The Art of Aviation Safety Benefits Analysis

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Notice

This document was originally published under the title *Guidelines for Conducting a Safety Benefits Analysis.*

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CONDUCTING A SAFETY BENEFIT ANALYSIS

PREFACE

This document describes an approach to predicting the safety benefits expected to accrue from a proposed project. The safety benefits analysis may be part of the Investment Analysis (IA) of a project specifically tasked to improve safety, or it may be part of an IA that has improved safety as one of several goals. In either case, the analysis methodology is the same.

There is another type of safety analyses that should be performed for any proposed project. The purpose of a *Systems Safety Assessment* is to ensure that the project has no negative effects on aviation safety or to provide mitigants to offset any negative effects. This evaluation is normally performed by a separate team. However, if the primary project goal is to enhance safety, then it is incumbent on the safety benefits analysis team to also consider if the project may have unanticipated negative safety consequences and to work with the *System Safety Assessment Team* to address such issues.

This document is a companion to and is partially based on *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis*[1] and to the Volpe report *Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development*.[2] This document only presents guidance on **predicting** the safety benefits of a proposed program. There is extensive guidance on evaluating the actual impact of a program **after** it is operational in *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis.*

And so we begin **…**

The Product Team (PT) will have identified the areas in which it expects the safety benefits to occur. It also should have reviewed how its product fits into the National Airspace System (NAS) architecture. However, the PT members may not be very familiar with developing supportable safety benefit estimates. Because it is important that the PT understand and assist the Investment Analysis Team (IAT) in the IA process, it is useful to have a step-by-step process for conducting the benefit analysis. This should also help in starting the formal benefit estimation process early.

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1 Operations Research and Analysis Division (ASD-430), Federal Aviation Administration, June 15, 2001. (Formerly published as, *General Guidelines for Conducting the Benefits Analysis Portion of an Investment Analysis)*.

2 Report No. WP-43-FA92F-99-1, Cambridge: Operations Assessment Division, DTS-59, Volpe National Transportation Systems Center, October 1998.

As with any effort, there are rules to follow. These may be found in Appendix A. Although the number of rules may seem excessive, if the benefit analysis generally follows the steps described below, it is unlikely that any of these rules will be violated. However, it is a good idea to frequently satisfy yourself that the analysis has not strayed beyond the bounds of the rules.

Documentation is an important part of the process, not only for historical records, but also to help clarify issues. By putting something on paper and then reviewing what was written, one often discovers "holes" and new insights. Full documentation is also needed so that future IAs will have access to information needed to develop their safety reference cases (which may include the impacts of your project). It also is needed for post-implementation assessment of the impacts of your project, which the General Accounting Office (GAO) has "requested" the FAA to do. ***The steps below that should be documented are prefaced with the underlined Greek letter delta**, **?** ?*

Documentation that is inappropriate for formal reports (possibly because of its detail) should be retained as part of the project file. Both paper and electronic copies of the project file should be placed in a central repository. The IA project leader should also retain paper and electronic copies. Far too often electronic copies of documentation produced by contractors has been lost.

Also, EVERYONE runs into unexpected difficulties. You will too, so start early.

A. FIRST STEPS ¾ THE SAFETY PROJECT AND ITS POSSIBILITIES

These first steps are particularly useful in focusing on the types of benefits that can be expected to occur, where they will occur, and what entities will play a part in their occurrence.

1. **?** Describe the project, including what and how it will "physically" and operationally change the NAS.

   For example, for ASDE-X, describe what it consists of and how it works: That is, include things like, "ASDE-X will locate and identify every aircraft on a runway or on a taxiway near a runway within ___ feet of its true position." At this stage, do not include statements like "ASDE-X will reduce runway accidents." Statements like the latter will come later.

2. *The Safety Benefits Universe*

   To assist the analyst in considering different aspects of a safety benefit analysis, the following pages include a set of diagrams termed *The Safety Benefits Universe*.[3]

[3] These diagrams have been adapted from *The Benefits Universe* diagrams in the document *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis*.

The *Universe* consists of four "dimensions" that help to categorize safety benefits with respect to different aspects of the National Airspace System (NAS) . Figure 1 presents the "top level" of this universe. The four "dimensions are

a) The *types* of safety benefits
b) The *entities* to whom safety benefits may accrue
c) The *operational domains* (environments) in which the safety benefits may accrue
d) The *enterprise regimes* that may be affected by the project and which may play a part in the generation of the benefits.

These four dimensions, illustrated in Figure 1, are described below.

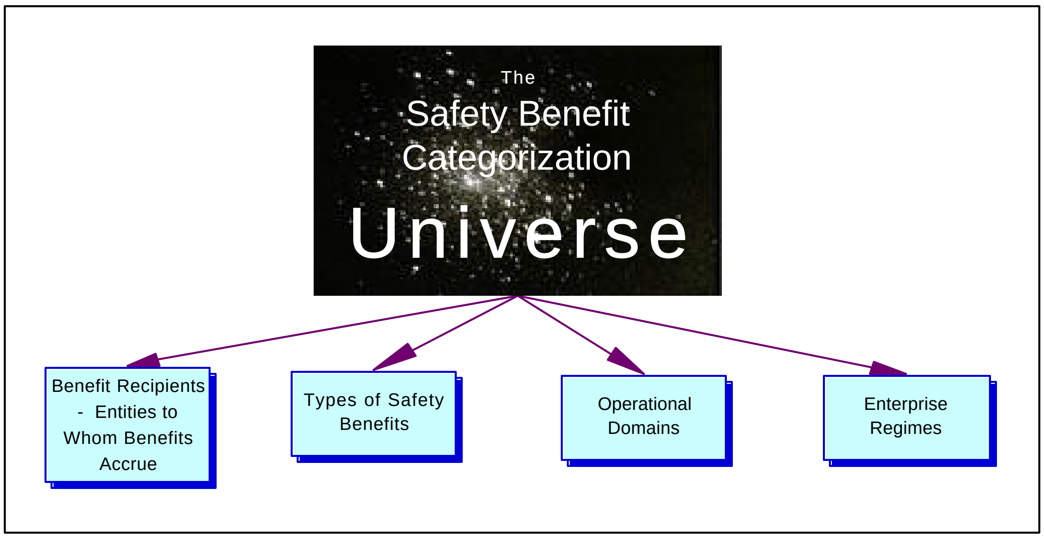


Figure 1
The Safety Benefits Universe

a) Let's first consider what we mean by safety benefits, that is, the types of safety benefits. Direct benefits include lives saved (not lost), injuries prevented or lessened in severity, and aircraft damage prevented or reduced. These types of benefits are converted (monetized) into dollar values using standard Department of Transportation (DOT) values.

   Some other direct benefits are usually not included in a safety benefit analysis because they are difficult to estimate or because they so seldom occur. An example would be buildings not destroyed by an airplane crash.

There are also secondary and tertiary benefit categories. These also are usually not quantified. For example, an aircraft crash prevented would have the effect of not delaying passengers who were to board the aircraft at its next stop.

