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Establishment and Discontinuance Criteria For Airport Traffic Control Towers

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16. Abstract

This report presents revised criteria for VFR Airport Traffic Control Tower establishment and discontinuance based on an economic analysis of tower benefits and costs. In compliance with P.L. 100-223, the previous tower establishment and discontinuance criteria have been revised to eliminate distinction according to aircraft size. In addition, benefit estimation procedures have been updated to reflect accident rate differentials between towered and nontowered airports experienced during the period 1983 to 1986. Costs reflect those experienced during 1988 by the FAA for tower construction, equipment, and operation.

Site-specific activity forecasts are used to estimate tower benefits from prevented collisions between aircraft, other prevented accidents, and reduced flying time. The present value of these safety and efficiency benefits are compared with the present value of tower costs over a fifteen-year time frame. Establishment costs include annual costs for staffing, maintenance, equipment, supplies and leased services and investment costs for facilities, equipment, and operational start up. A location becomes a candidate for tower establishment when the benefits which derive from operating the tower exceed the costs; a tower becomes a candidate for discontinuance, when the costs of continued operation exceed the benefits.

Application of these criteria enable the Federal Aviation Administration to prioritize investments among alternative sites according to the greatest return in benefits for dollar investments.

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EXECUTIVE SUMMARY

This report presents the criteria and computation methods to be used in determining eligibility of terminal locations for VFR tower establishment and discontinuance based on an economic analysis of the costs and benefits of Airport Traffic Control Towers. The criteria compare the present value of VFR tower benefits at a site with the present value of VFR tower costs over a fifteen-year time frame. A location is eligible for tower establishment when the benefits which derive from operating the tower exceed the installation and operation costs--the benefit-cost ratio is greater than or equal to one. A tower meets discontinuance criteria, when the costs of continued operation exceed the benefits--the benefit-cost ratio is less than one.

Site-specific activity forecasts are used to estimate three categories of tower benefits:

- Benefits from prevented collisions between aircraft
- Benefits from other prevented accidents
- Benefits from reduced flying time

Explicit dollar values are assigned to the prevention of fatalities and injuries and time saved.

Tower establishment costs include:

- Annual operating costs: staffing, maintenance, equipment, supplies and leased services
- Investment costs: facilities, equipment, and operational start up

Tower discontinuance costs consist of the same annual operating costs utilized for establishment decisions. Discontinuance decisions also consider the costs of shutting down the tower.

The criteria have been revised from those published in August 1983 in accordance with P.L. 100-223 to eliminate distinctions based on aircraft size. In addition, tower costs, accident rates and benefit unit values--including value of statistical lives saved, injuries avoided, and passenger time saved--have been updated to incorporate the most recent data.

In December 1988, there were a total of 400 FAA operated towers in the airport and airway system. Currently there are 140 Level I (Non-Radar) of which 20 are operated by contractors.

Based on projections of future aviation activity at sites, the new criteria suggest that 29 sites could be considered candidates for tower establishment, with benefit-cost ratios equal to or greater than 1; 31 VFR towers satisfy the benefit-cost criteria for discontinuance.

These criteria, as well as other criteria used in determining eligibility of terminal locations for establishment, discontinuance and improvements of air navigation facilities, equipment and services, are summarized in FAA Order 7031.2C, Airway Planning Standard Number One.

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I. INTRODUCTION

Effective management of federal airport and airway resources requires directing funds to projects where maximum benefits derive from proposed capital investments. FAA develops criteria with which it can assess installation and operation of facilities and equipment at potential sites. For inexpensive devices, the criteria may be simple traffic activity thresholds. For example an airport with 50,000 operations per year qualifies for an ATIS (Automatic Terminal Information Service). Evaluation of larger more expensive facilities, such as Airport Traffic Control Towers, are based on economic analysis of benefits and costs.

This report presents the methods and values for conducting economic analysis of costs and benefits of VFR Airport Traffic Control Towers.1/ It also summarizes results of an application of these methods to 4,070 airports in the U.S. based on current forecasts of future aviation activity. The application should be redone annually to evaluate changes in actual and forecast traffic at each site.

Criteria to establish Airport Traffic Control Towers has evolved over time. Initially applied in 1951, a minimum number of operations was required to qualify as a tower candidate. From 1951 through 1974, minimum qualifying levels were 24,000 annual itinerant operations at air carrier airports and 50,000 annual itinerant operations at GA airports. Differential levels of operations were established under the theory that at air carrier airports, there was a greater mix of traffic, utilizing aircraft with a wider range of performance characteristics, thus creating a greater potential for accidents.

Because of the increasing cost of tower establishment and operation, in 1975 the criteria were revised to incorporate benefit-cost analysis. The 1975 criteria considered collision and accident risk, reduction in flying time, mix of aircraft types, percentage of passengers injured and percent of aircraft damaged.

1/ A more general discussion of benefit-cost analysis may be found in "Economic Analysis of Investment and Regulatory Decisions - A Guide" (Reference 1).

A. Kinds of Benefits and Costs

FAA's control towers generally provide four kinds of direct benefits to aircraft operations and passengers and create two kinds of costs:

- Safety benefits occur at airports with control towers; midair collisions are less frequent, and fewer aircraft are damaged in landing accidents. Controllers are well positioned at airports to advise pilots of obstructions on runways or problems with landing gear, thus averting potential accidents.

- Aircraft operating costs are reduced and passengers' time is saved when flight paths are shortened. Towers shorten flight paths by allowing straight-in approaches.

- Productivity benefits result when an investment reduces required manpower. Tower controllers perform some functions which in their absence are performed by air carrier personnel.

- Other nonquantifiable benefits may be associated with tower services. Tower controllers may "save" lost pilots; knowledge of weather reported by a controller may convince a pilot to cancel a flight which would have crashed.

- Tower Investment costs include the capital expenditure for tower construction and equipment, and whatever site improvements must be made to accommodate it. Whenever possible site-specific costs would be substituted for national average costs because airports with fewer siting or construction problems will have lower costs. In a discontinuance benefit-cost analysis, one-time costs of discontinuing operation are tallied.

- Tower Operations and maintenance costs include both labor and materials costs.

B. Unit Economic Values and Activity Forecasts

Tower benefit estimates are prepared by assigning dollar values to prevented fatalities and injuries and time saved. Unit economic values for these as well as aircraft repair, replacement, and operating costs, are developed in Reference 2 as well as guidelines issued by the Office of the Secretary of Transportation in a memorandum dated June 22, 1990. Economic unit values should be updated annually, to reflect differences in inflation rates.

Aviation activity is an independent variable for tower benefit calculations. Tower benefit estimates are based on annual aviation activity forecasts and are computed for each of fifteen future years, discounted to present value with the ten percent rate directed by Office of Management and Budget. Annual site aviation activity is projected in FAA's annual Terminal Aviation Forecasts (Reference 3).

C. How Criteria are Applied

Establishment criteria are used to evaluate investments at particular locations prior to Facilities and Equipment (F&E) budget submissions, or reprogramming. Meeting the economic criteria is usually a necessary condition for including a site in the budget. When the number of qualifying sites is larger than overall budget constraints will allow, some sites may not be funded, even if economically justified. The converse is also true: locations may be excepted from meeting the economic criteria because of other factors such as terrain, severe weather, and site potential as a hub airport reliever.

Installations may be discontinued if the benefits fall below annual operation and maintenance costs, adjusted for any one-time shutdown cost. This can happen if activity levels drop, or reanalysis of benefits suggests that investments do not provide the same degree of benefit as previous believed.

D. Changes from Previous Criteria

For the first time, airport traffic control tower establishment and discontinuance criteria will be promulgated through rulemaking as required by Section 308 of P.L. 100-223. This report, and the change to Airway Planning Standard Number One that will result from it, establish methodology for implementing the new criteria. This methodology supersedes FAA report FAA-APO-83-2 "Establishment and Discontinuance Criteria for Airport Traffic Control Towers" (Reference 4).

In accordance with P.L. 100-223, Section 308, the criteria have been revised to consider traffic density (number of aircraft operations without consideration of aircraft size), terrain and other obstacles to navigation, weather characteristics, passengers served, and potential aircraft operating efficiencies. Accordingly, changes have been made in the elimination of aircraft size related user categories and in the application of accident rates. Accident rate differentials have been estimated based on recent experience (1983 to 1986). Costs of establishing control towers have been revised, economic unit values have been updated, and provision has been made for utilizing site specific activity forecasts. In addition, Phase I analysis, a preliminary manual screening technique, has been deleted due to the availability of computer programs to perform comprehensive site specific benefit calculations.

E. Organization of This Report

Benefit-cost criteria are presented in Chapter II. Complete details for the cost calculations are contained in Chapter III. Benefit estimation methodology is reported in Chapter IV. The results of applying the criteria are presented in Chapter V.

