away. So the total surplus when the capacity project is completed would equal consumer surplus, or the area acd.

¹⁰⁸ Technically we can observe operator costs at Q1, which will include own delay impacts. At lower levels of activity, the PMC curve may be lower. So PMC would be horizontal at very low levels of activity and then turn up at some point. In some cases, this complication may have to be accounted for in the analysis. Here we do not address it to keep the discussion less technical.

¹⁰⁹ Eliminating all delays and related costs may not be economically appropriate. An optimal level of delay would occur where the (social marginal costs) SMC equals incremental social benefits.

Exhibit D-5



To make a decision about whether it makes sense to build the capacity project, the analyst would compute the change in benefits for each year of the project's life and see if the difference exceeds the cost to build, operate and maintain the project over its life. All measures would be discounted to today's dollars.

In the example, the net change in benefits due to the project is:

$$\text{Scenario Net Benefits (acd)} - \text{Base Case Net Benefits (abg-fhg)}$$

This is equivalent to the sum of the areas $bcdg + fhg$. If these benefits, computed each year and discounted, exceed the discounted present value of the all money costs¹¹⁰ of the project over its life, the capacity project would have a net benefit to society.

D.6 Undertaking the Analysis

This section discusses a possible way to undertake an analysis of an airport capacity project. Ultimately the airport sponsor will have to decide on the level of detail and the resources to expend on the analysis. The following is based on past FAA benefit cost studies of the slot rule at New York Airports.¹¹¹

D.6.1 Level of Aggregation

It is important that the analysis accurately portray the impacts of the proposed project. In some cases, projects may make it possible for airports to serve larger aircraft which may in turn alter the relative share of operations among aircraft types. Or, a project may allow the airport to serve

¹¹⁰ In some cases, a project may require moving or retiring other facilities and/or operations; or there may be delay or other costs imposed on users during construction. All such costs are to be included in the BCA, which must account for all of society's benefits and costs.

¹¹¹ See for example: FINAL REGULATORY EVALUATION CONGESTION MANAGEMENT RULE FOR JOHN F. KENNEDY INTERNATIONAL AIRPORT AND NEWARK LIBERTY INTERNATIONAL AIRPORT (September, 2008)

more distant cities on a non-stop basis with certain aircraft types. In such cases, the analysis should be disaggregated to a level suitable to evaluate the changes in surplus among operators at the airport.

For example, in the New York slot cases, analysis was conducted at the non-stop segment level of operations (primarily city-pairs served by airlines) distributed across up to five different combinations of airline/aircraft types: Low Cost Carrier jet airline, Legacy (hub) jet airline, turboprop regional airline, jet regional airline and international airline. The analysis also developed estimates for unscheduled passenger operations.¹¹²

Distinguishing between aircraft and operator types may be particularly important at highly congested facilities. Consumer surplus is the value of air transportation to the consumer in excess of the full price of travel. Although it is not always the case, larger aircraft would tend to exhibit more consumer surplus per operation because there are more passengers on-board who tend to fly longer distances, expend more time traveling, and pay more for the service, than on a smaller aircraft. Smaller aircraft will tend to exhibit less consumer surplus per operation for the same reasons and in addition, to the extent smaller aircraft are used for shorter haul flights, their use may be less advantageous to consumers at a highly delayed airport with high cancellation rates. Consumers can more easily elect to take other forms of transportation, such as rail, in shorter haul markets if they are confronted with less reliable air service.

D.6.2 Example for Conducting a Benefit Cost Project

This example is not meant to convey a precise method for undertaking a benefit cost study of an airport capacity project. The sponsor, in consultation with the FAA, will be responsible for selecting the appropriate method to evaluate the project at hand. The following is based on FAA's various analyses of the slot rule in New York.

The analysis is carried out at the segment level, i.e., each non-stop destination from the subject airport is considered to be a separate market. To implement the analysis, estimates are needed for the full price of travel and social marginal costs.

The full price of travel (FPT) in each case is defined as:

FPT = money fare + value of scheduled time in transit + value of airport delay and cancellations
+ value of schedule delay

The analysis is conducted for a sample schedule day; data are available to estimate each term in the above equation:

- Money fare: Average segment fare for each of the four types of service from DOT DB1B data
- Average time in transit: Weighted average block time from the sample day
- Expected airport delay and cancellations

¹¹² No specific analysis was undertaken on the impacts on freight operators because many of their operations at the time took place in the middle of the night (when capacity was not in short supply).

- Value of travel time applied to transit time, delay and cancellations: US DOT: *Revised Departmental Guidance on the Valuation of Travel Time in Economic Analysis (2014)*; Passenger value of time is for “all purposes,” reflecting a mix of business and leisure travel in the New York area, valued at \$43.70 per hour¹¹³
- Schedule delay: Computed from the OAG data using a method described below
- Value of time in schedule delay: \$2.70 per hour from a study by Morrison and Winston

In addition, the analyst would need other data to implement the analysis of surplus:

- For capacity projects, estimated all weather delay per operation developed from simulation or queuing models for both Base and Scenario cases (see Appendix E.)
- For capacity projects, estimated cancellation rates at different levels of operation in both the Base and Scenario cases
- Airline operating costs from US DOT Form 41 data
- Airline schedules from the Official Airline Guide (OAG), Innovata or similar source
- Airline segment load factors from US DOT Form T100 data
- Airline segment fare data from US DOT Form DB1B
- Unscheduled operator costs by aircraft type from published sources such as Conklin & deDecker

For each segment, there are data on the level of service by the five types of aircraft operations (legacy, LCC, RJ, turboprop, and international). These data are aggregated up to the segment level to estimate an average money fare, passengers per day each way, measures of travel time, airport delay, and schedule delay. The resulting sample day full price of travel and number of passengers together represent a point on the segment full price of travel (FPT) demand curve. One additional point is required to identify the two demand curves (FPT and money) in mathematical terms. To do this, one additional roundtrip with the average load (for each type of service) on the segment is assumed. The FAA’s suggested money elasticity (see below) is applied to estimate the change in the money price at the increased level of service. This procedure provides another point on the (assumed) linear money demand curve for the flight segment. With this information, the FAA recalculates the other components of the full price of travel and thus another point on the FPT curve. Finally the FAA calculates the intercept point for the FPT demand curve by assuming it is linear and, with the fully identified function, estimates the total consumer surplus for the segment (the so-called welfare triangle).

In order to attribute consumer surplus to the different types of flying on a segment, the FAA calculates average segment consumer surplus per passenger. Then the FAA multiplies average consumer surplus by the number of passengers per flight for each type of flying to estimate consumer surplus per flight for a segment. For each type of flying, the FAA calculates total consumer surplus on a segment by multiplying by the number of flights.

¹¹³ Guidance may be periodically updated. [Revised Guidance on Valuation of Travel Time in Economic Analysis](#)

D.6.3 Estimating Schedule Delay

One of the important differences that needs to be accounted for between the cases is the effect of frequency and average seat size on consumer benefits. In general, consumers prefer more frequent flight opportunities and larger aircraft so that they can more easily accommodate their own schedules. For example, some consumers value legacy carrier operations at JFK and EWR highly because legacy carriers fly relatively large aircraft with high frequency. In contrast, LCC's fly larger aircraft on average but much less frequently, perhaps in part because they have less access to facilities. Economists measure the value of frequency using a concept termed "schedule delay." The idea is that consumers can reduce schedule delay when there are more frequent flights and more seats. For example, a businessperson can more precisely plan a business trip when there are more opportunities to fly to a distant city to make a meeting at a particular time. In contrast, when service is relatively infrequent, the traveler might incur wasted time or even have to stay overnight to accommodate a meeting schedule. Personal travelers also benefit from increased frequency.

For valuation purposes, schedule delay is broken into two components – frequency delay and stochastic delay. Frequency delay measures the average difference between a passenger's preferred departure time and the closest scheduled departure time. Frequency delay (FD) in minutes for a given market segment is parameterized as:

$$FD = 92F^{-0.456}$$

where F is daily flight frequency.

Stochastic delay measures the expected delay due to the probability that a passenger would not be able to obtain a seat on his most preferred departure because of capacity limitations of the aircraft. Stochastic delay (SD) is parameterized as:

where F = daily flight frequency
 P = passengers per flight and S = seats per flight

The sum of frequency delay and stochastic delay yields total schedule delay. Sample estimates of schedule delay from these equations for various values of F and S are shown below in Exhibit D-6 below (using the observed average JFK system load factor in 2007 of 68.6 percent):

Exhibit D-6: Equation Estimates of Schedule Delay (minutes)

Daily Frequency	Average Seat Size				
	50	75	100	125	150
4	213	149	120	103	92
6	150	108	88	77	69
8	118	86	71	63	57
10	98	72	60	54	49

Schedule delay is valued at \$2.70 per hour based on estimates developed by Morrison and Winston cited earlier.