Another example might be revenue not lost because of the prevention of a serious air carrier accident. If the accident were not prevented, the involved air carrier could be expected to lose passenger revenue for some period after an accident. This revenue would not be lost by the carrier if the accident were not to occur. Of course, we have no idea of which carrier would not have the accident, and it is likely that any revenue lost by a carrier after its involvement in a serious accident would be "picked up" by competing carriers.

Finally, there are less tangible benefits such as greater public confidence in aviation in general and in the FAA in particular.

Figure 2 is a diagram of the types of safety benefits that will ordinarily be considered in IA benefit estimation. Because there are so many possibilities for secondary, tertiary, and intangible benefits and because they are unlikely to be quantified, they are represented by the single *Secondary, Tertiary, "Intangibles"* box in Figure 2.

The word "accident" has a specific, official NTSB/FAA[4] meaning here. As used when speaking of aviation safety, an *accident* is an accident in which there has been a fatality, a serious injury, or substantial damage (relative to the value of the aircraft).

The reader will note that there are two categories of "incidents." Accidents that do not result in fatalities, serious injuries, or substantial aircraft damage (relative to the value of the aircraft) are termed "incidents." The second category of "incidents" are events that could lead to an accident. That is, these types of events may occur without a resulting accident, but an accident ordinarily will not occur unless at least one of these events first occur. (A mathematician would say that at least one of these is necessary but not sufficient for an accident to occur.)

To distinguish between these two meanings of "incident," we shall call those that are "minor accidents" *A-incidents* and those that are potential accident precursors *P-incidents.* We will also italicize *accident* when using its official meaning.

In an IA, reductions in *P-incidents* are not treated as benefits in and of themselves, because unless an *accident* (or *A-incident)* occurs, there is no monetary or human loss. Reductions in *P-incidents* are, however, often estimated as part of the process of predicting accident reduction. Reductions in *P-incidents* can also produce the intangible benefit of greater public confidence in the FAA and in aviation.

[4] The National Transportation Safety Board (NTSB), an independent Federal agency, is the official investigator of aviation accidents and the official provider of aviation accident statistics.

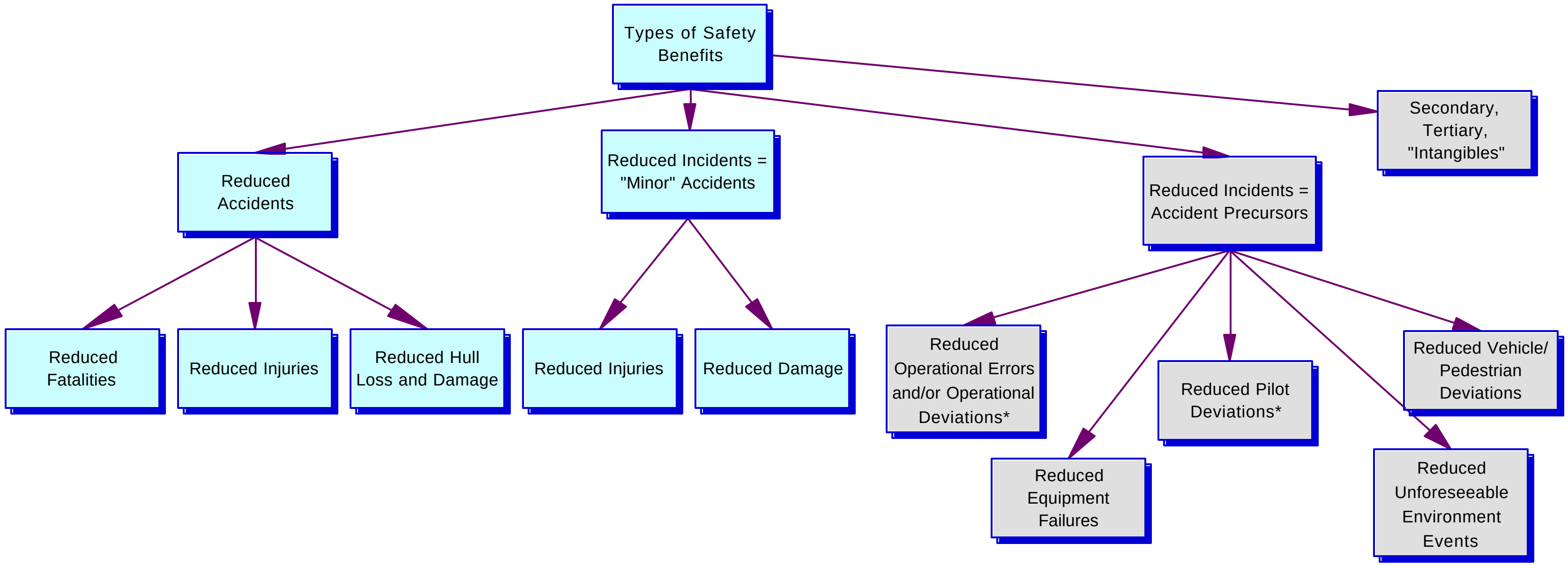


Figure 2
Types of Benefits

Because reductions in *P-incidents* and secondary, tertiary, and intangible benefits are not monetized in an IA, the corresponding boxes in Figure 2 are "grayed-out."

The reader may wonder why Figure 2 includes only five types of *P-incidents*. The reason is that other types of *P-incidents*, such as runway incursions and near-midair collisions, are the result of one or more of the *P-incidents* displayed in Figure 2. Note that equipment failures and unforeseeable environment events, such as extreme turbulence, are usually reported to the FAA as part of an accident, operational error/deviation, or pilot deviation report, or they are not reported to the FAA at all.[5]

b) A safety program may be targeted at a specific operational domain, such as the surface in the case of airport signage. Alternatively, some programs, such as ADS-B, may have a safety impact in several operational domains. Figure 3 is a diagram of the *operational domain* dimension of the *Safety Benefits Universe*.

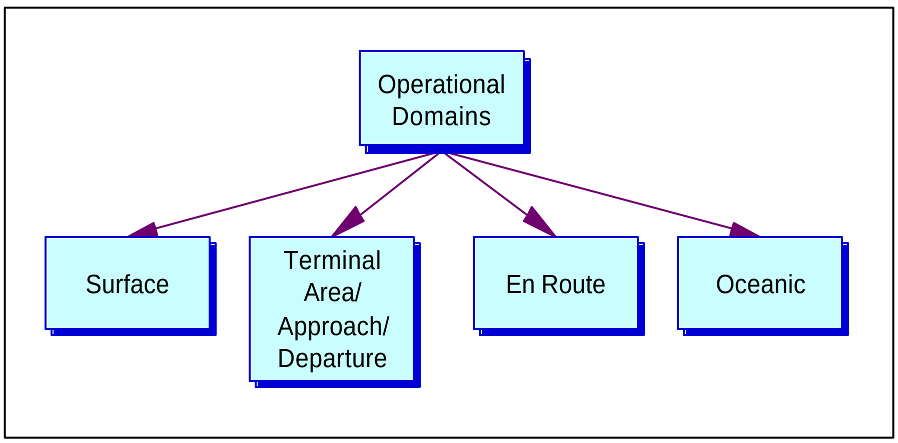


Figure 3
Operational Domains

c) Figure 5 provides a categorization of safety benefit recipients. By FAA and NTSB definition, an *accident* results in loss of life, serious injury, and/or substantial damage. Passengers (including crew) are the recipients of the first two of these benefit categories. Aircraft owners/operators are the recipients of the third category.