II. AIRPORT TRAFFIC CONTROL TOWER CRITERIA

The VFR airport traffic control tower criteria outlined below are intended to replace the tower criteria currently contained in Order 7031.2B, Airway Planning Standard Number One (Reference 5).1/ Meeting the candidacy requirements does not mean automatic qualification for either control tower establishment or discontinuance. The benefit-cost criteria screening is but one of several inputs to the FAA decisionmaking process with regard to tower establishment.

Benefit-Cost Criteria

The criteria compare the present value of tower benefits with the present value of costs over a fifteen-year time frame, using site-specific activity forecasts to develop estimated benefits. The present values are then obtained by discounting the future costs and benefits to the present time at a compound rate and summing the results.

An investment meets benefit-cost criteria when the ratio of benefits to cost is 1.0 or greater. This is the same as saying that values of benefits exceed costs. The investment fails to meet the criteria when this ratio is less than 1.0. Approximations and assumptions inherent in the analysis suggest that investments (or possibilities for discontinuance) where the ratio is within 0.1 of 1, i.e., between 0.9 and 1.1, are "too close to call." Decisions in these cases should consider factors in addition to the economic analysis outlined in this report.

1. Establishment Criteria: A site meets tower establishment criteria when the present value of airport traffic control tower benefits, BPV, equals or exceeds the present value of establishment costs, CPV. This is usually stated in ratio form:

   $$BPV/CPV \geq 1.00$$

2. Discontinuance Criteria: A tower meets tower discontinuance criteria when the present value of the cost of continued operation less the cost of closing the tower, CMPV, exceeds the present value of the benefits, i.e.

   $$BPV/CMPV < 1.00$$

1/ Previous criteria are discussed in References 4 and 6.

If continued tower operation is not economically justified, a site-specific analysis will be performed which shall include, but not be limited to:

- o Assurance that factors unique to the location such as weather and topography, are properly accounted for
- o Potential use of the site to provide capacity and training relief for a hub airport
- o Impact on adjacent facilities
- o Operational factors otherwise accounted for by the benefit-cost analysis
- o The possibility of significant changes in traffic activity attributable to unique local conditions
- o Military requirements.

The site may also be considered as a candidate for the contract tower program if it has an operating non-Federal control tower or a control tower structure available for occupancy that meets building standards. Rather than using FAA costs in the computation of the discontinuance benefit-cost ratio, the site-specific contractor proposed costs can be substituted in the analysis to determine if the tower meets criteria (i.e., above the discontinuance criteria) and should be considered for inclusion in this program.

III. TOWER COSTS

A. Tower Establishment Criteria Costs

Airport traffic control tower costs are given in Table 3.1. They fall into two categories:

- Annual costs: the costs of operating staff, maintenance, expendable equipment, supplies and leased services
- Investment costs: the one time costs of facilities, equipment and operational start up.

1. Annual Costs

Costs of operating and maintaining an airport traffic control tower for one year vary by the size of the tower and airport activity. However, the normal air traffic staffing for a low activity control tower (operating 12 hours daily) is one Air Traffic Manager and five controllers. At such a facility, the 1988 salary (in 1988 dollars) for the average manager (GS 11 step 5)1/ is $36,752 and for the average controller (GS 10 step 5) $32,070. These salaries must be adjusted upward by 29.65 percent to account for the total cost to the government of retirement, health and other benefits. Night differentials and premium pay approved by the Office of Personnel Management are already added on to the base pay rate. No adjustment is included here for leave and other absences, since leave considerations are already included in the staffing standard (Reference 7). Thus the effective cost shown in Table 3.1 is $47,649 for the manager and $41,579 for each of the controllers. In addition, each facility requires a part-time secretary, with an average annual salary of $7,656. Adjustment for benefits of 29.65 percent yields an effective annual salary of $9,926. The total annual staff cost is $265,470.

The cost of airway facilities staff for a low activity tower is $25,000. FAA experience suggests Controller change of station costs for one controller will be incurred every other year and are therefore estimated as 1/2 x $ 26,037 or $ 13,018. Leased communications are $ 22,000. In 1988, other costs for stocks and stores, rent, utilities, contracted services, related administrative costs and other objects approximated 3.7 percent of base air traffic salaries or a total of $ 6,769.2/

1/ Source: ATS-210

2/ Source: ATS-210

2. Investment Costs

On average, the primary investment cost of establishing a low activity tower is the facilities and equipment cost, estimated at $2 million in 1988.[3/] This figure includes all Airway Facility costs incurred from planning through the time that the equipment is installed and the tower is ready for operation.

The other major one-time expense of establishing a control tower is the "start-up" staffing cost, primarily transferring six experienced controllers from various other facilities and training replacements for these six controllers. The cost for one replacement controller, shown in Table 3.2, includes the cost of the basic air traffic control course at the FAA Academy, as well as associated travel costs and salary during the training period.

Additional "start-up" staffing cost for training Airway Facilities' personnel is estimated at $ 8,000 in 1988. The total investment cost of $2,239,594 is the sum of facilities, equipment, and start up staffing cost. Since costs vary considerably from site to site, application of the criteria should be based whenever possible on site specific values as opposed to average investment values.

3. Present Value

Tower benefits are compared with tower costs over a fifteen year time frame, by comparing present values. It is convenient to assume that investment costs all occur at the beginning of the time frame, so that their present value equals actual costs. Annual costs are assumed to remain constant (in 1988 dollars) over the 15 years. In particular, this assumption implies that growth in traffic over the period will not be sufficient to require an increased staffing level. If additional staffing is anticipated for a particular location, then site-specific costs, which include appropriate staffing costs, should be used. Since the annual costs will be constant for each year in the time frame, the present value is calculated as an actuarial parameter times this constant value. In this case, the parameter value for 15 years at the ten percent discount rate prescribed by the Office of Management and Budget is 7.977. Assuming that:

COSTA = Annual costs
COSTE = Establishment investment costs

the present value of tower establishment costs, CPV, is given by

CPV = (7.977 x COSTA) + COSTE
CPV = (7.977 x $ 332,257) + $2,239,594
CPV = $ 2,650,414 + $2,239,594
CPV = $ 4,890,008

3/ Source: APS-110

Table 3.1
Tower Establishment Criteria Costs
(1988 Dollars)

	Cost	Total Cost
Annual Operating and Maintenance Costs		
Staffing (including leave and benefits)		
Air Traffic a/	$265,470	
1 Manager @ $47,649		
5 Controllers @ $41,579 each		
Part Time Secretary $9,926		
Airway Facilities b/	$ 25,000	
Change of Station (1/2 x $26,037) c/	$ 13,018	
Leased Communications b/	$ 22,000	
Other Costs b/ (3.7% of base AT staffing)	$ 6,769	
Total annual costs		$332,257
Investment Costs		
Facilities and equipment d/	$2,000,000	
Start up staffing		
Air Traffic e/: $ 38,599 x 6 =	$ 231,594	
Airway Facilities f/	$ 8,000	
Total investment costs		$2,239,594

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a/ Source: ATS-210

b/ Source: ASM-200

c/ Assuming one controller move approximately every two years and moving cost of $26,037, the PCS national average from ATS-210.

d/ Source: APS-110

e/ Source: Table 3.2, this report

f/ Source: ASM-200

Table 3.2

Start-up Staffing Cost per Controller
(1988 Dollars)

	Cost
Moving expenses[a/]	$ 26,037
Training replacement controller	$ 5,000
Trainee's salary costs	
15 weeks of common screen and terminal follow on training	$ 7,562
Total per controller	$ 38,599

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a/ 1988 PCS national average from ATS-210

B. Tower Discontinuance Criteria Costs

The cost used in the tower discontinuance criteria is limited to the cost of continuing to operate the control tower and the one time cost of shutting it down. Shut down costs are given in Table 3.3. The dismantling costs include moving and salvaging some equipment, and removing controls for some remaining items. Costs of actually tearing down the tower are not included. The annual costs of continuing to operate the tower, also given in the table, are the same as for the establishment case.

Table 3.3

Tower Discontinuance Criteria Costs
(1988 dollars)

	Cost	Total Cost
Annual Costs of Continued Operation		
Total annual costs from Table 3.1		$332,257
Decommissioning Costs		
Dismantling a/	$120,000	
Relocating controllers - moving expenses for six controllers ($26,037 x 6) b/	$156,222	
Total decommissioning costs		$276,222

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a/ Source: APS-110

b/ Source: ATS-210

Thus, assuming

COSTD = Decommissioning costs

then the present value of the costs of continuing to operate the tower over the fifteen year time frame, CMPV, is given by

CPV = (7.977 x COSTA) - COSTD

CPV = (7.977 x $332,257) - $276,222

CPV = $2,650,414 - $ 276,222

CPV = $2,374,192

Both annual and shut down costs for the discontinuance case probably vary even more from site than for establishment investment costs. For example, while most new towers are staffed with one manager and five controllers, some potential discontinuance candidates might use as many as ten or as few as four controllers. In such cases, site-specific annual cost values may be calculated from the appropriate unit cost entries in Table 3.1 Decommissioning costs should reflect all shut-down costs anticipated at that site. For example, if a tower is already temporarily closed, the controller relocation costs shown in Table 3.3 should be eliminated and actual dismantling costs, if any, should be used. Any relocation, renovation, or modernization costs required to continue operating the tower over the 15-year benefit-cost analysis period should also be included as capital costs.