D.6.4 Example of Surplus Calculations

The following example illustrates one way to estimate consumer and producer surplus in an economic model. The illustration is for a single market segment Birmingham, AL (BHM) to LaGuardia Airport in New York circa 2007. At that time there were four non-stop flights with small RJ aircraft in the market. In an actual BCA, the analyst would have to consider impacts in all scheduled market segments and on unscheduled operators.

The example uses data from sources discussed previously. To demonstrate the methodology on one market segment, surplus is calculated twice: once with then existing average delays of 15.7 minutes per operation and expected cancellation rates of 5.7%, and then a second time assuming zero delays and zero cancellations. All of the calculations are discussed in the table itself.

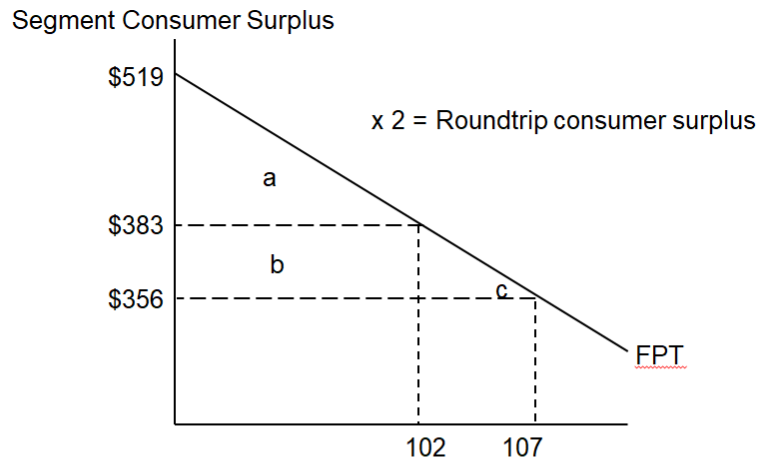
D.6.5 Consumer Surplus

The analysis assumes a linear demand curve. One point on the money demand curve is the actual observed average fare and average daily passengers. To make the analysis operational, the example assumes one additional flight per day between BHM and LGA. Because a single additional flight would not affect delays and cancellations appreciably, these are assumed to remain constant. It assumes that passengers grow in proportion to flights and the average fare falls based on the assumed elasticity of demand of -1.317. The resulting two points on the money demand curve can be used to:

- Estimate the price intercept of the linear demand curve
- Estimate the slope of the linear demand curve
- Create the full price of travel (FPT) demand curve, by adding the value of scheduled time in transit plus the value of airport delay and cancellations plus value of schedule delay to the money fare for the two points on the money demand curve; as a result the FPT demand curve can be fully specified (intercept and slope).

The analysis is illustrated in Exhibit D-7. The graphic shows the one-way consumer surplus estimates using the full price of travel demand curve. In the Base Case (observed equilibrium), the FPT is \$383 on the segment BHM-LGA, while daily passengers per day each way are 102. If delays and cancellations were eliminated, the FPT would fall by the amount of avoided delay and cancellation time-related costs resulting in a FPT equal to \$356. At a lower FPT, more passengers would fly (107). The consumer surplus is estimated as the area of a triangle defined by the price intercept on the demand curve and the average full price of travel, as well as the average number of passengers per day in the two cases. In order to obtain roundtrip estimates, consumer surplus is multiplied by two.

Exhibit D-7



$$\begin{aligned}
 a &= \text{Base Case Consumer Surplus} \\
 &= \frac{1}{2} (\$519 - \$383)(102) \\
 &= \$6,959 \\
 2 \times a &= \text{Roundtrip Base Case Consumer Surplus} = \$13,898 \\
 \\
 a + b + c &= \text{Scenario Case Consumer Surplus} \\
 &= \frac{1}{2} (\$519 - \$356)(107) \\
 &= \$8,769 \\
 2 \times (a+b+c) &= \text{Roundtrip Scenario Case Consumer Surplus} = \$17,538 \\
 \\
 b &= \text{added one-way surplus for Incumbent Travelers} \\
 &= (\$383 - \$356)(102) = \$2,758 \\
 c &= \text{added one-way surplus for New Travelers} \\
 &= (.5) (\$383 - \$356) (107-102) \\
 &= \$73
 \end{aligned}$$

The exhibit also shows how to separate the incremental benefits of eliminating delays and cancellations between incumbent (existing) passengers and new passengers. All of the details of the calculations, including defining the money and full price of travel demand curves are shown in Exhibit D-8.

D.6.6 Impact on Airlines

This analysis also includes estimated producer surplus impacts. For each type of flying (legacy, LCC, regional jet, turboprop, international, and cargo operations) carrier revenues are computed based on the estimated number of passengers served and the money fare (net of passenger taxes, segment and security fees, and Passenger Facility Charges). For present purposes, carrier costs include scheduled aircraft variable block-hour costs, airport delay costs, and cancellation costs. Variable block-hour costs are taken from the FAA "Economic Values" study completed in 2007.¹¹⁴ Estimated airport delay costs are computed as average delay minutes per operation

¹¹⁴ Updated values are available from the FAA:
[Benefit-Cost Analysis](#)

multiplied by the average variable block-hour costs summed across all operations and cancellation costs. In estimating delay costs, it is important to distinguish between costs incurred in the air, taxiing or at the gate. For example, one study suggests that fuel consumption during taxiing is roughly one-third the average rate in flight.¹¹⁵ In the analysis, carrier own delay costs are assumed to be 2/3's of average variable costs.

Cancellation costs are difficult to measure because some portion of crew and other costs may still be incurred, and downstream operations may be affected. Ignoring downstream effects, one can estimate a ceiling on such costs based on the delays discussed above. Clearly, a carrier will cancel a flight only when the net costs of doing so are less than those that would be incurred by operating it and accepting the consequent delays. So a ceiling on (own-airport) cancellation costs can be estimated by taking the difference between (1) net operating profits with no cancellations (and therefore very high delay costs) and (2) net profits with cancellations. For this analysis, incurred cancellation costs were assumed to be 50 percent of the profit estimate difference. This is likely to be a conservative estimate of cancellation costs since it does not include downstream effects.

D.6.7 Impact if Delays and Cancellations Were Eliminated

The last column reports what consumer and producer surplus would be if there were no delays or cancellations in the BHM-LGA segment. If these impacts were eliminated, the full price of travel would drop from \$383 to \$356. The entire reduction would be due to elimination of delays and cancellations. At this lower full price of travel, more people would fly on each segment. This would be a movement along the full price of travel demand curve. Segment passengers would go from 102.3 to 107.7 passengers. As a result, daily consumer surplus would increase from \$13,898 to \$17,538.

Producers would also benefit. They would avoid their own delay costs and they would earn additional revenue from the additional passengers. Daily airline profits would increase from \$13,543 to \$18,299. All of the consumer and producer surplus estimates are evaluated on a round trip basis. Exhibit C-7 illustrates the consumer surplus estimates graphically.

The annual Total Surplus is estimated to be \$3.06 million, consisting of the difference in consumer surplus and profits with and without delays. In theory, passengers and airlines in the BHM segment would be willing to pay up to this amount in a year to avoid the delays at LGA. The same type of analysis would be conducted for each market segment and then added up. The benefits would be projected over time and then compared to the cost of whatever policy or project would eliminate delays and cancellations. Both benefits and costs would be evaluated in a net present value framework. When the discounted present value of benefits exceed the net present value of costs, the policy or project would be justified.

¹¹⁵ Ryerson, Hao, Kang and Hansen: *Fuel Burn Impacts of Taxi-out Delay and their Implications for Gate-hold Benefits* (Nextor report)

Exhibit D-8: BHM-LGA Segment Analysis

[illegible]

Note for clarity a column for international operations is suppressed in LGA markets; Canadian operations were assumed to be domestic.

D.6.8 Money and Full Price of Travel Elasticities of Demand

Developing estimates of consumer surplus requires use of money and full price of travel elasticities of demand.

D.7 Money Elasticities of Demand

In the prior version of this Guidance (1989) FAA provided some indicative money elasticities based on a survey of the literature. Since then there have been more recent surveys of the literature by Gillen et al¹¹⁶, IATA¹¹⁷ and Price Waterhouse¹¹⁸. A summary of the FAA and three other survey results is shown in Exhibit D-9.

Exhibit D-9

	Domestic		Transatlantic		Trans Pacific		Cargo
	Short Haul	Long Haul	Short Haul	Long Haul	Short Haul	Long Haul	
FAA Leisure	-2.00	-1.00					
Gillen Leisure	-1.52	-2.18					
Average Leisure	-1.76	-1.59					
FAA Business	-1.60	-0.80					
Gillen Business	-1.05	-1.35					
Average Business	-1.33	-1.08					
Average All	-1.54	-1.33					
IATA	-1.53	-1.40	-1.85	-1.68	-0.92	-0.84	
Price Waterhouse							

The literature review consistently shows that the money elasticities on short-haul routes are higher than on long-haul routes. In part, this reflects the opportunity for inter-modal substitution on short haul routes (e.g., travelers can switch to rail or car in response to air fare increases). Business demand is generally less elastic than leisure demand because leisure travelers may have more scope to alter destinations, timing and other factors related to travel not available to business travelers.