[5] The annual FAA *Aviation System Indicators* report includes definitions of many of the terms used in Figure 2. Historically and currently efforts to obtain data on equipment failures have been made. Operators normally report these failures to the manufacturer, but not the FAA. A current FAA/Industry initiative to collect these data is the *Global Aviation Information Network* (GAIN), which promotes and facilitates the voluntary collection and sharing of aviation safety information worldwide. For more information see the Web page http://www.gainweb.org .

As described above, there are other types of safety benefits that are less easily quantified or are intangible. In Figure 5, the entities in the "grayed" boxes are recipients of only these types of benefits and, therefore, will usually not be included in any quantified benefit analysis although, in a report, the benefits they accrue may be worth describing in qualitative terms.

d) The final dimension of the *Safety Benefits Universe* is related to the mechanisms of how the NAS operates and how a project will "physically" and operationally achieve its benefits. This dimension, called the *Enterprise Regimes*, is displayed in Figure 4. It is useful to consider the *Enterprise Regime* entities to ensure that the full requirements and impact of your program have been covered.

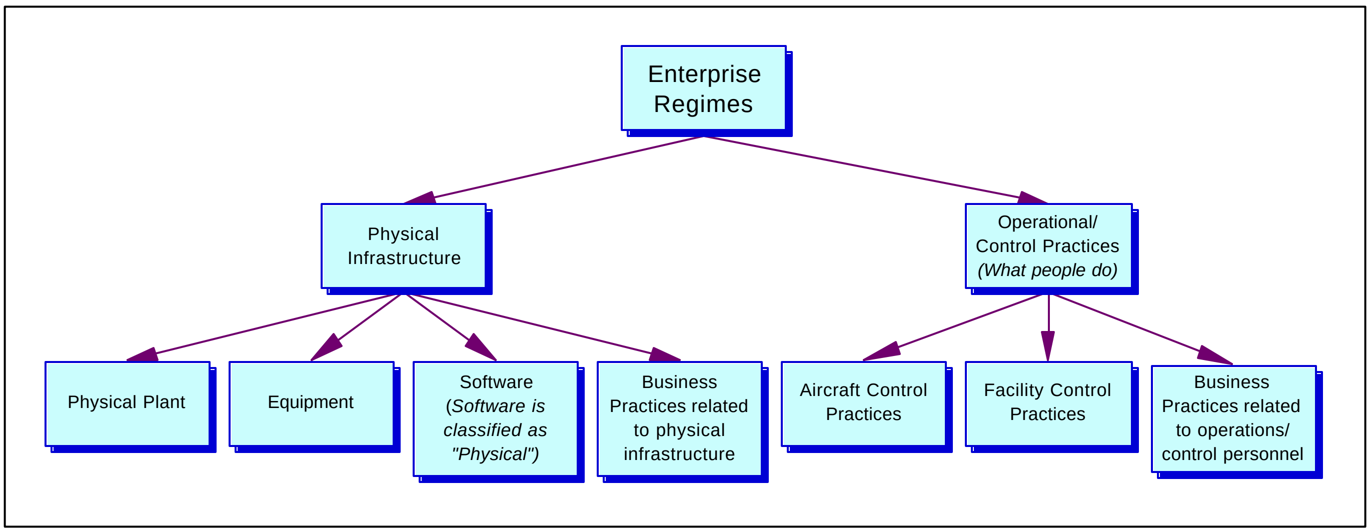


Figure 4
Enterprise Regimes

3. ? Write out a general description of what the future will be if your project is approved, proceeds as planned, and is successful.

Because the time value of money (net present value = NPV) is accounted for in the benefit analysis and because the system is forecast to change over time, you will later need to include year-by-year benefit estimates. So be sure to include in your general description any important dates, way points, etc. and what is significant about them.

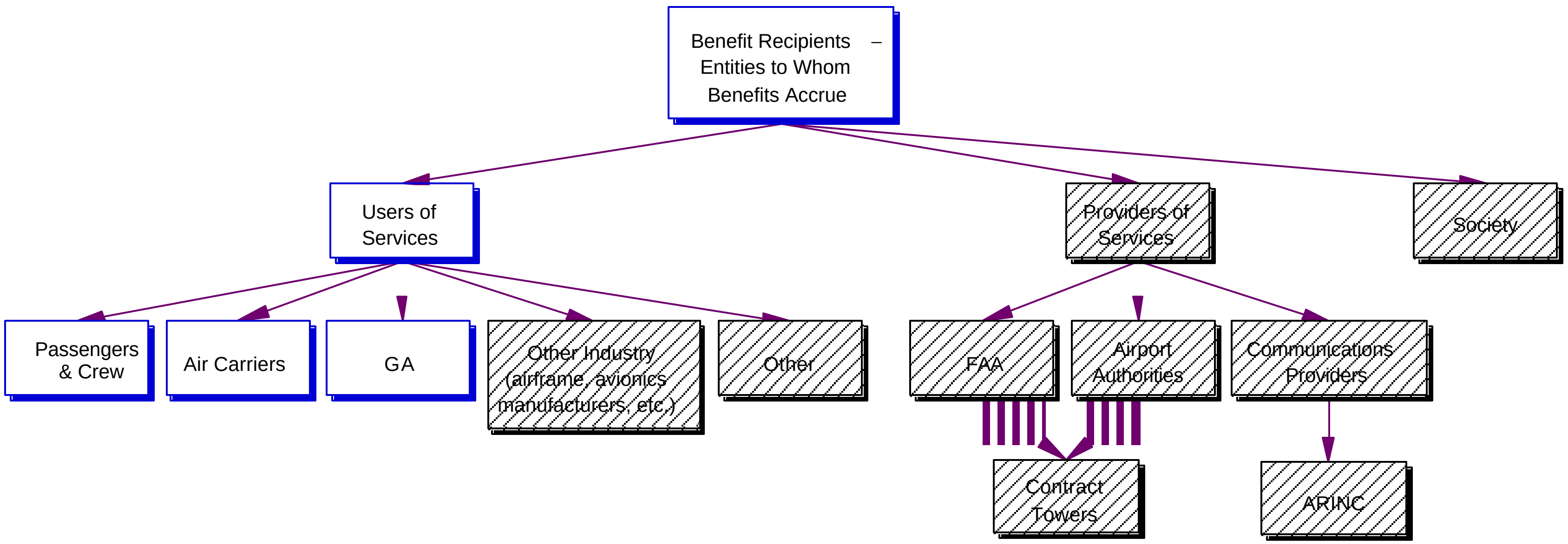


Figure 5
Benefit Recipients

4. **?** Write out a description of the "reference case"…what is expected to occur if this project is not accomplished. (Later, you will monetize this scenario.)

   a) There may be more than one possibility for a reference case. For example, another project may be under consideration that would provide some of the safety benefits that yours would. In such a case there would be two possible reference cases.

      i) Neither project is implemented,
      ii) Your project is not implemented, but the other project is implemented.

   b) When there is more than one possibility, you can try to get an up-front decision from management as to which reference case to use, but you may have to determine (as described below) the impact of each possibility, before management will make a choice. You might even have to do a benefit analysis that presents (net present value) results using each possible reference case, if management does not make a choice.

   c) Here, too, you should include any important dates, way points, etc. and what is significant about them.