Site-specific costs should be used where available. These costs must be adjusted for inflation. Anticipated future capital costs should also be appropriately discounted.

IV. TOWER BENEFITS

This section explains the derivation of benefits with primary emphasis on the prevention of accidents afforded by towers. Benefits derived from towers can be quantified in two basic categories, safety and efficiency. Safety benefits derive from preventing collisions between aircraft (such as midair or air to ground collisions) and preventing other accidents such as wheels-up landings or collisions with field obstructions. Efficiency benefits derive primarily from reducing flying time.

Additional benefits beyond these two categories are realized by the presence of a tower, but are not readily quantifiable. Included are flight emergency assistance, search and rescue activities, and furnishing emergency communications. Both direct and indirect economic benefits accrue to a community through the presence of the facility and its integration into the larger overall national airspace system. Offsetting to some degree these economic benefits are negative impacts of airports such as noise and aircraft engine emissions. Some economic benefits which a community gains from the presence of a tower are offset by lost benefits experienced by other communities. Because these additional economic benefits and their offsets are subjective, often controversial, and/or small in comparison to safety and efficiency benefits, they have been excluded from this analysis.

A. Background

The benefit estimation procedure presented below has been developed to:

- Comply with P.L. 100-223
- Make full utilization of existing data sources
- Recognize functional differences among classes of airport users in today's deregulated environment

The procedures also incorporate new accident rates and current economic values used to calculate benefits.

Section 308 of P.L. 100-223 states:

> "Not later than December 31, 1988, the Secretary shall promulgate regulations to establish criteria for the installation of airport control towers and other navigational aids. For each type of facility, the regulations shall, at a minimum, consider traffic density (number of aircraft operations without consideration of aircraft size), terrain and other obstacles to navigation, weather characteristics, passengers served, and potential operating efficiencies."

In fulfillment of the Congressional direction, the benefits methodology developed below makes no distinction with respect to aircraft size. Previous aircraft size dependent user classifications are replaced by generic functional user groupings. The value of tower prevented fatalities and injuries and saved passenger time is calculated based on operations and passengers served rather than aircraft size.

At towered airports, data are currently available on operations classified by scheduled commercial, nonscheduled commercial and noncommercial traffic. For nontowered airports, the Official Airline Guide (OAG) provides similar data for scheduled commercial operations, while Form 5010 data provided by airport proprietors may be used to determine operations for nonscheduled commercial and noncommercial operations. These data, both actual and forecast, are incorporated in FAA's Terminal Area Forecast (Reference 3).

Scheduled commercial operations utilize airline personnel to perform some of the functions outlined for tower personnel. Although they are not situated as well as tower personnel, airline personnel generally contact pilots to advise them on known traffic, runway usage and weather information.

Because of functional differences and availability of data required to calculate benefit-cost ratios, three generic functional categories of airport users are established:

SCS - Scheduled Commercial Service
NCS - Non-scheduled Commercial service
NC - Non-commercial Traffic.

Airport traffic control towers are effective in preventing collision between aircraft. The primary responsibility of the VFR tower controller is to provide aircraft sequencing in the air and separation on the ground. Controllers determine aircraft position and issue control instructions and clearances to pilots accordingly. Controllers determine aircraft position from pilot reports and by direct observation of the aircraft. Clearances issued by controllers for purposes of sequencing and separation are binding on pilots, unless the pilot refuses the clearance.

While controllers may direct pilots only for air traffic control purposes, they are well positioned to advise the pilot on matters such as adverse weather, obstructions on the airport site, or landing gear not extended. Controllers can also summon aid for pilots when needed, such as equipment for fire fighting or search and rescue.

A secondary responsibility is to expedite the flow of traffic. Normal safety procedures used in the absence of a control tower, such as entering and flying in the airport traffic pattern and overflying the airport to determine such information as wind direction and airport obstructions, result in additional flying time for aircraft landing at nontowered airports. Thus, the total safety benefits of VFR towers derive from more than the primary function of sequencing traffic.

Tower benefits are estimated in three main categories for each user class:

B1: Benefits from prevented collisions between aircraft.
B2: Benefits from other prevented accidents.
B3: Benefits from reduced flying time.

For a proposed tower establishment or discontinuance site, the tower benefits B1 through B3 for each year of a 15-year time frame are estimated based on actual and projected operations counts from FAA's Terminal Area Forecasts (Reference 3). The details of the derivation of each of the benefits are described in the following sections.

B. Benefits from Prevented Collisions between Aircraft

The effectiveness of air traffic control towers in reducing the risk of collisions between aircraft is measured by the difference in rates of collisions per annual operations at towered and non-towered airports. To assess this differential, data on collisions from the National Transportation Safety Board (NTSB) from 1983 through 1986 were analyzed. All collisions occurring within five miles of airports with 10,000 to 250,000 annual operations were included in this analysis except collisions involving:

- Intentional close proximity flying (such as formation flying)
- Accidents within five miles of military airports[1/]

A description of this analysis is contained in Appendix A.

Three categories of collisions were considered:

1. Collisions in which both aircraft were airborne
2. Collisions in which only one aircraft was airborne
3. Collisions in which both aircraft were on the ground

For all categories the annual number of collisions between aircraft at both towered and non-towered airports is considered to be directly proportional to the number of "potential collision pairs." The number

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1/ Unlike previous analysis used to develop establishment criteria, this analysis includes all classes of aircraft accidents: air carrier, commuter, air taxi, general aviation, helicopter, glider, and military operating at non-military controlled towers.

of potential collision pairs is the mathematical combination of the number of aircraft taken two at a time, which is approximately equal to the square of the annual operations divided by two[2/]. The following functional relationship between the annual number of collisions and the square of the annual operation count represent statistical "expected" or "mean" value for airport activity levels which bracket the range in which tower establishment decisions are typically made.

1. The expected number of collisions in which both aircraft were airborne (midair collisions) at towered airports, CM_T, is

$$CM_T = 0.834 \times (OPS/10^6)^2$$

   and at non-towered airports, CM_{XT}

$$CM_{XT} = 2.635 \times (OPS/10^6)^2$$

   where

   OPS = total annual operations

   Thus a tower may be expected to prevent

$$CM_{XT} - CM_T = 1.802 \times (OPS/10^6)^2$$

   midair collisions per year.

2. The expected number of collisions in which one aircraft was airborne at towered airports, CA_T, is

$$CA_T = 0.019 \times (OPS/10^6)^2$$

   and at non-towered airports, CA_{XT},

$$CA_{XT} = 1.257 \times (OPS/10^6)^2$$

   where

   OPS = total annual operations

   Thus a tower may be expected to prevent

$$CA_{XT} - CA_T = 1.238 \times (OPS/10^6)^2$$

   collisions, with one aircraft airborne, per year.

2/ The number of combinations of two elements that can be drawn from a set of n elements is n(n-1)/2. For large n, this is approximately equal to $n^2/2$. (See Appendix B)

3. The expected number of collisions on the ground at towered airports, CG_T, is

$$CG_T = 0.550 \times (OPS/10^6)^2$$

and at non-towered airports, CG_{XT},

$$CG_{XT} = 3.325 \times (OPS/10^6)^2$$

Thus a tower may be expected to prevent

$$CG_{XT} - CG_T = 2.775 \times (OPS/10^6)^2$$

collisions that occur on the ground per year.

For the above three accident categories, statistical difference of means t-tests were performed. These tests indicate the difference in nontowered and towered rates to be statistically significant at a 95 percent or higher confidence level.

Statistical confidence limits on differences in the number of collisions at towered and non-towered airports were also obtained, as discussed in Appendix A. Collision equations based on upper 95-percent confidence limits for the differences in the number of collisions at non-towered and towered airports for midair, one aircraft airborne and one on the ground, and both on the ground are:

with both aircraft airborne;

$$(CM_{XT} - CMT)^* = 3.978\ (OPS/10^6)^2$$

and with one aircraft airborne;

$$(CA_{XT} - CA_T)^* = 2.734\ (OPS/10^6)^2$$

and with both aircraft on the ground;

$$(CG_{XT} - CG_T)^* = 5.821 \times (OPS/10^6)^2$$

where the * denotes an estimate based on the upper bound 95-percent confidence interval.