In US domestic markets, the results of the studies are very consistent. The IATA study provides some visibility on demand in international markets. Absent other information, an analyst might use the IATA Trans-Atlantic and Trans-Pacific elasticities as indicative of these markets. Note that the higher elasticities in the Trans-Atlantic market may reflect the greater level of maturity of these markets at the time the studies were conducted, and the higher share of leisure travelers to Europe. Analysts should consider these factors when selecting money elasticities. Finally, the Price Waterhouse review found a cargo money elasticity of -1.02.

D.7.1 Full Price of Travel Elasticities in Passenger Markets

This section discusses how the elasticity of the full price of travel can be estimated based on the

¹¹⁶ Gillen, David; William Morrison and Christopher Stewart (2002). Air Travel Demand Elasticities: Concepts, Issues and Measurement. Final Report. Waterloo, Ontario: Wilfrid Laurier University. (Report prepared for the Department of Finance, Canada)

¹¹⁷ IATA: Estimating Air Travel Demand Elasticities (2007)

¹¹⁸ Price Waterhouse Coopers - Aviation Emissions and Policy Instruments, Final Report (2005)

elasticity of money demand and other variables described earlier. As was noted above, the full price of travel consists of the money price plus the value of several travel time metrics. Note that the full price of travel elasticity of demand (E_f) is the weighted sum of the money price elasticity of demand plus the elasticity with respect to time savings (E_t), where the weights are the share of the full price of travel:

$$(1) \quad E_f = E_d (P / (P + vT)) + E_t (vT / (P + vT))$$

In equation (1), P is money fare, v is the value of time and T is total trip time (money fare + value of scheduled time in transit + value of airport delay and cancellations + value of schedule delay). Exhibit C-9 provides estimates of airline-own price elasticity of demand E_d —the percentage change in output Q due to a percentage change in P (the money fare). This same change in money fare represents a lesser percentage of the full price of travel ($P + vT$), but results in the same change in output Q . This means that:

$$(2) \quad (\text{change } P) / P * E_d = (\text{change } P) / (P + vT) * E_f$$

Rearranging terms, we find that

$$(3) \quad E_d = (\text{change } P) / (P + vT) * E_f$$

Also note that a change in the value of time (vT) on the route would have the same effect on Q whether it is examined solely using E_t (elasticity of time) or E_f (the elasticity of full price of travel):

$$(4) \quad (\text{change } vT) / vT * E_t = (\text{change } vT) / (P + vT) * E_f$$

Again rearranging terms:

$$(5) \quad E_t = (\text{change } vT) / (P + vT) * E_f$$

Solving for E_t using (3) and (5):

$$(6) \quad E_t = E_d (vT / P)$$

So the full price of travel elasticity E_f will be (substituting (6) into (1)):

$$(7) \quad E_f = E_d (P / (P + vT)) + E_d (vT / P) (vT / (P + vT)) \\ = E_d ((P / (P + vT)) + (vT / P) (vT / (P + vT)))$$

It is clear from (7) that the full price of travel elasticity (E_f) will depend on two factors:

- The money elasticity (E_d)
- The relative importance of the money price (P) and the value of the time metrics (vT) outlined earlier

D.8 Assumptions about the Demand Curve

A linear demand curve was assumed in the example in the BHM-LGA market above. On the money demand curve, an analyst observes a price/ quantity equilibrium in the market, and then estimates another price/ quantity equilibrium assuming an appropriate elasticity. This allows the analyst to fully specify the demand curve and carry out the analysis. To derive the full of price of travel demand curve, the analyst adds the value of time metrics described earlier to the money demand curve. The full price elasticity can be estimated using the methods described immediately above.

In some cases where there are anticipated to be relatively small movements along the full price of travel demand curve, the analyst may choose to assume a constant elasticity demand curve. A constant elasticity demand curve is illustrated in Exhibit D-10

Exhibit D-10

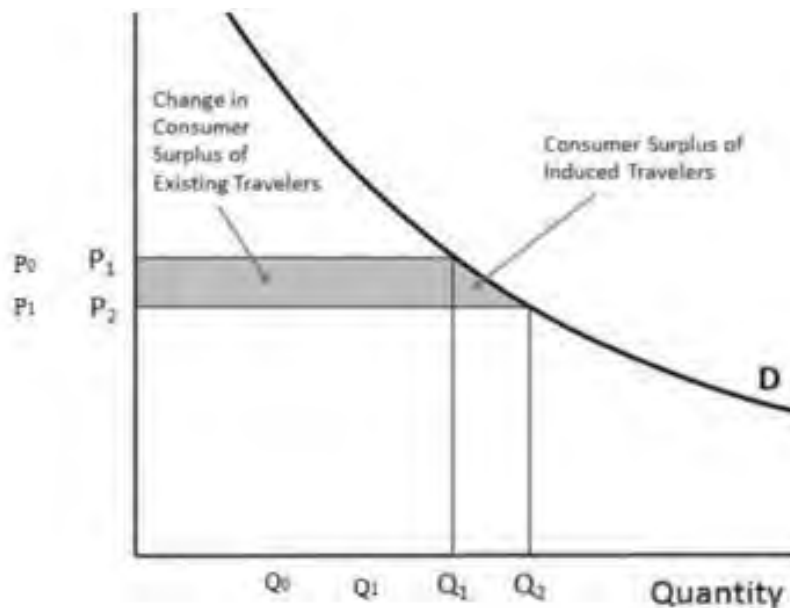


Exhibit D-10 shows a movement along the full price of travel demand curve similar to the one shown in Exhibit C-8, except now the demand curve is non-linear and has a constant elasticity. The change in consumer surplus (due to change in the full price of travel from P_0 to P_1) can be directly calculated using the following formula:

$$\text{Change in Consumer Surplus} = -\frac{P_0 Q_0}{(1 + \epsilon)} \left[\left(1 + \frac{\Delta P}{P_0} \right)^{1 + \epsilon} - 1 \right]$$

where ϵ is the elasticity of demand, P_0 and Q_0 is the observed equilibrium and ΔP is $(P_1 - P_0)$.

D.9 Induced Demand

The methods described in this appendix are designed to evaluate the benefits to consumers and

producers of a capacity project. The very nature of the demand curve is to describe the relationship between full prices of travel and output levels. When time related costs (due to delays or other time related factors) decline, more demand will be induced. So for example a new runway project might expand the capacity of the airport, reduce delays and thus induce a movement along the full price of travel demand curve.

Inevitably there will be some uncertainty about how much output will change as a result of the project. This is especially the case because an infrastructure project has to be evaluated using projections of demand over the life of the asset (usually 20 years). If a project makes a substantial change in the opportunities to fly at the airport, it may be the case that the forecast in the Base Case will diverge from the Scenario Case. Following are the factors that might be considered:

- **Induced Passenger Demand due to Time Savings:** Part of this uncertainty relates to how consumers will behave in reaction to the project, which the full price of travel model captures well. In other words, each year the consumer surplus analysis will capture the change in demand due to the lower full price of travel made possible the capacity project.
- **Induced Additions to Output Due to Lower Costs:** When capacity projects substantially lower the operating costs of operators, operations may grow faster than in the Base Case. Examples might include improvements that (1) make longer range flights possible, (2) substantially lower operating costs due to avoided delays, (3) accommodate new carriers or other operators, etc. The sponsor should consult with FAA when adjusting the forecast for added operations in the Scenario Case beyond those implied by the full price of travel demand curve.

Appendix E: Interpreting Simulation of Aircraft Operations at Airports for Use in Benefit-Cost Studies

This appendix describes fast time simulation models of capacity and delay of the airfield—primarily runways and taxiways. Improvements to these facilities are a primary focus for most Letter of Intent (LOI) applications requiring detailed benefit-cost studies. The following is meant to help an economics analyst contribute to and interpret the simulation work, which usually will be undertaken by a specialist. Note, APP-400 maintains the primary source for simulation guidance applicable to airport capacity projects.

Simulation models produce estimates of aircraft delays in a Base Case (without the improvement) and a Scenario Case (with the improvement). An important feature of simulation models is the ability to focus on specific airport features which may contribute to delays; this allows the economics analyst to focus on whether planned improvements will reduce delays experienced by aircraft and passengers, or if instead if a project would transfer the choke-point from one part of a facility to another as is often the case.

E.1 Outcomes of Simulations for Benefit Cost Analysis

Before describing simulation models in more detail, it is useful to review how they are used in benefit-cost studies. Usually a capacity enhancing project—e.g., a new runway or extended runway, or high speed runway exits—is the primary issue addressed in the BCA. As a result of the enhancement, average delays in the Scenario Case are typically lower than in the Base Case, which results in benefits to passengers (time saved) and aircraft operators (avoided operating costs). The simulation model provides a way to estimate the realized benefits using current and forecast future operations scenarios. A minimum of three and preferably four distinct analysis years are represented in the analysis, with schedules for a representative day input in the model for each year. Multiple assumptions are required to run the models, which are discussed below. For the economics analyst, the primary outputs of the model are estimated average annual all-weather (AAAW) delays to aircraft in the Base and Scenario Cases. AAAW delays are weighted averages taking account of a number of factors summarized in Exhibit E-1.