B. <u>PLANNING THE ANALYSIS</u>

Step 5 is a check to help ensure that no interactions with other parts of the NAS and other programs have been overlooked. Step 6 is a final, pre-benefit-estimation check on your understanding of how the project will work and generate safety benefits in the real world. The actual safety benefit prediction analysis begins in Step 7 with planning how the analysis will be done. Step 7 includes suggestions to help you scope the size of the analysis effort. The execution of this plan is carried out in Part C, Step 8.

5. The Product Team (PT) will have determined how the project fits into the NAS Architecture, but it is important for you to check this as well. Visit the Architecture home page at http://www.nas-architecture.faa.gov. This page has links to several pages including the must-see *Capability Architecture Tool Suite* (CATS). Note that the version of CATS accessible from the home page may be different from the private FAA page, http://172.27.164.125/cats/

   a) Ask yourself
      i) On what does this project depend?
      ii) What depends on this project?
      iii) What other interactions are possible?

      See Steps 9 and 10 for further guidance evaluating interactions of your program with other parts of the NAS.

b) The Architecture is in a continual state of flux, so it is wise occasionally to check CATS for changes.

c) Other documents you may wish to check include

i) The *NAS Architecture Version 4 Report* http://172.27.164.125/CATS/Tutorials/NASArch.htm

ii) The *NAS Blueprint* http://172.27.164.125/CATS/Tutorials/Blueprint.htm

iii) The *FAA National Aviation Research Plan* (formerly the *RE&D Plan*) http://172.27.164.125/CATS/Tutorials/NARP.htm

iv) *Aviation Glossary* http://172.27.164.125/CATS/Search/default.cfm?SG=TRUE

v) Other related documents http://172.27.164.125/CATS/Tutorials/Other-Intro.htm

6. Discuss the anticipated benefit categories with individuals from the PT or, if necessary, elsewhere, who **directly** work in the areas that the project will impact.

a) Whenever possible, get your information from people who actually do the job(s) that might be impacted by the project. If possible and relevant, also watch them doing the job.

b) If you cannot get access to someone who actually does the job that might be impacted by the project, and instead you must obtain information from others, try to verify the information with additional sources.

c) It is surprising how often the way an "expert" insists things work is not the way they actually work.

d) **Ask probing questions.**

e) Try to arrange for an as-needed availability of your subject area experts.

f) You may need management assistance to obtain access to the expertise you need.

7. **?** Develop a plan for how the benefit estimation will be done.

a) **Benefits are usually first calculated as (changes in) metric values** such as reduced fatalities. Later these metric values are monetized (valued in dollars) to derive the final benefits values.

b) Because the time value of money is included in the benefits computations, benefits (changes in metric values) are usually computed on a yearly basis.

c) Determine your data needs and data availability.

Before beginning the actual benefit estimation, you should ascertain that all of the data you believe will be required are available and that there is a commitment to provide you these data. If some data are not available you will have to modify your plan, perhaps finding other data that can be used as proxies for the unavailable data. Of course, you may later find that you need additional data.

It is **strongly** suggested that you read Parts 7, 8, 9, and 10 before working on Part 7.

Table 1 summarizes sources of safety-related data.

Additional sources of data are presented in Appendix B.

d) **WARNING:** Data are quite often other than what you believe them to represent. This is particularly true of coded data (as opposed to narratives). It is vital that you discuss the data with people who are intimately familiar with the data, preferably including both people who collect and people who use the data regularly.

e) Whatever your safety project's goal, you will certainly need at least the following types of information in order to estimate safety benefits. This information will probably need to be disaggregated by type of aircraft operation (long-haul, regional/commuter, air taxi, etc.) and aircraft size classification. If there is any factor that significantly affects both fatality occurrence (in the absence of your project) and the effectiveness of your project in preventing accidents, the disaggregation will also need to be based on this factor. See Appendix C for an explanation of this requirement.

i) *Accident* count data for the types of accidents being addressed by the project.
ii) *Accident* reports, and in particular, the written narratives in the reports.
iii) Exposure data (flight hours, departures, etc.) for the types and sizes of aircraft that are involved in the accidents being addressed. Both historical and forecast exposure data are needed.
iv) Passenger count data, both historical and forecast.
v) Historical fatality data, and quite possibly injury and property damage data.

The warning in Table 1 is worth repeating:

The exposure data used by the FAA and the NTSB in safety statistics is different from that used in other aviation statistics.

Table 1
Sources of Safety-Related Information

Provider of Information	Type of Information	Comments
National Transportation Safety Board (NTSB) 490 L'Enfant Plaza East 6th Floor Washington DC 20594 http://www.ntsb.gov/aviation/aviation.htm http://www.avweb.com/toc/database.html	Complete Accident Reports. Also accident statistics and some *A-Incident Statistics*. [However the statistics can be obtained more conveniently from NASDAC] Reports may be viewed in the NTSB library and may be obtained by telephoning the Public Inquiry Section, (202) 314-6551.	The National Transportation Safety Board (NTSB) is the official investigator of aviation accidents and is the official producer of aviation accident statistics. The FAA also participates in these investigations and, for minor accidents, the NTSB may authorize the FAA to perform the investigation. The reports contain data on the aircraft specifications, the environment, the findings of the investigators and NTSB Board, and a detailed description of the accident scenario.
National Aviation Safety Data Analysis Center (NASDAC) FAA Room 1006 800 Independence Ave., SW Washington, DC 20591 (202) 493-4247 http://nasdac.faa.gov http://nasdac.faa.gov/safety_data	NTSB Summary *Accident* Reports. *A-incident* and *P-incident* data. Flight hour and departure exposure data for safety analyses. Other types of safety-related data, including data from other sources. Referrals to other data sources.	NASDAC should be your first stop for safety data. Much of its data can be obtained from its Web site, but more complete information can be obtained by visiting its office, where trained personnel will work with you to meet your specific needs. **Note that the exposure data used by the FAA and the NTSB in safety statistics is different from that used in other aviation statistics**. This is because the classification of aircraft for safety purposes differs from that for other purposes. Safety exposure data is developed by Sarah Hodges-Austin, AFS-40. Other types of exposure data may be obtained from the BTS and from the FAA/ASD-400 PMAC data system.
Aviation Safety Reporting System (ASRS) Contact: Mark Bazy, FAA,ASY-300, 202-493-4619; mark.bazy@faa.gov	Contains operational errors, pilot deviations, and other air traffic problems voluntarily reported by pilots, controllers. or others. ASRS data are used to identify safety deficiencies in the NAS so that these can be remedied by appropriate authorities, support policy formulation and planning for (and improvements to) the NAS, and strengthen the foundation of aviation human factors safety research.	ASRS data can only be used to "suggest" problems or to inform of a specific problem at a specific airport , etc. (incorrect signage, for example). ASRS data cannot be used for statistical analysis. ASRS data are collected by Battelle under the guidance of NASA, but the program is funded by the FAA. A variety of ASRS reports are available.