Economic analysis generally assigns mean or expected values to parameters used in the computation of benefits and costs. The practice is followed here for tower establishment with the realization that other, more pessimistic or optimistic values may be substituted where site specific considerations dictate. For tower discontinuance, however, we do not normally know nor can we ascertain the site specific (as opposed to mean or expected) likelihood of collision occurrence in the absence of the tower. To ensure safety in the absence of such site-specific information, the upper bound, 95-percent confidence bound is used to assess the safety impact of existing towers.

To estimate the benefits of prevented collisions, it is necessary to determine the expected number of aircraft of each user class that would be involved in these prevented collisions. This derivation is presented in Appendix B. Briefly, the appendix demonstrates that the potential collision pairs for each user class is given by the product of its operations and total operations. Applying the prevented accident coefficient and multiplying by two to reflect aircraft rather than collisions yields the desired result:

$$2 \times RC(k) \times OPSM(i) \times OPSALL$$

where:

RC(k) = a collision coefficient for collision type k from Table 4.1

OPSM(i) = total operations for user class i <u>in millions</u> from Terminal Area Forecasts

$$OPSALL = \sum_{i=1}^{3} OPSM(i) \text{ (also in millions)}$$

Once the number of aircraft for each user class that would be involved in the prevented accidents is known, benefits are estimated by determining the avoided fatalities, serious and minor injuries, and aircraft damage associated with these accidents and assigning explicit values to these avoided losses. The following presents the detailed methodology to estimate avoided fatalities, serious and minor injuries, and aircraft damage.

The number of fatalities in collisions between aircraft is the product of the number of aircraft in collisions and the number of fatalities per aircraft--the fraction of occupants killed per aircraft times number of occupants. Thus the number of fatalities for user class, i, is

$$FCM(i) = 2 \times (RCM \times OPSM(i) \times OPSALL) \times (CMIF \times LO(i))$$

in collisions with both aircraft airborne, FCM(i),

$$FCA(i) = 2 \times (RCA \times OPSM(i) \times OPSALL) \times (CAIF \times LO(i))$$

in collisions with one aircraft airborne, FCA(i), and

$$FCG(i) = 2 \times (RCG \times OPSM(i) \times OPSALL) \times (CGIF \times LO(i))$$

in collisions with both aircraft on the ground, FCG(i), where

RCM = coefficient for collisions for both aircraft airborne from Table 4.1

Table 4.1

Coefficients Used to Calculate Differences in Number of Collisions Without and With Towers[a/]
(Per Million Operations)

Collision Type	Symbol RC(k)	Establishment Mean Value	Discontinuance Upper Bound
Both airborne	RCM	1.802	3.978
One airborne	RCA	1.238	2.734
Both on ground	RCG	2.775	5.821

a/ From Appendix A

RCA	-	coefficient for collisions for one aircraft airborne from Table 4.1
RCG	-	collision coefficient for both aircraft on the ground from Table 4.1
CMIF	-	fraction of occupants killed in collisions with both aircraft airborne from Table 4.2
CAIF	-	fraction of occupants killed in collisions with one aircraft airborne from Table 4.2
CGIF	-	fraction of occupants killed in collisions with both aircraft on the ground from Table 4.2
LO(i)	-	average number of occupants aboard user class i aircraft estimated on an airport specific basis[3/]

3/ For scheduled commercial service, LO is estimated based on passengers served and operations at each airport. For other users, the estimate is based on aircraft serving the airport.

The expected number of fatalities for user class i prevented by a tower is the sum of the fatalities in the three collision categories:

$$FCM(i) + FCA(i) + FCG(i) = 2 \times (RCM \times CMIF + RCA \times CAIF + RCG \times CGIF) \times OPSM(i) \times OPSALL \times LO(i)$$

The total number of fatalities in all collisions a tower may prevent in one year, IF1, is obtained by summing over the three user classes:

$$IF1 = \sum_{i=1}^{3} 2 \times (RCM \times CMIF + RCA \times CAIF + RCG \times CGIF) \times OPSM(i) \times OPSALL \times LO(i)$$

The expressions for the number of serious injuries, IS1, and the number of minor injuries, IM1, are analogous to the above:

$$IS1 = \sum_{i=1}^{3} 2 \times (RCM \times CMIS + RCA \times CAIS + RCG \times CGIS) \times OPSM(i) \times OPSALL \times LO(i)$$

$$IM1 = \sum_{i=1}^{3} 2 \times (RCM \times CMIM + RCA \times CAIM + RCG \times CGIM) \times OPSM(i) \times OPSALL \times LO(i)$$

where

CMIS, CMIM = fraction of occupants sustaining serious, minor injuries in collisions with one or both aircraft airborne from Table 4.2.

CAIS, CAIM = fraction of occupants sustaining serious, minor injuries in collisions with one aircraft airborne from Table 4.2.

CGIS, CGIM = fraction of occupants sustaining serious, minor injuries in collisions with both aircraft on the ground from Table 4.2.

Similar expressions are developed to estimate the number of destroyed or substantially damaged aircraft which would be prevented by installing a tower. The number of of user class i aircraft destroyed, for example, is the product of the fraction of aircraft destroyed (Table 4.2) and the number of aircraft involved in collisions:

$$2 \times (RCM \times CMDS + RCA \times CADS + RCG \times CDGS) \times OPSM(i) \times OPSALL$$

where

CMDS, CADS, CDGS = fraction of aircraft destroyed in the corresponding collision category from Table 4.2

Table 4.2

Injury Severity and Damage Severity Fractions in Collisions Between Aircraft[a]

Injury Severity	Both Airborne Symbol	Both Airborne Value	One Airborne Symbol	One Airborne Value	Both on Ground Symbol	Both on Ground Value
Fatal	CMIF	0.534	CAIF	0.000	CGIF	0.024
Serious	CMIS	0.113	CAIS	0.025	CGIS	0.028
Minor	CMIM	0.086	CAIM	0.150	CGIM	0.071
None	-	0.267	-	0.825	-	0.877
Damage Severity						
Destroyed	CMDS	0.495	CADS	0.154	CGDS	0.136
Substantial	CMDM	0.380	CADM	0.654	CGDM	0.700
Minor/None	-	0.125	-	0.192	0	0.164

a/ Calculated from NTSB data accident file for 1983 through 1986.

To obtain the dollar value of all aircraft destroyed in collisions, DS1, the product of the number of user class i aircraft and the value of the user class i aircraft are summed over the three user classes:

$$DS1 = \sum_{i=1}^{3} 2 \times (RCM \times CMDS + RCA \times CADS + RCG \times CGDS) \times OPSM(i) \times OPSALL \times VDS(i)$$

and similarly, the dollar value of all aircraft substantially damaged in collisions, DM1, is.

$$DM1 = \sum_{i=1}^{3} 2 \times (RCM \times CMDM + RCA \times CADM + RCG \times CGDM) \times OPSM(i) \times OPSALL \times VDM(i)$$

where

VDS(i), VDM(i) = dollar value of destroyed, substantially damaged aircraft of user class i estimated on an airport specific basis[4/]

CMDM, CADM, CGDM = fraction of aircraft substantially damaged in the corresponding collision category from Table 4.2

The annual benefit from prevented collisions between aircraft, is the sum of the dollar values of the differences between expected fatalities, injuries and property losses without a tower and with a tower:

$$B1 = (IF1 \times VF) + (IS1 \times VS) + (IM1 \times VM) + DS1 + DM1$$

where

VF, VS, VM = dollar value of one fatality, $1,500,000; serious injury, $640,000; minor injury, $2,300.

In order to provide the public and government officials with a benchmark comparison of the expected safety benefits of rulemaking actions over an extended period of time with estimated costs in dollars, the FAA currently uses a value of $1.5 million to statistically represent a human fatality avoided. This is in accordance with guidelines issued by the Office of the Secretary of Transportation in a memorandum dated June 22, 1990.

C. <u>Benefits from Other Tower Preventable Accidents</u>

In addition to collisions between aircraft, other kinds of accidents occur with lower frequency at towered airports. Two techniques may be used to estimate the number and value of accidents preventable by a tower. The first technique is based upon an analyst's review of detailed accident records. A determination is made as to whether or not a tower could have prevented that accident. For example, pilots who crashed with landing gear retracted might have corrected their error if the tower had observed it. Such accidents are deemed preventable in daylight but not at night

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4/ For scheduled commercial service, VDS and DVM are estimated on operations and passengers served. Values for other users are based on aircraft serving the airport.

when a controller cannot see the gear. The accidents which are judged avoidable and which occurred at non-towered airports are counted, and divided by operations counts at non-towered airports to yield a preventable accident rate.