For illustrative purposes, Exhibit E-1 shows only two runway configurations. Complex airports will normally have more than two configurations that are used frequently, which might have to be accounted for to adequately model the proposed infrastructure changes. AC 150/5060-5 requires that configurations with more than 2% of operating use must be accounted for in the capacity analysis. However, this does not require simulation of every configuration; rather historic called rates used in a configuration can be used to estimate delays. Impacts due to convective weather and winter operations (deicing) should be accounted for in the configuration weighting, even if they are not modeled directly.

For the purposes of the BCA, the delays calculated need to be for the average annual day (AAD) rather than average day peak month (ADPM). Since simulation is often conducted using ADPM during facility planning, interpolation between multiple years of data is used to calculate

representative delays on the AAD. Note AAD input is also normally developed for NEPA analyses.

Exhibit E-1: Average Annual All Weather Delay

Average Annual All Weather Delay

Base Case or Scenario Case

Simulation Year; Representative Day

Arrival Airspace, or Departure Grand Delay or

Average Delay per Operation

		VMC	IMC
Runway Configuration 1	x%	Y%	X%
Runway Configuration 2	(1-x)%		
VMC	a%	a%	b%
IMC	b%		
AAAW Delay: VMC; IMC			
AAAW Delay			

Individual runs of the simulation model may have to be made to account for several factors. At a minimum, runs would be made for each analysis year (using a representative day) for both the Base and Scenario cases. Typically, the model will separately report arrival delays, departure delays and average delay per operation. In most FAA BCA's, the simulation will have to account for runway configuration (e.g., east flow vs west flow), and weather condition (VMC vs IMC). However many runs are made, the AAW is calculated as a operationally weighted average of the runs.

The economics analyst, in consultation with the simulation specialist, should propose only the number of runs needed to capture the effects of the proposed infrastructure changes. Simulations can be expensive to create and run so resources should be preserved where feasible.

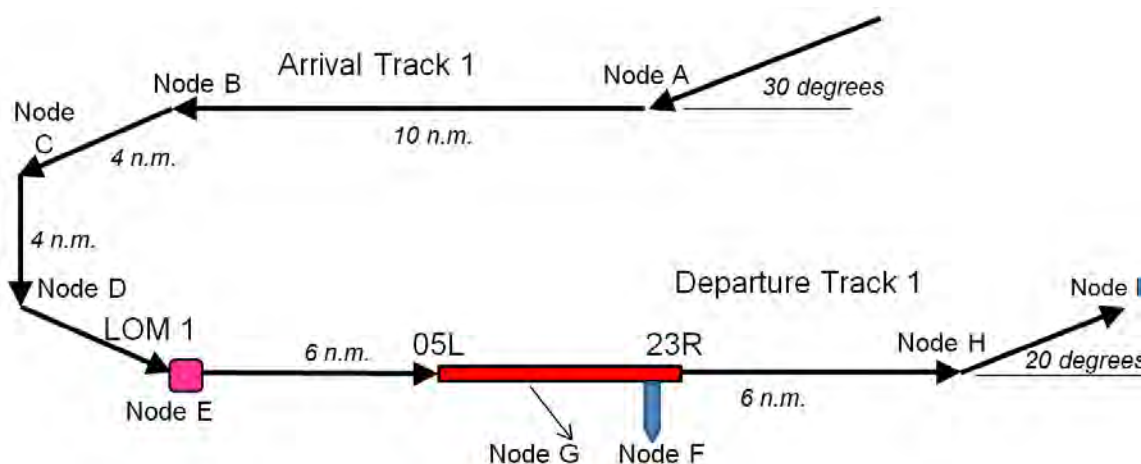
Once the AAW delays estimates are available, the economics analyst will value delay savings due to the proposed infrastructure, taking account of savings in passenger time and aircraft operating costs. It will be particularly important to account for cost savings where they occur—at the gate, taxiing, in the queue for takeoff, or in the air. As discussed in Section 10, unit costs should be adjusted to be accurate for where the delays occur. Simulation models are particularly adept at evaluating the location of delays. Later in this appendix a methodology is presented to modify Form 41 average variable costs¹¹⁹ into estimates of marginal resource costs at different stages of flight. Marginal costs are the appropriate measure of resource savings due to marginal delay reductions.

E.2 Description of the Simulation Process

All simulation models describe airport systems in terms of nodes and links. Aircraft move in a defined sequence from node to node at speeds defined in the model. Exhibit E-2 illustrates the link–node concept for a single runway.

¹¹⁹ [Economic Values for FAA Investment and Regulatory Decisions, A Guide](#)

Exhibit E-2: Runway Links and Node



An aircraft approaches runway 05L by entering the arrival track at Node A. Absent any congestion, the model flies the aircraft at “nominal” speed assumed in the model. The model keeps track of the time it takes to fly Arrival Track 1 and maintains legal separation between aircraft. If there are other aircraft that are scheduled to enter the arrival track at Node A, the model holds them until the aircraft are sufficiently separated. This is an example of how a simulation model might accumulate delay, in this case if demand for entry into Arrival Track 1 exceeded its ability to process traffic. But, it is important to note that this would not tell us where the chokepoint(s) is that is causing the delay. For this further analysis would be required.

In the exhibit, the aircraft would continue to “fly” from Node A to B and onward until it reaches the Final Approach Fix (FAF) at Node E where it makes its final approach to 05L, always flying the appropriate nominal speed and maintaining separation from traffic in front of it. Because the model keeps track of individual aircraft/engine combinations it assigns the aircraft to a runway exit. In this case, it is assumed that the aircraft must exit the runway near the end at Node F, which is perpendicular to the runway in the Base Case. If the analyst is evaluating the benefit of a high speed exit to be constructed at Node G (closer to the middle of the runway), the model would evaluate whether the aircraft could use the high speed exit at an appropriate exit speed; when possible, the aircraft’s runway occupancy time would be reduced, which would free up additional runway capacity.¹²⁰ If there were no other chokepoints, the queue of aircraft waiting to enter Arrival Track 1 would be slightly reduced. Both passengers and aircraft operators would benefit if they could save some marginal time.. The benefit would extend to all aircraft and passengers processed through the airport system during a congested time period. The queue of aircraft waiting to enter the arrival stream would be cleared earlier and the benefits to each aircraft (and its passengers) could be evaluated.

¹²⁰ (Note: most fast-time simulation models are not optimized to evaluate runway occupancy time reductions with high speed exits. Rather, Virginia Tech’s updated REDIM model is preferred method for analysis of high speed exit benefits. An average ROT of <50 seconds by runway end is needed to enable reduced 2.5 mile aircraft-to-aircraft separations. This is the minimum threshold at which any changes to runway hourly capacity would be expected. Results of the REDIM model can be inserted into the fast-time simulation model, if needed to assess a more comprehensive project.)

It is very important that the BCA document that the projected time savings could actually be realized. In the above example, if the project time savings are very marginal, they might not result in a change in arrival call rates. In that case, controllers would not be operating in a way that would allow the time savings to be realized. It is recommended that the sponsor coordinate the proposed time savings with APP-400 prior to incorporating it into a BCA.

The foregoing is a simplified illustration of a complex airport system. To make it complete, the simulation analyst would have to assess all of the nodes linked to the runway to insure that the benefits are actually realized. For example, the simulation models can also keep track of aircraft passing through the taxiway and ramp systems all the way to the gate. If an aircraft is destined for a terminal where an appropriate gate is not available, it will have to taxi to the ramp and hold in an assigned area until the gate becomes available. So in that case, assuming no rescheduling of gate assignments, the runway's capacity would be enhanced by the high speed exit, but this aircraft and its passengers might not realize any reduction in actual block time. In other words, there would not be any delay savings for passengers for that particular flight, even though other aircraft further behind in the queue might benefit if they can reach their gates without being impeded. But, because the delays would be taken on the ground instead of in the air, operators would still save some variable costs (primarily fuel).¹²¹ This illustrates the power of the simulation model to isolate where delays occur, and how those might change as a result of an airfield improvement. The example also illustrates why it is important to estimate operator costs by each phase of flight.

Similarly, a reduction in runway occupancy time made possible by the high speed exit might benefit departing aircraft during mixed operations. Slightly less time would be spent processing at least some arriving aircraft which in turn will make it possible to clear aircraft onto the runway end for departure slightly sooner and/or more often than in the Base Case. How often this happens would depend on the mix of arrivals and departures. Not all departing aircraft would necessarily benefit.

In summary, a simulation model consists of a mathematical description of nodes that are linked together in a defined pattern governed by operating rules so that the time required to transit between nodes can be calculated. So for example, an aircraft arriving on runway 05L in Exhibit E-2 might enter the taxiway near its defined gate and would follow a defined route to that gate. The same flight arriving in different wind conditions might arrive on runway 23R and be much farther from its gate and have to transit the taxiway system in a very different way. A very long list of assumptions has to be made and validated to operate the models. These are summarized immediately below.