Table 1 (concluded)
Sources of Safety-Related Information

Provider of Information	Type of Information	Comments
Bureau of Transportation Statistics (BTS), 400 Seventh Street, SW Rm. 3430 Washington, D.C. 20590 202-366-1270	BTS collects and provides many types of transportation-related data, including information on aviation flight hours, departures, etc.	**BTS Products: 202-366-DATA** **http://206.4.84.245/btsproducts** BTS Information Services: 1-800-853-1351, answers@bts.gov

C. ESTIMATING THE BENEFITS

Note: Parts 8, 9, and 10 should be reviewed before beginning the benefit estimation effort.

8. **? This is the heart of the benefit analysis.**

There are five steps in this stage of the benefit analysis:

- Determine the theoretical effectiveness of the new technology and/or procedures in various environments.
- Analyze accident reports to estimate the effectiveness in use (in the real world).
- Separate the results of the accident report analysis into categories.
- Estimate the resultant reductions in accidents and fatality, injury, and damage amounts and rates in each category.
- Predict the resultant reduction in future accidents, fatalities, injuries, and property damage.

Each of these steps will be described in turn. **To shorten the verbiage, we shall use the term "product" in place of "the new technology and/or procedures."**

a) ? Determine the theoretical effectiveness of the product in various environments.

This will have been done by the PT before the beginning of the IA.

For technology solutions, the theoretical effectiveness would have been determined through

- Engineering analysis,

- Engineering tests in various situational environments (e.g., weather, stage of flight, flight mode—level or transitioning, etc.),
- Expert opinion and logical analysis of the effectiveness of the technology in various situational environments (e.g., weather, stage of flight, flight mode—level or transitioning, etc.),
- Simulations (fast-time and human-in-the-loop real-time), and
- Trial operational (flight) testing.

For new operational procedures, the theoretical effectiveness would have been determined through

- Expert opinion and logical analysis of the effectiveness of the procedures in various situational environments (e.g., weather, stage of flight, flight mode—level or transitioning, etc.),
- Simulations (fast-time and human-in-the-loop real-time), and
- Trial operational (flight) testing

Before proceeding with the next step, you should review the documentation of this work and ask probing questions of the PT (and vendor, if appropriate). Vendors, and even sponsors, may exaggerate the effectiveness of their product. For example, a few years ago a vendor and sponsor gave a technical presentation in which they claimed that their product would work properly 99,999 out of 100,000 times, and they claimed that this was proven by their having tested it about 25 times.

b) ? Analyze accident reports to estimate the effectiveness in use (in the real world).

The essence of this step is to estimate how effective the product would have been in preventing past accidents.[6] The means for doing this is primarily based on analyzing reports of such accidents.

In the following, when we speak of "relevant accident report" we mean a report of an accident of a kind that the product is designed to prevent or mitigate and one which is sufficiently recent that its outcome would not have been affected by any subsequent changes in the NAS.

i) In analyzing the accident reports it will be necessary to interpret ("read between the lines") the data and the narrative descriptions. This can best be done by former or active air traffic controllers and pilots. An analyst should also participate.

[6] If the primary purpose of the product is other than safety enhancement, then there may not have been any relevant prior accidents. A safety analysis in this case would be for the purpose of ensuring that the product does not degrade safety. In this case a *system safety assessment*, as described in the Preface on page 1, should be performed. This will usually be performed by a separate team. The usual approach for this type of assessment includes the use of failure modes and effects analysis and fault and/or event trees.

ii) Choose some recent time period and either obtain reports of all of the relevant accidents during this period, or obtain a large, random sample of such reports. (The randomness is important.)

The meaning of "large" depends upon the product and the availability of useful information in the reports. Twenty reports is probably a minimum. If the product provides several different safety enhancements or its theoretical effectiveness is substantially different in different circumstances, you will need more reports.

iii) An accident results from an initial misstep or failure followed by additional errors or failures in mitigation. The product is designed either to prevent the initial problem or to prevent or mitigate one of the subsequent failures.

iv) **The purpose of the accident report analysis process is to determine, for each relevant accident, how likely it is that the accident would not have occurred if the product had been present.**

To do this, the time line of each accident is separated into discrete pivotal events, beginning with the event in which the product first plays a part.

v) **In the first event, the reviewer estimates the probability that the product would perform as desired. In each of the following events, the reviewer estimates the probability that the event would produce a "beneficial outcome" if all proceeding events "went well" (i.e., P=1).**

By "beneficial outcome" we mean that the event would proceed in such a way as to help prevent the accident. For example, if the event were "controller's actions" and a controller had been unaware of a dangerous situation and the product would have caused him/her to become aware of the situation and act appropriately, then this event would have a beneficial outcome, and it would be assigned a probability of P=1.

Conversely, if in this event the controller had been aware of the situation and the reviewer decides that the controller would not have changed his/her actions even after the product confirmed the situation, then there would not be a beneficial outcome in this event and it would be assigned a probability of P=0.

The process is presented in Figure 6.

- As part of the process, it is important to record information that may have been relevant to the occurrence of each accident and that will be relevant to the prediction of future benefits. Therefore, part of the process in Figure 6 involves recording such information. The specific information that should be recorded depends upon the kind(s) of accidents the product should reduce and on the nature of the product itself. The type of operation (air carrier, commuter/regional. air taxi, GA, etc,) certainly should be included. Also include any factor that might influence both fatality accident counts (in the absence of the product) and the effectiveness of the product in preventing accidents.[7] Table 2 is an illustration of one scheme for recording the information.

- **After each accident has been analyzed, the estimated pivotal event probabilities are multiplied together to obtain the estimated probability that the product would have prevented the accident.** The explanation for the multiplication is provided next.

  In Figure 6, when estimating the probability that a pivotal event is "beneficial," the analyst is told to pretend that all prior pivotal events were (fully) beneficial. This requirement is the result of a law of probability: The joint probability of two events occurring, that is, the probability that both will occur, can be calculated as the probability of the first event occurring times the probability that the second event occurs given that (i.e., assuming or pretending that) the first event occurs. Symbolically,

$$P(A \& B) = P(A) \times P(B|A) \ ,$$

where P(A) is the probability of event A, P(B|A) is the probability of B occurring assuming that event A has occurred, and P(A & B) is the probability of both events occurring.

For three events, the equation is

$$P(A \& B \& C) = P(A) \times P(B|A) \times P(C| A \& B) \ .$$

The project will only prevent an accident if the results of all of the pivotal events are "beneficial." The probability that an accident is preventable is, therefore, the probability of all of the pivotal events being "beneficial." That is,

[7] The importance of including factors that might influence both fatalities (in the absence of the product) and the effectiveness of the product in preventing accidents is explained in Appendix C.