A second technique is to calculate accident rates for towered and non-towered airports. The difference in rates between towered and non-towered airports yields a rate for preventable accidents.

A difficulty with the first technique is that the judgment is largely subjective and relies on standard accident reports which may not contain sufficient information to draw an inference. The second technique, used to compare rates at towered and non-towered airports corrects for this difficulty. However, the accident rate difference is not solely attributable to the tower because of differences in the total physical and operational environment between towered and non-towered airports. For example, towered airports typically have multiple runways, more paved runways, runway lights, landing aids (ILS, VASI, REIL and approach lights) and more UNICOM service available. Furthermore, there appear to be differences in the level of pilot experience as well as the types of aircraft.

The shortcomings of the second method can be largely overcome by restricting the analysis to those classes of accidents which a tower, and not other types of equipment, primarily prevent 5/. Accordingly, accidents from 1983 to 1986 were examined in detail and the inappropriate ones deleted without consideration of whether a tower was operating. Then the difference in rates between the group of non-towered and towered airports was obtained. The analysis focused on the following six tower preventable accident categories:

1. Wheels-up landings. Theoretically, an accident could be prevented if the pilot is warned by the controller of the gear retraction.

2. Collisions of aircraft with objects other than aircraft. Other objects include construction barriers or other unusual hazardous objects of which the controller could warn the pilot.

3. Landing on wrong runway relative to existing wind. This category includes cases where the aircraft landed in the wrong direction relative to the wind.

4. Not aligned with the runway (or intended landing area). The tower controller could theoretically spot an aircraft in danger of landing off the runway and warn the pilot of the erroneous heading.

5/ Appendix A presents evidence that this approach is largely successful in eliminating the impacts of other equipment and airport characteristics.

5. Overshoots.

6. Undershoots.

The resultant mean values are 2.583 accidents per million operations at non-towered airports vs. 1.398 accidents per million at towered airports, a difference of 1.185 accidents per million operations. Using a difference of means t-test, this difference in accident rates was statistically significant at the 99 + percent level of confidence. For each user group, other tower prevented accidents are given by:

$$1.185 \times OPSM(i)$$

As in the collision analysis, we conservatively use statistical confidence limits on the number of accidents in discontinuance criteria, whereas mean values are used in establishment criteria. The upper 95-percent confidence limit for the difference in the number of accidents which a tower might prevent in one year (from Appendix A) is

$$1.546 \times OPSM(i)$$

The above accident functions are used to compute prevented accidents for each user class except scheduled commercial. Scheduled commercial pilots are required to have radio communication with ground personnel who are able to observe some of the conditions which lead to these accidents. But such personnel would not normally have as good a view of the airport environment as a controller would, and after providing an initial traffic advisory, there is little further visual contact. Thus, the carrier ground personnel may not be as effective as a tower in preventing some of these accidents. Since limited data are available to calculate scheduled accident rates for these accident types, one half of the rate used for other classes is used at an approximation for scheduled commercial carriers.

The annual benefit from other tower preventable accidents, B2, is the sum of the dollar values of the additional fatalities, injuries, and property losses expected to occur if no tower is installed or an existing tower is discontinued:

$$B2 = (IF2 \times VF) + (IS2 \times VS) + (IM2 \times VM) + DS2+DM2$$

where

IF2, IS2, IM2 =	expected number of fatal, serious and minor injuries in tower-preventable accidents (calculated below)
VF, VS, VM =	dollar value of one fatality, $1,500,000; serious injury, $640,000; minor injury, $2,300
DS2, DM2 =	dollar value of destroyed, damaged aircraft in these preventable accidents (calculated below)

The expressions used to calculate IF2, IS2, IM2, DS2, DM2 are similar to the corresponding expressions for B1, except that the number of accidents is equal to the number of aircraft involved. For example, the number of fatalities prevented for user class i is the product of the number of aircraft involved in a tower preventable accident and the number of fatalities per aircraft--the fraction of occupants killed per aircraft times the number of occupants per aircraft:

$$(R2(i) \times OPSM(i)) \times (FIF2(i) \times LO(i))$$

where

R2(i) = tower preventable accident rate from Table 4.3

FIF2 = fraction of occupants killed from Table 4.4

LO(i), OPSM(i) are as defined above

Table 4.3

Tower Preventable Accident Rates[a/]
(Per Million Operations)

Classes	Scheduled	Nonscheduled Commercial	Noncommercial
Mean value	.593	1.185	1.185
Confidence limit	.773	1.546	1.546

a/ From Appendix A

The total number of fatalities in tower preventable accidents in one year is obtained by summing over the three user classes:

$$IF2 = \sum_{i=1}^{3} R2(i) \times FIF2(i) \times LO(i) \times OPSM(i)$$

Similarly,

$$IS2 = \sum_{i=1}^{3} R2(i) \times FIS2(i) \times LO(i) \times OPSM(i)$$

$$IM2 = \sum_{i=1}^{3} R2(i) \times FIM2(i) \times LO(i) \times OPSM(i)$$

$$DS2 = \sum_{i=1}^{3} R2(i) \times FDS2(i) \times OPSM(i) \times VDS(i)$$

$$DM2 = \sum_{i=1}^{3} R2(i) \times FDM2(i) \times OPSM(i) \times VDM(i)$$

where

FIS2(i), F2M2(i) = fraction of occupants sustaining, serious and minor injuries from Table 4.4

FDS2(i), FDM2(i) = fraction of aircraft destroyed, substantially damaged from Table 4.4

VDS(i), VDM(i) are as defined above

Table 4.4

Values for Injury and Damage Fractions used to Calculate Accident Benefits[a/]

User Group	Fraction Fatalities FIF2(i)	Fraction Serious Injuries FIS2(i)	Fraction Minor Injuries FIM2(i)	Fraction Aircraft Destroyed FDS2(i)	Fraction Aircraft Substantially Damaged FDM2(i)
1. Scheduled Commercial	.131	.035	.083	.185	.778
2. Nonscheduled Commercial	.004	.015	.090	.039	.922
3. All Other	.013	.033	.103	.062	.930

a/ Calculated from NTSB data used to develop other tower preventable accident rates.

D. Benefits From Reduced Flying Time

A control tower increases the efficiency of aircraft approaches and landings resulting in savings of aircraft operating costs and passengers' time. According to standard traffic procedures, some aircraft must overfly a non-towered airport to obtain such information as wind direction and traffic pattern direction and configuration which would be available from a controller at a towered airport.

Furthermore, the controller can direct aircraft to enter the traffic pattern on a right or left base leg or fly a straight-in approach. At a non-towered airport the usual procedure would be for a pilot to enter the airport traffic pattern on the upwind, crosswind, or downwind leg, which would result in additional flying time for many aircraft. The benefits from reduced flying time, B3, consist of these two categories--avoided overflying and avoided traffic pattern flying.

1. Overflying

We first derive the amount of additional time required for overflying each year. Before attempting a landing, the pilot must obtain such information as wind direction, obstructions, and traffic. If there is no tower, UNICOM, or Flight Service Station, the pilot will usually overfly the airport to obtain this information. However, a pilot approaching an airport when the wind is greater than 15 knots would usually have some other way to determine wind direction (Reference 9), and will probably not overfly the airport.

We further assume that most local flights will already have the required information, and will not overfly. Neither will IFR flights, since an instrument approach at a non-towered airport is usually "straight-in." Furthermore, scheduled carriers are required to have air-ground radio communication to obtain this same information, and would rarely, if ever overfly an airport.

Thus, the number of aircraft which overfly when there is no tower is the product of:

- number of itinerant landings by other than scheduled operators (half the number of itinerant operations by user classes other than scheduled service = NOPS(i)/2)
- fraction of landings with wind less than 15 knots[6/] (0.89)
- fraction of landings in visual conditions[6/] (0.9744)
- fraction of time UNICOM is not operating[6/] (0.30)

[6/] From Reference 9.

[7/] From Reference 4.

Annually, the number of aircraft by user class other than scheduled service which overfly is

$$0.89 \times 0.9744 \times 0.30 \times NOPS(i)/2 = .13 \times NOPS(i)$$

In other words, overflying is associated with approximately 13 percent of the operations (26 percent of the landings).

The additional time required to overfly an airport is approximately 1.5 minutes[7] or 0.025 hours for all itinerant flights but scheduled carriers. Thus annual additional overflying time is given by

$$0.130 \times NOPS(i) \times 0.025 \text{ hours} = 0.00325 \times NOPS(i) \text{ hours.}$$

Because overflying will not occur in the presence of a nearby flight service station (FSS), overflying time is set to zero when an FSS is nearby.