E.3 Key Assumptions Made in Simulation Models

The economics analyst will want to understand the inputs into the simulation model to better interpret the reliability of the results. Modern simulation models like AirTop or TAAM provide graphical interfaces that allow the user to visualize how well the airport operates in the various weather and configuration conditions described above. Ultimately the simulation specialist will be responsible for running the model but the economics analyst should make sure that the

¹²¹ Assuming an increase in air traffic arrival call rates.

assumptions appropriately describe how the airport will operate in the Base and Scenario cases.

Exhibit E-3 provides a list of key assumptions required to run the link-node simulation models. The BCA report should provide a summary of the assumptions in the simulation model, as well as information on data sources and intermediate steps taken to create input data. Following is a short discussion of each assumption category.

Exhibit E-3: Key Simulation Assumptions

Hourly Operations by aircraft type for representative day
Forecast of future operations by aircraft type/carrier
Scheduled, unscheduled (GA, cargo, military) flights
Arrival times and departure times for each flight
Separation standards by aircraft type
Approach and departure speeds by aircraft type

Wind, ceiling and visibility probabilities
Dry/wet runway probabilities

Airspace structure by airport configuration
Local approach and departure procedures

Airport geometry (runways, taxiways, ramps)
Routing of aircraft on the airport surface
Nominal/unimpeded speeds taxiways/ramps
Calculated runway occupancy times
Node to node times
Gate in/out procedures

Distribution of operations to runways

Terminal
Gate assignments by flight/airline
General Aviation area capacity and assignments
Cargo area capacity and assignments

E.4 Hourly Operations by Aircraft Type for a Representative Day

Simulation models operate using a single day's schedule for each run. Often the economics analyst will be involved in creating the schedule for the simulation.

Essentially the simulation specialist inputs an OAG-style schedule for all types of operations (scheduled and unscheduled) in to the model, with information on arrival or departure times for each operation, the aircraft type, user type, airline name (if appropriate), flight number and origin and destination. It will also be necessary to match arriving flights with subsequent departing flights so that the model can keep track of cases where arrival delays cascade into departure delays during congested periods of time, considering typical airline aircraft turn times at the airport's gates.

A recent day of actual operations will typically be selected to represent current operations of the airport. Care should be taken to select a model day that is representative (usually an average day in the peak month of the year).¹²² TFMS data can be used to develop a pattern of unscheduled IFR operations (GA, military, cargo) for the model day. Unscheduled operations may have to be adjusted upward to account for flights operated without flight plans and/or local operations. FAA CountOps¹²³ data (via request to ADO) or OpsNet may be available at FAA towered airports, which would provide counts for all aircraft (IFR and VFR) operations.

By examining the distribution of total daily operations over a year, the analyst can extrapolate annualization factors that when multiplied by operations on the peak and off-peak model days add up to total operations in the year. These annualization factors may be used for future years as well.

Future year operations will have to be forecast and then converted to OAG-style daily schedules. Developing these future year forecasts may be the most consequential step in simulation analysis because all of the results depend on them. It will be particularly important that the BCA describe very clearly the assumptions and rationale for these daily forecasts. The pattern of operations within the day will have a significant impact on delay estimates.

Developing these forecasts may entail many or all of the following steps;¹²⁴ each must be described in detail in the BCA report:

1. The FAA Terminal Area Forecast (TAF) or sponsor developed forecast approved by FAA is the starting point as the basis for unconstrained annual demand for the airport; the TAF includes forecasts of user operations and commercial enplanements.
2. Additional data can be compiled and analyzed to derive more detailed annual unconstrained forecast information beyond what is provided in the FAA TAF. The forecast should also consider trends in aircraft gauge (average seat per flight or payload capacity) and industry load factors which may increase the number of enplanements or payload per operation.
3. Historical data on operations demand by hour and month can be used to develop assumptions regarding the future share of peak month activity in relation to forecast annual demand.
4. Peak month activity would be divided by the number of days in the peak month to derive forecasts of unconstrained peak month average day (PMAD) activity levels, which is the standard demand level used in simulation studies.
5. Detailed unconstrained OAG-style flight schedules would then be developed based on an actual schedule day in the peak month and assessments of airline strategic plans and fleet development.

¹²² Usually historic data on the seasonal variation in activity is used to estimate monthly operations and passenger enplanements. The average day for each month is then calculated. For a BCA, the average annual day is the appropriate representative day for analysis. To do this, operations are disaggregated into an OAG style schedule showing arrivals and departures by an operator and aircraft type and time of day for both scheduled and unscheduled operations.

¹²³ [CountOps Reports](#)

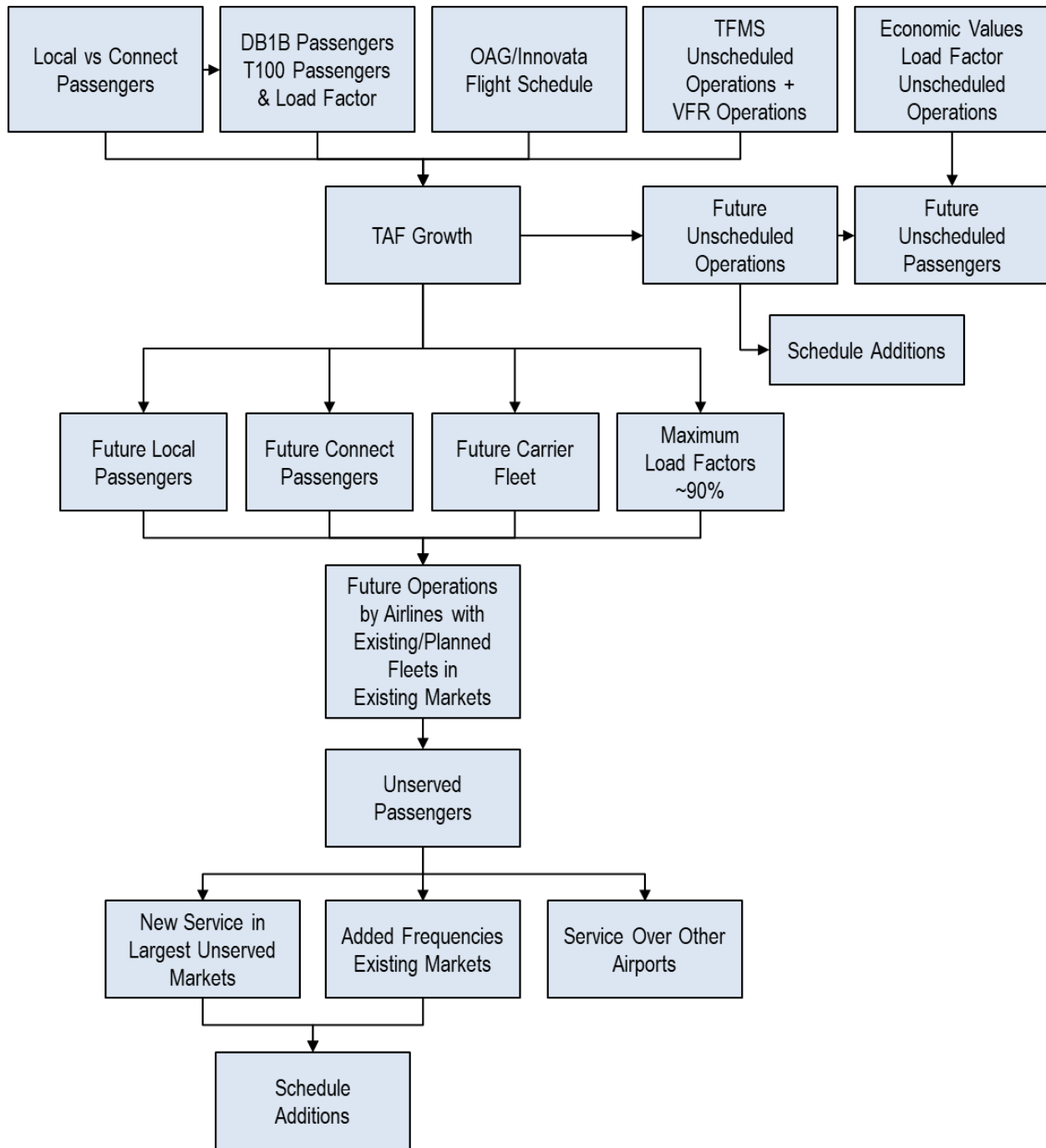
¹²⁴ Please see ACRP Report 163: *Guidebook for Preparing and Using Airport Design Day Flight Schedules*
[ACRP Report 163](#)

6. Where there are constraints to growth at the airport, constrained demand flight schedules would be prepared, based on the estimated constrained level of demand and the assumed airline response to scheduling activity in a constrained scenario.
7. The constrained demand flight schedules would then be used to develop a forecast of constrained annual demand, based on the estimated relationship of peak month to annual demand.