Table 2
Example Accident Analysis Recording Form

Row #	Accident Number	Type of Operation	Aircraft Type	No. of Passengers	Accident Location	Accident Causal Factor 1	Accident Causal Factor 2	Accident Causal Factor 3	Fatalities	Injuries			Stage of Flight	Visibility/ Weather	Pivotal Event Probabilities				Acc. Prob.	Notes
										Serious	Moderate	Minor			1	2	3	4		

Notes: Each row summarizes the results of an accident report analysis. Codes are used in some columns, such as Causal Factor, to save space. The table must include a means of identifying the accident, the numbers of fatalities and injuries of various types, and the probabilities. It should also include any other items that are needed to distinguish important differences among accidents and among the severities of the accidents.

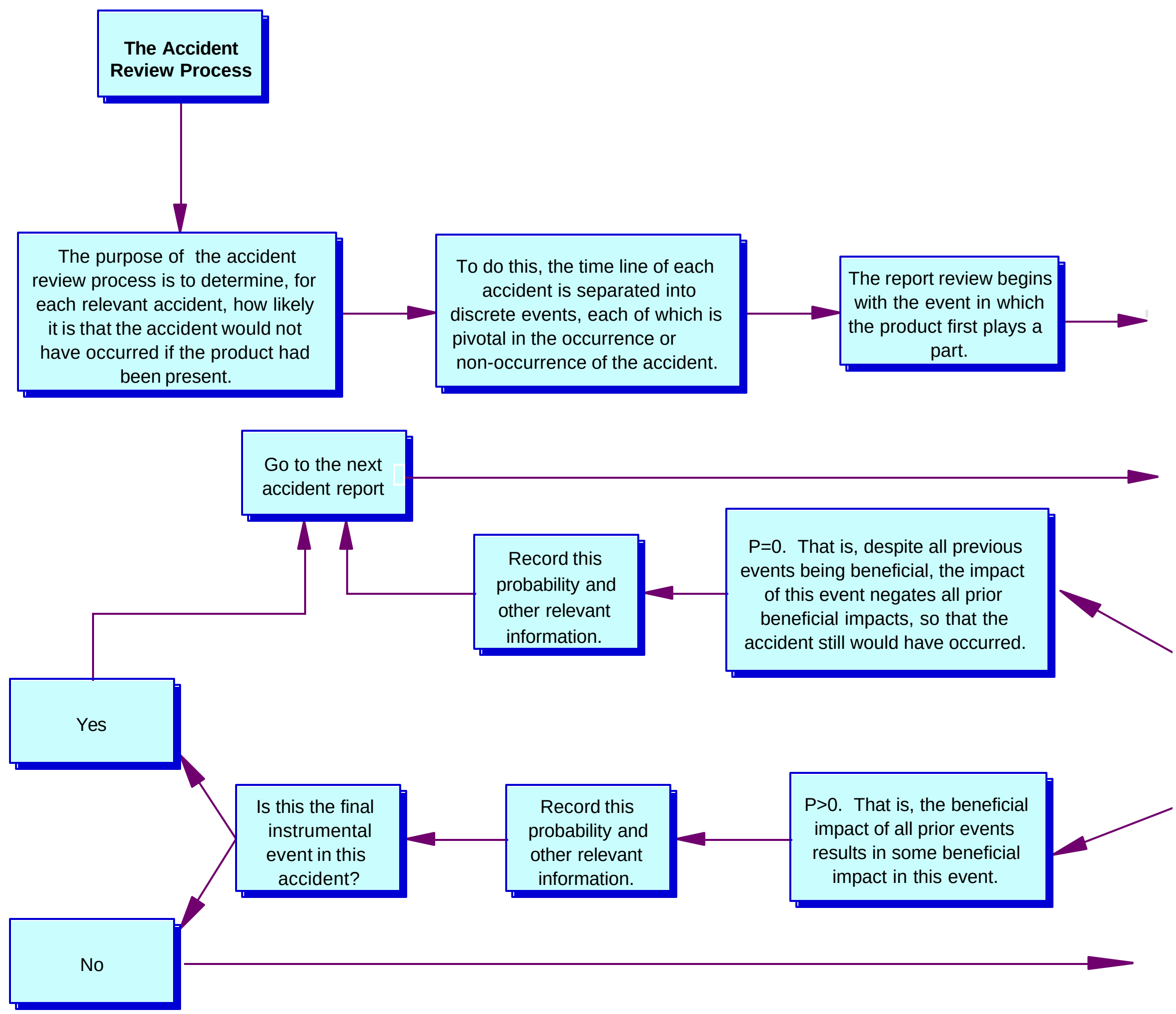
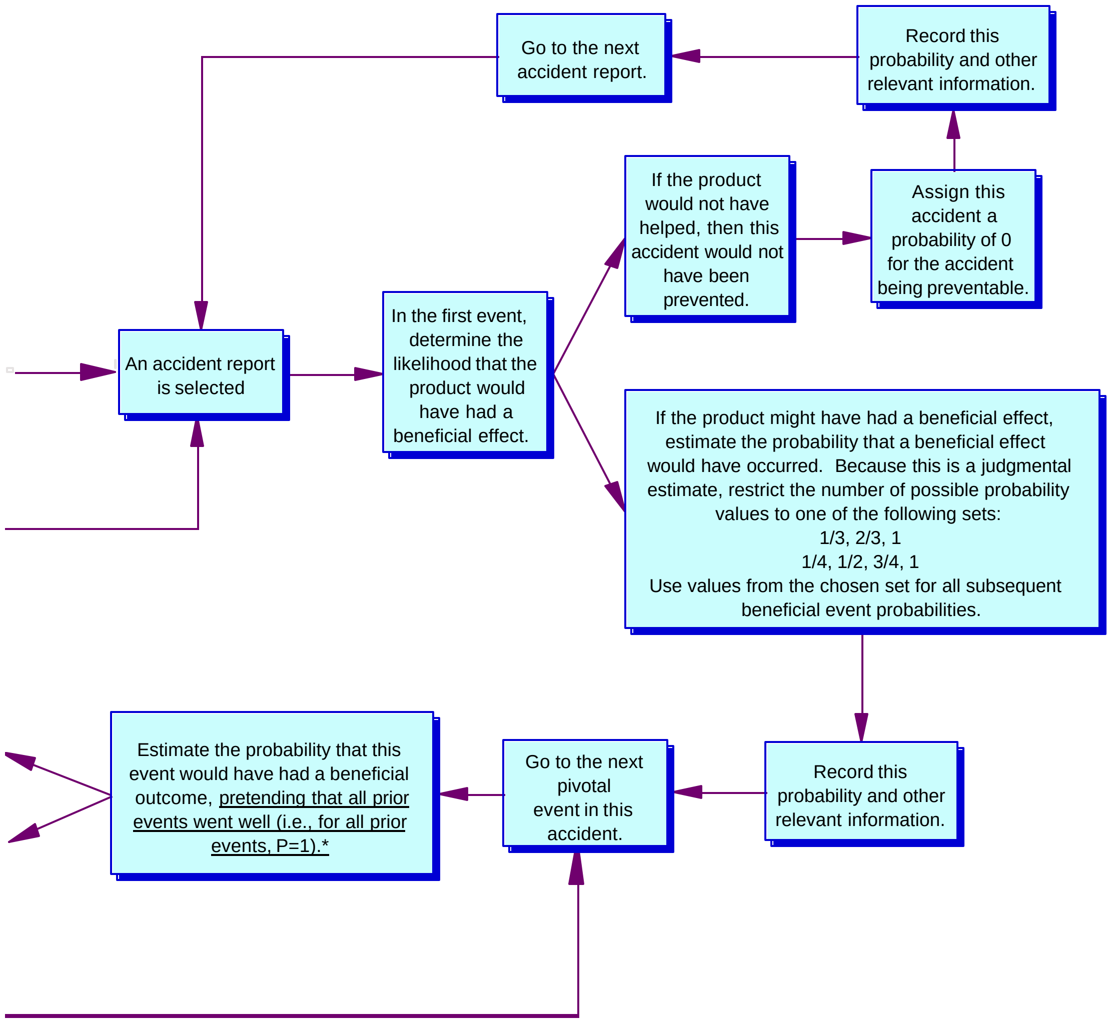