2. Traffic Pattern Flying

We now derive the additional time required to enter and fly in the airport traffic pattern at a non-towered airport. Figure 4.1 gives an example of a typical active runway and traffic pattern configuration. Aircraft approaching between A and D or D and C will simply enter the traffic pattern with no additional flying time required. However aircraft approaching between A and B which could make the shortest approach under air traffic control will need additional time to fly over to enter the upwind leg and then fly the entire upwind leg and the remainder of the traffic pattern. This will require from one to two minutes additional flying time.

Aircraft approaching between B and C will have to fly the upwind, crosswind, and downwind legs instead of making a more direct approach. This will result in between zero and one minute additional flying time. If we assume a uniform distribution of aircraft approaching the airport from all directions, then the amount of additional flying time will average

1/2 minute or 1/120 hours.

Case (a): If there is a flight service station, hence no overflying, then the nonscheduled itinerant arrivals, NOPS(i)/2, will fly an additional

$$NOPS(i)/2 \times (1/120 \text{ hours}) = 0.00417 \times NOPS(i)$$

hours in one year.

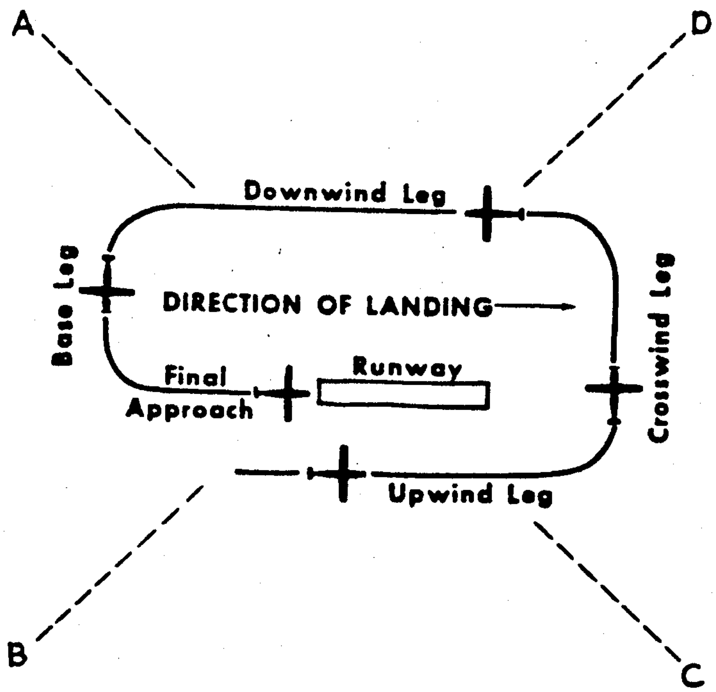

Figure 4.1 Example of Airport Traffic Pattern

Case (b): If there is no flight service station, the 26 percent of the itinerant arrivals which overfly will not require the additional traffic pattern time since this time is already included in the overflying time. Thus the remaining 74 percent arrivals will have the additional one-half minute time in the traffic pattern. Thus,

$$0.74 \times (NOPS(i)/2) = 0.37 \times NOPS(i)$$

aircraft will fly

$$(0.37 \times NOPS(i)) \times (1/120 \text{ hours}) = 0.00308 \times NOPS(i)$$

hours each year.

3. Sum of Reduced Flying Time

The total reduced flying time for the two cases is summarized below:

Case (a): The additional flying time at a non-towered airport with no FSS is

0.00325 x NOPS(i) hours for overflying
0.00308 x NOPS(i) hours for traffic pattern
0.00633 x NOPS(i) hours total

Case (b): With a nearby FSS, additional flying time is

0.00417 x OPS(i) hours total (for traffic pattern only)

4. Converting to Monetary Units

To evaluate the benefit from reduced flying, B3, in dollars, the reduced flying time for each nonscheduled user class is multiplied by the average "value" specific to that class for flying an aircraft for one hour at the airport being evaluated. This average "value" is the sum of the variable operating cost for one hour, VO, and the product of the average number of passengers, LP(i), times the value of passengers' time per hour ($35), VT:

VHR(i) = VO(i) + (LP(i) x VT(i))

Thus B3 = (TIME x NOPS(i) x VHR(i))

where

TIME = additional flying time coefficient from above: 0.00633 if no nearby FSS, 0.00417 for nearby FSS, and

the sum extends over the nonscheduled commercial and noncommercial users.

E. Other Benefits

These benefits which are considered nonquantifiable include benefits to the total system, providing advance information to other facilities and aircraft, providing emergency in-flight assistance, participating in search and rescue activities, acting as communication centers in times of natural disasters, stimulating the local economy, etc. While acknowledging these other benefits, the current analysis does not quantify them.

In order to conduct operations at a non-towered airport, a scheduled carrier must be furnished local traffic advisory information from an air/ground radio communications facility located in a position from which the operator is capable of observing local traffic and issuing traffic advisories. This means that the carrier must have a trained observer on site as well as the communications equipment. Thus, an additional tower benefit, not considered in this analysis, derives from not having to provide this service. For the small number of scheduled operations at non-towered airports, the costs of this service are not significant, because the work is a collateral duty for someone who would be on site for ticket taking, baggage handling, etc. For very large numbers of scheduled operations--many more than is typical of airports qualifying for towers--the work avoided by a tower could have a benefit of avoided salary to the carrier.

F. Adjusting Benefits to Account for Hours of Operation

It is important, at this point, to make some adjustments to account for differences between benefit calculations for establishment criteria and decommisioning criteria. We first note that forecasts of operations given in Reference 3 and used to calculate tower benefits represent 24 hours per day at non-towered airports, but only the hours when the tower is operating at towered airports.

In calculating the benefits of establishing a control tower, then, the above benefit calculations must be modified to represent the fact that new towers will only operate 12 hours per day. Generally 92.5 percent of the operations occur in the busiest 12 hour period. Thus there would be no benefit to the 7.5 percent of the operations occurring in the other twelve hours. Therefore, only 92.5 percent of the benefits should be assigned to tower establishment. Thus, to calculate the benefits of tower establishment, B1, B2, and B3 calculated above are replaced by (0.925 x B1), (0.925 x B2), and (0.925 x B3). If a tower establishment candidate will operate less than 12 hours per day, the 92.5 percent should be adjusted to reflect the percentage of daily operations which will occur when the tower is open.

On the other hand, all of the benefits calculated above are used for the discontinuance case, since towered airport operation counts already reflect only those hours when the tower is operating.

G. Total Annual Benefits

The total annual benefits, BT, of an airport traffic control tower is the sum of the benefits in the three categories above:

$$BT = B1 + B2 + B3$$

Using the TAF data, this benefit sum can be computed as discussed above for each year of the 15-year time-frame.

H. Total Lifetime Benefits

For each year j, in the 15-year time frame of our analysis, let BT(j) be the total annual benefit calculated above. The present value BPV of these BT(j)'s is calculated as follows:

$$BPV = \sum_{j=1}^{15} \frac{BT(j)}{(1 + DISC)^{j-0.5}}$$

where DISC is the discount rate expressed in fractional form. We use a 10 percent discount rate, i.e. DISC = 0.10, as prescribed by the Office of Management and Budget.

V. RESULTS AND IMPACT OF TOWER CRITERIA

The tower criteria were applied to the 4070 airports in the latest version of the Terminal Area Forecast (TAF) file to determine the number of airport sites which become candidates for tower establishment or discontinuance.[1] A total of 64 military airports, 11 RAPCON/RATCF, 10 traffic control, and 2 common IFR rooms were excluded from analysis. For the resulting list of 3983 airports, benefit-cost analysis was performed to obtain a screening list of establishment and discontinuance candidates which will be evaluated using site-specific data.

Benefit-cost analysis utilized the most recent aviation activity forecast from the 1989 TAF file, the standard economic unit values, costs and benefits developed in Chapters III and IV. This TAF file contains reported activity data through 1987 and forecast activity data for the years 1988 through 2005. Economic unit values include: the statistical value of life, the dollar value associated with serious injury and minor injuries, and the dollar value of passenger time. All calculations were performed in 1988 dollars and assume tower installation in 1990.

For this initial screening of all airports, standardized national average costs were applied to all airports. For those airports that qualify under this initial screening, a site-specific analysis will be conducted using site-specific costs rather than national averages.

Within the TAF file, activity data for non-towered airports is reported by the airport operator. Before the airport may become an FAA tower candidate, activity levels must be verified by three on-site traffic surveys.

A. Establishment Criteria Results

A total of 3,582 airports without FAA towers were evaluated for tower establishment. The distribution of airports by tower status follows:

Table 5.1

Distribution of Sites Screened for Establishment by Tower Status

No tower	3,496
Decommissioned	4
FAA contract towers	20
Nonfederal towers	43
FAA tower temporarily closed	19
Total	3,582

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1 As of December 1989.

Of the total number of airports considered for establishment, 29 had benefit-cost ratios equal to or greater than 1, and thus qualify to be further evaluated on a site specific basis.