The economics analyst should be an active participant in developing the detailed forecasts for the simulation, and the BCA report should contain a section outlining the assumptions made and justification or source for each assumption.

To provide further background, the following discussion reviews one approach to creating simulation schedules. Although there is no single way to produce OAG-style daily forecasts, Exhibit E-4 illustrates one approach.

Exhibit E-4: Future Schedule Development



The idea is to anchor future model days in the current pattern of operations by scheduled and unscheduled operators, and then forecast them forward based on the Terminal Area Forecast (or other BCA forecast approved by FAA).

E.4.1 Operations and Enplanements for a Current Model Day

For scheduled operations, the OAG or Innovata actual schedule for an average day in the peak

month would be selected. This schedule would show arrivals and departures by airline, aircraft type and city-pair by hour of the day. Load factors would be based on DOT T100¹²⁵ data for the same time period. Enplanements would be developed from DB1B data (to account for connections) and airport enplanement counts. The analyst will have to account for local and connect passengers.

The pattern of unscheduled operations (including commercial cargo) can be identified from TFMS (for IFR flights) and Countops or airport data for VFR flights. Load factors for these flights would be based on FAA Economic Values.¹²⁶

This characterization of the current airport activity will provide sufficient detail that can be forecast into the future based on expected demand, expected operator fleet changes and potential new services.

E.4.2 Future Schedule Day

The TAF can be used directly to forecast future unscheduled operations. Future unscheduled passenger demand can be developed using the load factors from FAA Economic Values. Where growth in operations is expected, the analyst would take account of:

- Additional operations to existing airports at attractive times of the day
- The potential to operate to more distant airports on a non-stop basis in the Scenario Case of the BCA (with the investment)
- Long term prospects for additional cargo or military operations, taking account of up-gauging opportunities for some missions
- Trends in the GA, military and cargo fleets.

For commercial operations, growth in future total daily enplanements and operations can be taken from TAF or another forecast approved by FAA. The effort will then involve first assessing the implications of growth for current operations in the schedule and then identifying potential additional future operations.

Current Operations: The analyst should assume a maximum load factor for operations in the peak month. For example, when load factors are forecast to average more than 90%, operators may be tempted to up-gauge equipment relative to the current or actual schedule. The analyst would take account of announced operator fleet plans and independent fleet forecasts to identify these up-gauging opportunities. The analyst can also consult with FAA-APO on its fleet forecast used in FAA's Aerospace Forecast. If forecast load factors in other markets are below 90%, the analyst could leave those operations unchanged in the forecast (absent fleet retirements, for example). With these two steps, the analyst will have added some seat capacity flown in current markets, and accounted for some of the forecast growth in enplanements without adding more flights to the schedule.

Additional Future Operations: In Exhibit E-4, the remaining forecast enplanements not

¹²⁵ [Terminal Area Forecast \(TAF\)](#)

¹²⁶ [Economic Values for FAA Investment and Regulatory Decisions, A Guide](#)

accounted for by current operations are labeled “unserved passengers.” The analyst would then take account of market factors like the following to add commercial flights to the schedule:

- Opportunities to add service to a carrier’s hub bank at a different time of day
- Additional frequencies to an under-served existing market
- Instances where forecast enplanement growth in a market has reached a minimum level that may make the market viable economically
- Carrier announced long term strategy to expand to selected markets
- Input from airlines or air service development professionals concerning carrier expressed interest in adding service at the airport

In all cases, assumed additional arrivals and departures to the schedule would be assumed to be operated at viable times (from a marketing and hub strategy perspective) with aircraft that are now or expected to be in a carrier’s fleet and from gates that are available or will be available in the future.

The result will be a revised schedule. It is possible that in some cases there will be still be some “unserved passengers” not allocated to current or additional operations in the forecast. These enplanements could be assumed to take place at competing airports where passengers connect onward to a different location. They should not be used to influence aircraft size or operations in the markets identified in the future schedule.

Finally it should be noted that simulation models are capable of adding random variation to the schedule input. The idea is to simulate actual airport experience where flights can sometimes bunch up into small time windows while at the other times the airport will operate far below capacity. Some data sets discussed below in the Verification and Validation section provide information on scheduled and actual arrival and departure times. The variation between planned and actual performance during slack periods of time (when weather and demand are not driving delays) may provide the best information on this random factor.

E.5 Wind, Ceiling, Visibility and Wet/Dry Runways

Weather data for US airports or nearby weather stations can be obtained from NOAA.¹²⁷ The database includes time-stamped observations on wind direction, wind velocity, meteorological ceiling and visibility for individual weather stations. The data can be translated into the probability of IMC and VMC weather by hour of the day and used in the simulation model. A minimum of 10 years of hourly data should be used to avoid anomalous weather assumptions.

- Ceiling and visibility are a leading, but not the only determinants of whether an airport is in VMC or IMC conditions.¹²⁸ Variations can occur with dynamic conditions in traffic flow management, minimum vectoring altitudes, and higher wind speeds. A common error is to assume that VMC conditions and capacities are always available

¹²⁷ [NOAA](#)

¹²⁸ See A. Chow and J. Gulding: *Capacity Variation Algorithms for Simulation Modeling and Performance Analysis* 2013 Aviation Technology, Integration, and Operations Conference ; August 12-14, 2013, Los Angeles, CA A (AIAA-2013-4355)

during conditions with better than 3 miles visibility and 1000 foot ceilings. Often IMC or MMC rates are still in use. For the 77 airports tracked in ASPM that are part of Traffic Flow Management, historic configuration and called rate data is available.

- The annualization estimated from weather and ASPM configuration data should be compared to the operationally weighted average of called rates/throughput over the course of a year; the annualization should be adjusted to align with the operationally weighted average of called rates/throughput to indicate that the Base Case model is not overly optimistic or pessimistic.
- Wind direction and speed are important to establish the configuration of the airport. Higher wind speeds can also reduce the throughput rates on runways as additional spacing is needed between aircraft given variation in aircraft speeds. At some airports, IMC weather may be more prevalent when the wind is blowing in one direction.
- The time stamps allow the analyst to test how weather and wind conditions vary by season and by hour of the day. For example, airports near water may be subject to more ground fog early in the morning.

Wet or dry runway conditions usually cannot be determined directly from weather data, as a runway may not be wet for the entire day when there is precipitation on that day, but may still be wet from previous precipitation during an hour with no recorded precipitation. For projects involving runway extensions, distinguishing the percentage of time runways are wet will influence how often each aircraft type may benefit from the improvement during takeoff and landing. Runway occupancy times are also longer for arrivals when the runway is wet. Generally, the hourly weather data can be evaluated such that at the operation (takeoff/landing) time, runway is considered to be wet if:

- Significant Weather (SW) field contains Drizzle, Rain, Snow, Ice Crystals, Hail, or Mist; or
- Relative Humidity (RH) > 0 and precipitation in previous 1 hour or 3 hour period; or
- Ground Snow Water Equivalent (gsWEq) > 0

On average, 91.2% of operations are conducted on dry runways and 8.8% on wet runways across a sample of 36 busy hub airports and approximately 60.4M operations records.¹²⁹ This is meant as a benchmark and may be useful for testing the sensitivity of BCA results to alternative wet/dry conditions.

E.6 Airspace Structure by Airport Configuration

Simulation models mimic the flight procedures operators use for approach and departure taking account of the configuration the airport is in and whether operations occur in IMC or VMC conditions. In many cases, runway capacity in IMC conditions is substantially less than in VMC conditions. Capacity normally changes by airport configuration as well.

To mimic these conditions, the models define approach and departure procedures using the link-node method described above. When aircraft spacing increases, the effective speed of aircraft slows down and fewer aircraft are processed in any time period. For approaching aircraft, the

¹²⁹ MITRE analysis conducted in 2020 for APP-400 at 36 airports with ASDE-X or ASSC.

models will hold aircraft prior to entering the arrival track until the runway becomes available. The models will report delays taken in the air in these cases.

Airport configuration also changes the routing of aircraft on the airport surface. In some cases, high speed taxiway exits operate only in the primary configuration defined by prevalent winds. In most cases, simulation models assume that aircraft move along the surface (from node to node) at observed nominal or unimpeded speeds during uncongested periods. As demand increases relative to airfield capacity, congestion may occur on the airport surface. Some arriving aircraft may be delayed on the ground as congestion occurs at gates or elsewhere on the surface. Departing aircraft will also be affected as queues form to enter the taxiway system or the runway, or as aircraft are held on the ground due to enroute airspace congestion or ground stops at the destination airport. The models will report these delays as being taken on the ground.

The model will need to incorporate typical airspace constraints that affect arrival or departure flows as well. This can include metering to the arrival procedures, or miles-in-trail restrictions for departures going on specific routes. The airspace structure should not be assumed to be able to support unconstrained operations from major new capacity infrastructure, such as new runways.