Figure 6
The Benefit Estimation

* See the text for an explanation of why the condition "pretending that all prior events went well (i.e., for all prior events, P=1)" is needed.



Accident Analysis Process

$$\mathbf{P}\begin{pmatrix}\textbf{accident is}\\\textbf{preventable}\end{pmatrix} = \mathbf{P}\begin{pmatrix}\textbf{all pivotal events}\\\textbf{are beneficial}\end{pmatrix}$$

$$= \mathbf{P}\begin{pmatrix}\textbf{(first event is beneficial) \&}\\\textbf{(second event is beneficial) \& ...}\end{pmatrix}$$

$$= \mathbf{P}\begin{pmatrix}\textbf{first event}\\\textbf{is beneficial}\end{pmatrix} \times \mathbf{P}\left(\begin{pmatrix}\textbf{second event}\\\textbf{is beneficial}\end{pmatrix} \middle| \begin{pmatrix}\textbf{first event}\\\textbf{is beneficial}\end{pmatrix}\right) \times ...$$

Thus, to estimate the probability that the project would have prevented an accident we multiply the pivotal event probabilities estimated in Figure 6.

- After the accident analysis is completed, transfer the recorded information to a spreadsheet. You will be sorting and filtering this information later. Have someone else verify that the information has been correctly transferred.

c) ? Separate the results of the accident report analysis into categories.

In Step 8 (b) the probability that the project would prevent each of the analyzed accidents was calculated. Also, information was recorded about accident particulars including the type of operation, size of aircraft, number of passengers, numbers of fatalities and injuries of different severities, and property damage.

The accidents analyzed in Step 8 (b) need to be sorted with respect to the factors that are associated with significant differences in accident outcome. It is almost certain that these factors include will include the type of operation and size of aircraft, as these will undoubtedly be associated with significant differences in fatality and injury counts as well as property damage. This may also be true for other factors that were recorded in Step 8 (b).

- Determine by inspection what factors are associated with significant differences in accident outcomes, including numbers or rates of fatalities, injuries of different severities, property damage and likelihood that the product is effective in preventing accidents.[8] (There are statistical methods that can be used to select these factors, if there are sufficient data, but inspection should suffice.)

- List each combination of such factors and call it a "category." The most likely factors will be type of operation (e.g., large air carrier, commuter/regional, air taxi, general aviation) and/or aircraft size (e.g., 60 passengers or more, 30-59

[8] The importance of include factors that might influence both fatality accident counts (in the absence of the product) and the effectiveness of the product in preventing accidents is explained in Appendix C.

passengers, etc.)

- Sort or filter the analyzed accidents by these categories. You may find it easiest to create separate spreadsheets of accident results for each category.

- If any of these categories include only a small number of accidents (say less than five), try to find another category based on some of the same factors that has fatality counts or rates and accident prevention probabilities[9] not too different from that of the small category. If you find such a category, combine the small category with it.

- Fatality, injury, and property damage counts and rates will later be used to predict the future benefits of the project. In particular, for each category, the average numbers and rates of fatalities, injuries in each severity class, and average property damage will be needed.

d) ? Estimate the resultant reductions in accidents and fatality, injury, and damage amounts and rates.

- Each of the categories selected in Step 8 (c) should be treated separately.

- Each estimation is based on a probability calculation.

  To estimate the average accident rate reduction in a chosen category, average the accident reduction probabilities estimated in Step 8 (b,vii). To express this as an equation, suppose in the chosen category there are **n** accidents. For accident $\mathbf{A_i}$, let $\mathbf{p_i}$ denote the estimated accident prevention probability obtained in the Step 8 (b,vii) multiplication. Then, in each category, the average accident rate reduction, $\mathbf{r_A^{PI}}$, resulting from the NAS-wide implementation of the project given by

$$\mathbf{r_A^{PI}} = \frac{\mathbf{p_1 + p_2 + \ldots + p_n}}{\mathbf{n}} .$$

- The calculations for the average reductions in fatality, injury, and property damage amounts are similar. The fatality count reduction will be used to illustrate the computation.

  For accident $\mathbf{A_i}$, let $\mathbf{f_i}$ denote the number of fatalities in accident $\mathbf{A_i}$. Then, for this category, the average per accident number of fatalities without the project is given by

$$\mathbf{F_A} = \frac{\mathbf{f_1 + f_2 + \ldots + f_n}}{\mathbf{n}}$$

[9] Ibid.

- The expected reduction, $\mathbf{R_F^{PI}}$, in the number of fatalities per accident is given by

$$\mathbf{R_F^{PI} = r_A^{PI} \cdot F_A} .$$

e) ? Predict the resultant reduction in future fatalities, injuries, and property damage.

WARNING! In calculating a benefit, use either reduced accident rates or reduced fatality (injury, etc.) rates, but not both. Using both will result in double-counting benefits.

The official sources for predictions of future aviation operations are the annual *Terminal Area Forecasts (TAF)* and the *Long Range Forecasts (LRF)* documents produced by APO.

The proper way to estimate future, year **x** accident, fatality, injury, and property rate reductions, is to do it on a category-by-category basis, using the categories selected in Step 8 (c).

The following computations assume that the number of accidents is proportional to the number of flights. When this is not true, far more sophisticated methods, tailored to the specific project, are needed to predict future benefits.

For each category,

- First, use historical data to estimate the average annual number of flights, $\mathbf{N_{past}}$, for the span of years covered by the Step 8 (b) accident analysis.

- Then, use the *TAF* or *LRF* to estimate the number of flights, $\mathbf{N_x}$, in each future year **x**.

- Calculate the ratio,

$$\mathbf{r_X = \frac{N_X}{N_{past}}} .$$

- Use historical data to obtain the average annual number of relevant accidents, $\mathbf{A_{past}}$, during the period covered by the Step 8 (b) accident analysis.