Of these 29 airports, with benefit-cost ratios equal to or greater than 1, 17 were non-towered airports, 3 were FAA contract towers, and 9 were non-federal control towers.

The distribution of establishment benefit cost ratios follows:

Table 5.2

New Establishment Criteria Results,
Sorted by Benefit-Cost Ratio Ranges

B/C Range Results	Number of Airports
0.00 - 0.4999	3,499
0.50 - 0.7499	34
0.75 - 0.8999	16
0.90 - 0.9999	4
1.00 - 1.0999	1
1.10 - 1.9999	14
2.00 - over	14

Of those airports, with benefit cost ratios in excess of 1, 14 sites have benefit-cost ratios greater than 2.0; in other words, the benefits from installing a tower would be more than double the costs over the fifteen years. An additional 14 sites have benefit-cost ratios greater than 1.1.

Sites with benefit-cost ratios between 0.9 and 1.09 are considered "borderline" candidates. Consideration of these sites as potential establishment candidates should be based on other economic and non-economic factors not captured in the criteria. Five sites have ratios between 0.9 and 1.0999.

B. Tower Discontinuance Results

All current FAA towers, excluding 20 contract towers, were considered for tower discontinuance. Of those airports, 31 VFR towered sites have benefit-cost ratios less than 1 and thus are candidates for discontinuance.

The distribution of discontinuance benefit-cost ratios follows:

Table 5.3

New Discontinuance Criteria Results,
Sorted by Benefit-Cost Ratio Ranges

B/C Range Results	Number of VFR Towered Airports
0.00 - 0.7499	21
0.75 - 0.8999	4
0.90 - 0.9999	6
1.00 - 1.0999	8
1.10 - 1.9999	31
2.00 - over	121

For discontinuance criteria, only those benefit-cost ratios between 0.9 and 1 are considered borderline candidates. Six sites have ratios between 0.9 and 0.9999. Again, discontinuance decisions for these 6 sites would be based on other economic or non-economic factors, not captured in the criteria.

C. Comparison with Previous Results

Since major changes have been instituted in methodology, costs, and standard unit economic values, a comparison of screening results under old and new criteria was made. Results from application of benefit-cost estimating procedures incorporated in 1983 criteria (OLD) differed somewhat from results derived by applying methodology outlined in new (NEW) criteria. The summary results are presented in Table 5.4.

Table 5.4

Comparison of Old and New Benefit-Cost Screening Results

	OLD	NEW
Establishment		
1 and over	32	29
Discontinuance		
0.0 - 1	26	31

The old criteria, with old costs and old economic values formed the base analysis. If no changes were made to 1983 criteria, 32 sites would have been candidates for site specific establishment analysis, while 26 airports would have been candidates for site-specific discontinuance analysis. The new criteria, reflecting updated accident rates, updated standard unit economic values and elimination of reference to aircraft size, yields 29 establishment candidates and 31 candidates for discontinuance.

REFERENCES

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2. Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Report Number FAA-APO-89-10, FAA, October 1989.

3. Terminal Area Forecasts Fiscal Years 1989-2005, Report Number FAA-APO-89-5, FAA, April 1989.

4. Establishment and Discontinuance Criteria for Airport Traffic Control Towers, Final Report, Report Number APO-83-2, FAA, August 1981.

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6. Establishment Criteria for Airport Traffic Control Towers (ATCT), Report Number ASP-75-4, FAA, October 1975.

7. Air Traffic Staffing Standards System, FAA Order 1380.33B, March 10, 1980.

8. Airman's Information Manual, Official Guide to Basic Flight Information and ATC Procedures, FAA, 1986.

9. Establishment and Discontinuance Criteria for Automated Weather Observing Systems (AWOS), Report Number APO-83-6, FAA, May 1983.

APPENDIX A

DETERMINATION OF ACCIDENT RATE REDUCTION BENEFITS

This Appendix describes the procedures that were used in determining the accident reduction benefits of towers.

Accident Information

The National Transportation Safety Board (NTSB) maintains computer summaries of all accidents involving U.S. civil and foreign registered aircraft on U.S. soil. All accidents for the period extending from 1983 through 1987 were initially considered. The original accident data were then screened based on several criteria that were determined to be appropriate for this study.

1. Accidents which occurred outside the five mile radius of an airport were excluded from consideration.

2. Accidents that were not determined to be tower preventable were excluded.

3. Collisions involving intentional close flying and accidents which occurred at military towered airports were excluded.

4. The NTSB data includes only those accidents where the investigation is concluded and the cause of the accident has been determined. Due to the large proportion of incomplete investigations for 1987 accidents and the inability to control for the resulting bias of using partial data, the 93 releasable accidents that occurred in 1987 were excluded.

These screenings left the following numbers of accidents available for further consideration.

Collisions	
Midair	52
One Airborne	13
Both on Ground	52
Other Tower Preventable Accidents	1483

Total	1600

Operations Information

Annual operations data and tower information for the top nonmilitary towered 4008 U.S. airports were taken from the Aviation and Data Analysis System (ADA) developed and maintained by the FAA Office of Aviation Policy and Plans. The accident information for each airport was then matched and merged with the location identifiers in the operations data set. Of the 1600 available accident records, matches were found for 1178. The inability to match the remaining 422 records is explained by three factors.

1. The NTSB airport code for 172 of these accidents was listed as "None" even though they were described as being within five miles of an airport.

2. The majority of the remaining accidents that did not match occurred at extremely small airports not included in the ADA data set. All of these accidents occurred at nontowered airports and their omission reduces the calculated difference between tower and nontower accident rates. However, as described later, these accidents would have been omitted anyway since they occurred at airports outside the reasonable scope of consideration for tower establishment.

3. The location identifiers for a limited number of the accident records did not match due to minor variations in coding; e.g., NC5 versus NC05, NC-5, or NCO5. Where it was possible, these differences were manually corrected.

The match/merge operation resulted in the following numbers of remaining accidents distributed over four years at the 4008 airports.

Collisions	
Midair	44
One Airborne	11
Both on Ground	47
Other Tower Preventable Accidents	1103

Total	1178

<u>Airport Selection Criteria</u>

The final selection process excluded the airports, and any associated accidents, where there were less than 10,000 or more than 250,000 annual operations. Limiting consideration to the airports within this range served two purposes. First, the accident rate difference would then be based on the range of airports where the establishment or discontinuance of a tower was a reasonable consideration. Secondly, and just as important, the exclusion of airports with over 250,000 operations served as an additional control for the accident reduction benefits of the other facilities and equipment that are disproportionately found at larger airports. The combination of excluding large airports and only considering tower preventable accidents effectively controls for the impact of other facilities and equipment.

The final selection process resulted in a data set containing 2227 airports with the following distribution of their associated accidents.

Collisions	
Midair	33
One Airborne	8
Both on Ground	36
Other Tower Preventable Accidents	787

Total	864

Accident Rate Calculation Procedure

Average incidence rates for each of the four accident categories were calculated at both towered and nontowered airports. For the category "other preventable accidents" the rates were expressed as annual accidents per million annual operations. By contrast, the existing literature and FAA experience have shown that collisions between planes, as opposed to single aircraft accidents, are better explained as a function of accidents per operation squared. This is because collision opportunity is measured as the number of potential pairs of aircraft (combinations), which in turn is a function of the square of the numbers of operations. Accordingly, the collision accident rates were expressed as annual accidents per million annual operations squared.

Average accident rates were first calculated across the four year period (1983 - 1986) at each airport and then the averages for towered and nontowered airports were computed. The difference in means between nontowered and towered airports was conducted for each accident category using a t-test. The rates, differences and confidence levels are presented in Table A-1. As indicated, all accident rate differences were significant at the 95 percent or better confidence level.

TABLE A-1
AVERAGE ACCIDENT RATES, DIFFERENCES AND CONFIDENCE LEVELS

	COLLISIONS			
	MIDAIRS	ONE AIRBORNE	BOTH ON GROUND	OTHER PREVENTABLE ACCIDENTS
NO TOWER				
Rate	2.635	1.257	3.325	2.583
TOWER				
Rate	0.834	0.019	0.550	1.398
DIFFERENCE				
Rate	1.801	1.238	2.775	1.185
Confidence	95%	95%	96%	99 + %

Tower Benefit Rate For Discontinuance Criteria

The need to ensure safety, combined with the acknowledged imprecision of benefit-cost methodology, requires that a preponderance of supporting evidence be available before recommending that an existing tower be closed. Precedence supports the policy that the criteria necessary to retain an existing tower should be lower than the criteria necessary to establish a new one.