It is very important that the BCA reflect the appropriate unit costs to value aircraft reported aircraft delays. Analysts can apply full variable costs only to delays taken in the air. See Section 10.5.5.1 and the second to last section in this appendix for further information on different ways of valuing delays taken in the takeoff queue, taxiing, in the air, or at the gate.

E.7 Airport Geometry (Runways, Taxiways, Ramps, Gates)

As discussed above, the simulation models describe the airport surface using the link-node method. Aircraft surface routings depend on airport configuration (the direction of travel on landing), available taxiways, and the routings for aircraft to reach their assigned gates, or GA and cargo locations. Aircraft move at observed nominal or unimpeded speeds until a facility becomes congested, at which point they slow down and eventually queues form.¹³⁰

Modern simulation models include very detailed graphical user interfaces (GUI) that can show animations of aircraft arriving and departing the airport, and moving along the surface. This makes it possible for the economics analyst and the simulation specialist to visualize how and under what conditions the proposed improvement would reduce delays.

E.8 Distribution of Aircraft to Runways

At many airports, there are advantages if operators select a certain runway for arrival or departure. Arriving aircraft may minimize taxi times if they land on one runway versus another, depending on wind conditions, time of arrival and their destination on the airport surface. Similarly departing aircraft can minimize taxi time and departure flight time (due to turns onto their ultimate routing) if they select one runway versus another. Simulation models can mimic these behaviors by assigning specific aircraft or operators to specific runways, and then define

¹³⁰ At large airports, ASDE-X data may be available to help assess the efficiency of ground operations.

their arrival and departure procedures and the taxi route to and from the runway. Runway use data is available from airport flight tracking systems as well as FAA CountOps and PBN data analytics systems.

E.9 Terminal

Finally, as has been noted above, the simulation models assign each operation to a terminal or parking area on the airport surface. When gate or parking areas are congested or otherwise unavailable, the models assign aircraft to holding areas and delays begin to accrue. When terminal ramps are modeled in detail, congestion in these facilities may cause aircraft to be delayed at the gate.

E.10 Verification and Validation

The simulation specialist will be largely responsible for the implementation of the model. The simulation report should include information on how the inputs were verified as appropriate and how the model was validated – meaning it replicated hourly capacity rates and aggregate taxi times and behaviors at the airport in a reasonable manner. The economics analyst should primarily focus on validation of aircraft behaviors in relation to the proposed improvements. The simulation report should describe how the improvement results in delay savings and where those savings will take place and these findings should be included in the BCA report.

Following are some sample questions about verification and validation that might help the economist understand if the model addresses the critical infrastructure.

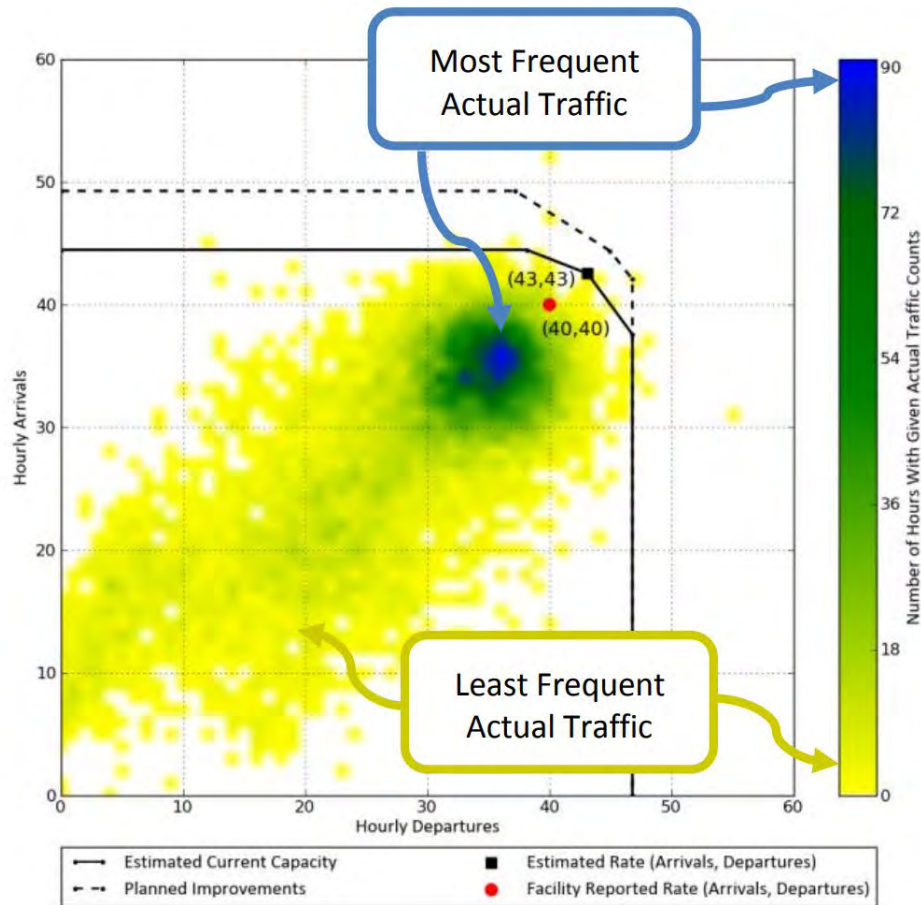
- Verify aircraft separation at the airport during the conditions and configurations being modeled are accurate
- Verify nominal and unimpeded speeds from ASDE-X or other authoritative source
- Verify flight schedule input into the model replicates hourly departures and arrival by aircraft and user type – commercial passenger (by airline), cargo (by airline), GA and military
- Validate ground movements: Confirm the appropriate operators are using the right gates, runway entrances, runway exits, and aircraft stands; confirm parallel taxiways are being used appropriately for departures and arrivals, and that taxiway routings are typical for the airport configuration being modeled.
- Validate flight tracks and procedures: Confirm that the model is replicating the flight tracks and procedures aircraft actually use given the configuration and ceiling/visibility conditions being modeled.
- Reviews of the simulation models should normally be conducted by FAA ATCT and TRACON controllers.

However, the most important way to validate the simulation results for a BCA is to ensure that the model replicates base year hourly throughput of the airport expressed as hourly arrival and departure rates (either ATC called rates or actual throughput, whichever is higher hour-by-hour). For the 77 airports included in the FAA's ASPM system,¹³¹ an analyst can assemble arrival and

¹³¹ [Aviation System Performance Metrics \(ASPM\)](#)

departure hourly throughput (for VMC or IMC conditions and by airport configuration) and compare it to simulation outputs in similar conditions. Other airports' arrival and departure data (with less information on weather) can be found in CountOps data.¹³² The simulation model should closely correspond to actual performance, by individual configuration as well as the AAAW (compared to operationally weighted average of called rates/throughput) Pareto graphs such as Exhibit E-5 can be assembled to make the comparison between modeled and actual departure and arrival rates.

Exhibit E-5: Pareto Graph of Arrival and Departure Throughput



Source: FAA Capacity Profiles (May 2014)

Data, metrics and resources that may be useful for calibrating baseline models include:

- ASPM/OpsNet/CountOps Data for hourly throughputs, weather conditions, and runway configurations (FAA data access may be required)
- Bureau of Transportation Statistics (BTS) data for taxi times and airline-reported delays
- System Wide Information Management (SWIM) Traffic Flow Management (TFM) or National Offload Program (NOP) data for aircraft tracks and flight plan data (FAA)

¹³² [CountOps Report Manual](#)

SWIM data access required, or NOP data can be requested via ADO data release processes)

- Airport Surface Detection Equipment, Model X (ASDE-X) data for ground tracks and arrival and departure records (FOIA request)
- Airline post-operational analysis data from tools such as POET (Post Operations Evaluation Tool)

A simulation of an airport will never exactly match or replicate actual operations. Focusing on whether the model produces results within the range of actual operations is more useful since the latter will vary by weather, airport configuration and vagaries of day to day operations.

E.11 Valuing Simulation Delays Using Estimated Marginal Costs

Simulation models measure delays as time in excess of a nominal or unimpeded time when transiting from one node to another in the model. For example, suppose a simulated arrival was first held at an airspace node in order to provide adequate separation between it and a preceding arrival; then, after landing, was held at a runway crossing point because other traffic was using the runway, and finally was held near its gate until a departing flight using the same gate was pushed back. The duration the flight was held in each of these instances would be counted as delay by a simulation model. The model would count these delays even if the flight arrived ahead of its scheduled arrival time. Thus, simulation models do not measure on-time performance directly but rather assess unimpeded airport system performance relative to the Base Case versus the Scenario Case.

In a cost benefit analysis, the economics analyst compares a Scenario Case (with a proposed capacity enhancement) to a Base Case (without the enhancement). In theory the result is an estimate of the *marginal delays* avoided as a result of the capacity enhancement. These avoided delays should be valued using *marginal costs* instead of average variable costs. Marginal costs will be equal to or less than average variable costs because they exclude fixed costs embedded in a schedule and correctly apportion cycles-based maintenance costs across marginal delay minutes.

In a benefit cost study, it is appropriate to value time saved using valuation parameters that reflect actual resources saved. So for example, if a flight is delayed at the departure gate, it is burning much less fuel than during in-flight or even taxi operations. The same delay would incur only small maintenance costs and marginal crew costs (depending on how crews are paid and when they arrive to operate the flight).

Because simulation models can identify where the delays are incurred, the analyst has the opportunity to assign appropriate avoidable marginal costs for each stage of a flight: at the departure gate, taxiing for departure, holding in the runway queue, enroute, in arrival flow control, in arrival airspace, taxiing after arrival, or holding for a gate.

Exhibit E-6 presents factors that can be multiplied by average variable cost categories (per minute or other unit of time) to derive estimates of marginal costs, based on phase of flight. Fuel costs are based on the estimates provided by Ryerson et al. At the gate, marginal fuel costs are assumed to be 10% of average fuel burn recognizing that APU's are powered by aviation fuel

and produce the same electrical power as the engines but not thrust.¹³³ The taxi phase estimate comes directly from Ryerson. The in queue fuel costs are an average of the gate and taxi factors. The average Form 41 fuel costs are appropriate estimates of marginal costs when the aircraft is in flight.

In the U.S., crew costs are largely based on duty time and usually begin to be incurred when the door closes on the aircraft or the aircraft pushes back from the gate. If some delays are avoided at the gate, eventually at least some of these savings may be incorporated in duty times that airlines use to develop crew schedules. But it is not clear how much resource time would be saved. Exhibit E-6 assumes that half of marginal delay at the gate would be saved. For all other types of delays, average Form 41 costs are appropriate estimates of marginal costs.

Large portions of maintenance costs are fixed or cycle (take-off or landing) based and would not change in the event of a marginal delay. The most maintenance intensive activity is take-off; the amount of time required for take-off and the wear and tear on engines will usually be relatively unaffected by an airport capacity project. Cook and Tanner provide estimates of marginal maintenance factors at the gate (very small) and in the air. Taxiing and in-queue maintenance costs are averages of the gate and in-the-air values.

No other airline or operator costs are likely to be incurred as a result of marginal delays. It is possible that very large delay savings could result in significant network-wide savings for operators including better aircraft utilization (which would affect all inputs including capital costs), but estimating these benefits would require a special study taking account of the operators' ability to reschedule crew and flight equipment and perhaps reduce invested capital. Finally passenger costs (Pax. in the Exhibit) are incurred at the full value of time regardless of where they are incurred, per USDOT guidance.

¹³³ See Zhang et al: *Assessment Method of Fuel Consumption and Emissions of Aircraft during Taxiing on Airport Surface under Given Meteorological Conditions*; Sustainability (2019, 11) which shows that APU's consume about 1/3 the fuel of aircraft engines when taxiing.

Exhibit E-6

Factors to Multiply by Average Form 41 Costs to Estimate Marginal Costs of Delay

	Location of Delay	Fuel*	Crew	Maintenance**	Pax
Ground	At gate	0.1	0.5	0.04	1.0
	Taxiing	0.3	1.0	0.17	1.0
	In Queue	0.2	1.0	0.17	1.0
In Air	Enroute	1.0	1.0	0.30	1.0
	Arrival Flow Control Delay	1.0	1.0	0.30	1.0
	Arrival Airspace Delay	1.0	1.0	0.30	1.0

*Ryerson, et al: *Fuel Burn Impacts of Taxi-out Delay and Their Implications for Gate-hold Benefits*, Transportation Research Part C Emerging Technologies – January 2015

**Cook & Tanner: *The challenge of managing airline delay costs*. German Aviation Research Society and University of Belgrade, Faculty of Transport and Traffic Engineering. Conference on Air Traffic Management (ATM) Economics, University of Belgrade, 10-11 September 2009.

To illustrate how to use the Factors, consider Exhibit E-7. The top part of the exhibit reports simulation results showing the **difference** in clock time expended by the average operation at different stages of a flight in the Base Case (without a capacity improvement) and the Scenario Case (with the improvement). The time savings are reported in minutes per operation in VMC conditions (making up 96% of the year) and IMC (making up 4%). The exhibit reports the weighted average time savings due to the improvement at each stage of the average flight.¹³⁴ Adjacent to the time savings estimates in Exhibit 7 are the factors from Exhibit E-6 that apply to each stage of the flight. The factors are the portion of fuel, crew and maintenance average costs that can be applied to estimate the marginal resource costs operators may avoid at each stage of the flight.

The middle of the exhibit shows the average operating costs per block hour for a sample aircraft converted into costs per minute. These costs are directly from the Economic Values report cited in the table for Part 121 commercial jet aircraft less than or equal to 160 seats.

The bottom of the chart then reports the marginal cost avoided at each stage of the flight which is a product of the following for each cost category:

(weighted average time savings) x (marginal cost factor) x (average cost per minute)

The total marginal resource costs per operation avoided using this methodology is \$79.74. If instead we just summed up the total time saved (2.9 minutes) and multiplied by average operating costs per minute (\$63.88), the total estimated average costs per operation would be \$185.01, more than twice as much.

Of course the impact of using marginal costs instead of average variable costs will vary depending on where delays are avoided. But using marginal costs provides a better estimate of the resources society will save as a result of a capacity project.

It may be the case that special circumstances would make it appropriate to use different factors than those shown in Exhibit E-6 to estimate marginal costs. For example, at airports where APU

¹³⁴ It is important to note that the time savings are net at each stage meaning that in the example there are no off-setting time savings and so the savings can be added up to a total annual all weather delay savings of 2.9 minutes.

power to aircraft at the gates is provided by electricity, resource costs at the gate (the factor) would be lower than those implied in Exhibit E-6. Sponsors may use alternative factors where they are properly documented in the BCA report.

Finally, as was noted above, passenger time savings would also be estimated as part of a BCA for a capacity project. But, these can be estimated as total time saved per operation (2.9 minutes in this case) multiplied by the appropriate value of time published by US DOT.

Exhibit E-7: Estimating the Marginal Cost Savings of an Airport Improvement

	Time Saved per Operation (Minutes)			Factors to Estimate Marginal Costs		
	VMC 96%	IMC 4%	Weighted Average	Fuel	Crew	Maintenance
Average Daily Statistic						
Arrival air delay	0.2	0.8	0.22	1.0	1.0	0.3
Arrival ground delay	0.1	0.1	0.10	1.0	1.0	0.3
Departure ground delay	0.5	2.0	0.56	0.2	1.0	0.3
Taxi-in time	0.6	2.4	0.67	0.3	1.0	0.17
Taxi-out time	1.0	3.2	1.09	0.3	1.0	0.17
At gate	0.2	1.5	0.25	0.1	0.5	0.04
				Operating Cost per Block Hour*		
				Fuel	Crew	Maintenance
Part 121 Carrier; <= 160 seat Narrow Body ----->				\$2,394	\$724	\$715
Per Minute----->				\$39.90	\$12.07	\$11.92
Arrival air delay		0.22	\$8.94	\$2.70	\$0.80	\$12.44
Arrival ground delay		0.10	\$3.99	\$1.21	\$0.36	\$5.55
Departure ground delay		0.56	\$4.47	\$6.76	\$2.00	\$13.23
Taxi-in time		0.67	\$8.04	\$8.11	\$1.36	\$17.51
Taxi-out time		1.09	\$13.02	\$13.13	\$2.20	\$28.36
At gate		0.25	\$1.01	\$1.52	\$0.12	\$2.65
Total		2.90				\$79.74
Total if evaluated at Average Block Hour Costs: 2.9 minutes x				\$63.88		\$185.01

*[Aircraft Operating Costs](#)

E-12 Simulation Models

If an LOI calls for significant capacity enhancements at a major airport (e.g. new runways, major airfield reconfigurations, or significant airspace changes) high fidelity models such as are appropriate simulation tools. Note that model selection is subject to APP-400 review and approval for use in NEPA and BCA analyses. These models require significant effort and resources in terms of data processing, preparation, setup, and calibration, but they also provide the necessary granularity and environmental controls to support decisions involving hundreds of millions of dollars. Exhibit E-8 provides information where analysts can find additional information on these models.

Exhibit E-8: Simulation Models

Model	Source	Website
Air Top	Airtopsoft	airtopsoft
CAST Aircraft	Airport Research Center GmH	ARC CAST
SIMMODPro	ATAC	ATAC Simmod PRO!
TAAM	Jeppesen/Boeing	Jeppesen Total Airspace and Airport Modeler

There are also less sophisticated models that do not simulate the full details of the movement of aircraft from/to airspace through the airport surface such as runwaySimulator. [runwaySimulator](#)
[Airport Capacity Model](#)

Several ACRP reports provide additional information on simulation tools and their relative strengths and weaknesses; however note that the ACRP reports do not replace or supersede FAA guidance:

- ACRP Report 79: Evaluating Airfield Capacity
- ACRP Report 104: Defining and Measuring Aircraft Delay and Airport Capacity Thresholds
- ACRP Synthesis 98: Simulation Options for Airport Planning