For tower discontinuance, the previous FAA procedure employed the 95 percent upper confidence level of the estimated tower benefit as compared to the calculated mean benefit, described above, which is used for tower establishment. The upper confidence level concept was determined to be equally valid for the revised procedures described herein. Using this approach, we can be 95 percent confident that the true accident reduction benefit that would be lost by removing a tower is not actually larger than the benefit level that would be used in making the determination.

The following steps were followed in determining the tower benefit rates for discontinuance considerations. The differences between the average accident rates, by accident type, at towered and nontowered airports (Table A-1) represent the mean accident reduction benefits of towers. The standard errors of the tower benefit estimates were then calculated from the standard deviations of the towered and nontowered accident rates. Following that, the upper bound confidence levels were computed by adding the products of 1.96 (Z for 95 percent) times the standard errors for each accident type to their respective mean benefit levels. For comparison, both the mean and the 95 percent confidence level estimates for tower benefits are shown in Table A-2.

TABLE A-2
Tower Accident Reduction Benefits

	COLLISIONS			
	MIDAIRS	ONE AIRBORNE	BOTH GROUND	OTHER PREVENTABLE ACCIDENTS
MEAN BENEFIT	1.802	1.238	2.775	1.185
95% UPPER BOUND	3.978	2.734	5.821	1.546

Exploring Other Methods to Compute Accident Rates

After extensive research and testing of alternate approaches, the FAA determined that the best method of assessing the impact of towers on accident rates is to measure the difference between accident rates at nontowered and towered airports. This was done, as described above, for the three types of collisions and for other selected accidents. Two steps were taken to control for the impact of other safety related facilities and equipment (F&E), which are disproportionately co-located at towered airports, on measured accident rate differences. First, the range of airports considered was restricted to those airports likely to be the subject of a tower establishment or discontinuance decision (10,000 to 250,000 operations). Thus, the impact of F&E investments typically made at smaller or larger airports was minimized. Second, with respect to accidents other than collisions, the analysis was restricted to accidents known to be prevented primarily by towers.

To access whether or not investments other than towers were adequately controlled for, collision rates and other tower preventable accident rates were regressed on F&E endowments across airports. Although a variety of regression equations were tried, the basic form of the equation was:

Accident Rate = f (TOWER, APPCOV, NORNWYS, MAXRWLTH, HDRNWYS, ILS, NPA, VASI, REILS, LIGHTS, PCTGA)

where TOWER = The binary variable denoting the existence of a tower.

APPCOV = The binary variable denoting the existence of radar approach control at the airport.

NORNWYS = The number of operational runways at the airport.

MAXRWLTH = The maximum runway length at the airport.

HDRNWYS = The number of physical hard surfaced runways at the airport.

ILS = The number of instrument landing systems at the airport.

NPA = The binary variable denoting the existence of non-precision approach equipment at the airport.

VASI = The number of visual approach slope indicators at the airport.

REILS = The number of runway end identification light systems in place.

LIGHTS = The number of runway light systems in place.

PCTGA = The proportion of nonscheduled aircraft operations.

It was anticipated that the results would indicate a significant impact for towers in reducing accident rates and an insignificant effect for all other F&E, thus indicating that the impact of the other F&E had been adequately controlled. However, due to multicolinearity and other data problems, the results in general were not statistically reliable. Towers did have the expected sign in all cases at confidence levels of 90 percent or better.

Alternate research attempted to isolate the marginal effect of towers and other F&E on improving safety using multivariate analysis. This procedure employed a logit model which related the probability of an accident at an airport to the F&E investments made at the airport. This analysis yielded promising but inconclusive results for scheduled carriers. For noncommercial users, no credible results were obtained.

The failure of the logit multivariate analysis to isolate the marginal impact of towers and other F&E, other things held constant, may be attributed to at least two factors. First, accidents are very rare events with their occurrence subject to a large random component. This makes the measurement of the impact of safety investments on them difficult. Second, significant data problems existed in this effort. For example, exposure data--operations or other activity measures--are subject to large errors, sometimes in excess of 100 percent, at airports lacking FAA towers. Moreover, over 40 percent of the 11,407 accident files examined in this study could not be utilized. Without airport specific location identifiers, the accident files could not be tied using computer techniques to specific airports as required by the multivariate technique.

FAA is continuing to pursue the multivariate approach, hoping that additional analytical techniques will yield credible, usable results. Until such time, FAA believes that the accident rate reductions reported above in this appendix are the best estimates that can be made.

APPENDIX B

EXTENSION OF COLLISION FUNCTIONS TO MULTIPLE USER CLASSES

This Appendix documents details of the extension of collision functions to multiple user classes required for B1 benefit calculations which are not included in Chapter IV.

We assume that the collision functions CM_T, CM_{XT}, CA_T, CA_{XT}, CG_T, and CG_{XT} in Section IV.A apply to all three user classes. The following example shows how to extend results for one class to three aircraft classes.

Suppose the three user classes, 1, 2 and 3, have n_1, n_2 and n_3 operations in one year, where $n_1 + n_2 + n_3 = N$ and that there are C accidents per "potential collision pair."

<u>Case 1:</u> The number of "potential collision pairs" of aircraft in the same user class i is approximately

$$(n_i \times n_i)/2.$$

Thus we expect

$$C \times (n_i \times n_i)/2$$

collisions involving

$$C \times n_i \times n_i$$

user class i aircraft (two aircraft in each collision).

<u>Case 2</u>: The number of "potential collision pairs" of aircraft in different user classes i, j is simply

$$n_i \times n_j.$$

Thus we expect

$$C \times n_i \times n_j$$

collisions between class i and class j aircraft involving

$$C \times n_i \times n_j$$

aircraft from each user class.

Table B.1 shows how to calculate the number of aircraft involved in collisions for each class. As can be seen, the number of user class 1 aircraft involved in collisions is the sum of the number which collide with each class, namely $C \times n_1 \times N$. The total number of collisions for all classes is $C \times N^2/2$; the total number of aircraft in all classes involved is

$$(C \times n_1 \times N) + (C \times n_2 \times N) + (C \times n_3 \times N)$$

$$= C \times (n_1 + n_2 + n_3) \times N$$

$$= C \times N^2$$

namely two aircraft per collision (as expected).

To apply these results, they must be restated in terms of aircraft rather than collisions. As used above, C is the number of accidents per collision pair, namely per $N^2/2$, but the collision coefficients used in this report RC(k) are for the number of collisions, this is, for N^2 rather than $N^2/2$. Thus if the number of collisions to type k avoided by operating a tower for one year is

$$RC(k) \times (OPS/10^6)^2$$

then

$$2 \times RC(k) \times (OPS/10^6)^2$$

aircraft are involved per year. The number of collisions involving user two class i aircraft is

$$RC(k) \times [OPSM(i)]^2$$

and

$$2 \times R1 \times [OPS(i)]^2$$

user class i aircraft are involved in these collisions (two aircraft in each collision), where

R1 = a collision coefficient from Table 4.1

OPSM(i) = operations per user class i <u>in millions</u>

The number of collisions involving one user class i aircraft and one aircraft from a different user class j is

Table B.1

Calculating Expected Number of
Aircraft Involved in Collisions for Each User Class

User Class Combination	Number of Collisions[a]	Number of Aircraft Involved: Class 1	Class 2	Class 3
1,1	$C \times (n_1 \times n_1)/2$	$C \times n_1 \times n_1$		
1,2	$C \times n_1 \times n_2$	$C \times n_1 \times n_2$	$C \times n_1 \times n_2$	
1,3	$C \times n_1 \times n_3$	$C \times n_1 \times n_3$		$C \times n_1 \times n_3$
2,2	$C \times (n_2 \times n_2)/2$		$C \times n_2 \times n_2$	
2,3	$C \times n_2 \times n_3$		$C \times n_2 \times n_3$	$C \times n_2 \times n_3$
3,3	$C \times (n_3 \times n_3)/2$			$C \times n_3 \times n_3$
Total	$C \times (n_1 + n_2 + n_3)^2/2$ = $C \times N^2/2$	$C \times n_1 \times (n_1 + n_2 + n_3)$ = $C \times n_1 \times N$	$C \times n_2 \times (n_1 + n_2 + n_3)$ = $C \times n_2 \times N$	$C \times n_3 \times (n_1 + n_2 + n_3)$ = $C \times n_3 \times N$

a The number of combinations of two elements that can be drawn from a set of n elements is n(n-1)/2. For large n, this is approximately equal to $n^2/2$.

$$RC(k) \times OPSM(i) \times OPSM(j)$$

and

$$2 \times RC(k) \times OPSM(i) \times OPSM(j)$$

user class i aircraft are involved in these collisions. (There are, of course, an equal number of user class j aircraft involved.) The total number of user class i aircraft involved in all collisions is

$$2 \times RC(k) \times OPSM(i) \times OPSALL$$

where

$$OPSALL = \sum_{i=1}^{3} OPSM(i) \text{ (also in millions)}$$

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