- The predicted number of accidents without the project in year **x** is then given by

$$\mathbf{A_x = r_x \cdot A_{past}} .$$

- The predicted number of accidents in year **x** if the project is implemented throughout the NAS is given by

$$A_x^{PI} = (1-r_A^{PI}) \cdot A_x ,$$

while the number of accidents prevented in year **x** is given by

$$AP_x^{PI} = r_A^{PI} \cdot A_x .$$

- The predicted number of fatalities in year **x** without the project is given by

$$F_x = F_A \cdot A_x = F_A \cdot r_x \cdot A_{past} ,$$

while the predicted number of lives saved in year **x** if the project is implemented NAS-wide is given by

$$LS_x^{PI} = F_A \cdot AP_x^{PI} = F_A \cdot r_A^{PI} \cdot A_x .$$

9. ? Check for the possibility that the program may have unintended, adverse consequences, particularly in the safety area. (The PT should have done this before the IA began, but you may have had new insights or discovered new information since then. Also the architecture or its time frame may have changed.)

   a) A separate System Safety Assessment is now required as part of the Investment Analysis. This task is required whether or not it is believed that your project will have any adverse safety impacts. While it is unlikely that a safety project will produce any adverse safety consequences, if it is found that your project may have adverse consequences, the PT will have to develop mitigants to ensure that the project doesn't reduce safety. The costs of these mitigants must be included in the IA. The results of the Safety Assessment will be reviewed by the ASD-110 Safety Team, presently led by Scott VanBuren. The IA team must plan for the time it takes ASD-110 to complete this review and for the possibility that the review may find the Safety Assessment to be inadequate.

   b) If there are possible non-safety disbenefits, they need to be estimated.

   c) Subtract the disbenefits from the benefits. (If there is, say, only an estimated 20% probability of incurring disbenefits, you may wish only to subtract 20% of the possible disbenefits from the benefits, or you may wish to provide both benefit values with no disbenefits included and benefit values with the maximum disbenefits included.)

10. ? Check for double counting of benefits and the impact of other programs on your benefits.

It sometimes happens that another Investment Analysis has claimed benefits that your project is claiming. For example, if another project will serve as infrastructure for your project, the IA for that project may have claimed some of the benefits that actually will accrue only after your project becomes operational.

a) Only claim benefits that will directly accrue from the implementation of your project. If another project that will serve as infrastructure for yours has improperly claimed benefits that will only directly accrue from your project, then claim these benefits for your project, but also include in your report the information that the other project has claimed some of these benefits.

   A more sophisticated approach than this may be needed depending on the circumstances of the other project. For example,

   i) If the other project will only serve as infrastructure for your project alone, and it will produce no benefits other than those that would accrue as a result of your project's implementation, and the other project has not yet incurred any development or implementation expenses, then the IA Cost Team should include the costs of both projects and these costs should be compared with the benefits that would accrue from the implementation of both.

   ii) If the other project will only serve as infrastructure for your project alone, and it will produce no benefits other than those that would accrue as a result of your project's implementation, and the other project has already been implemented, then its development and capital costs are "sunk" (already spent), and the IA Cost Team should include only its ongoing costs as part of the costs of achieving the benefits of your project.

   iii) Most likely, the other project will serve as infrastructure for several projects. In this case, allocation of its costs against the benefits of these several projects can become quite complex and politics almost certainly will enter into the determination. Serious discussions with management are appropriate.

b) It is also possible that another project may impact your reference case scenario in such a way as to reduce the size of the safety problem that your project would help mitigate. One possible way this might happen is if your project is delayed and another safety program is instituted that has a broad scope that partially or totally includes the safety problem your program is to address. Figure 7 provides an illustration of this.

   In this example, Project A will result in a large percentage of general aviation (GA) aircraft becoming equipped with TCAS-1. Project B, an ADS-B equipage project originally scheduled to begin 6 years later than Project A, is designed to include some of the GA aircraft included in Project A. A three-year delay in Project A not only results in the loss of the benefits anticipated for its first three years, but also results in some of the benefits predicted for its sixth and succeeding years also being achievable by the ADS-B equipped GA aircraft included in Project B

11. ? Net Present Value (NPV) benefit computation

a) In this step, the yearly safety benefits estimated in Step 8 are converted to monetary values using standard FAA and DOT values. These standard values include the value of a human life, the values of different severities of injury, and information on property damage values.

These values may be found in the document *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, FAA-APO-98-8, June 1998, (or later). The latest version (as of May 2000) of this guide, which includes an **additional useful chapter** not present in the paper version, may be found at

http://api.hq.faa.gov/economic/toc.htm .

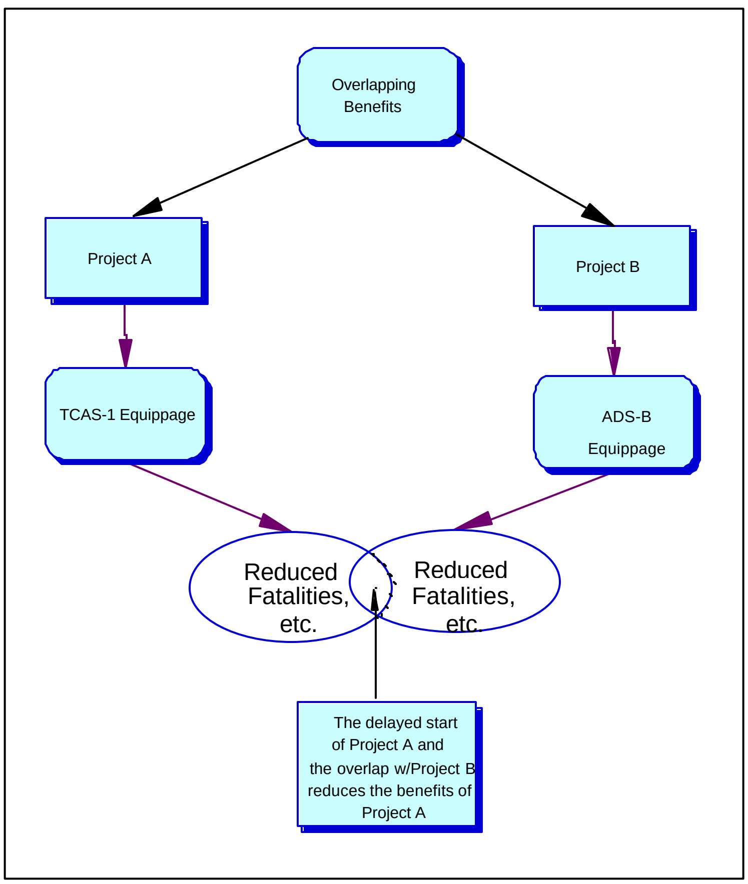


FIGURE 7

Reduced Benefits Resulting from Overlapping Projects

Other useful publications, data bases, and information may be found at
http://api.hq.faa.gov/apo_pubs.htm

http://www.apo.data.faa.gov/

http://api.hq.faa.gov/apo_pubs.htm#ANCHOR98_10 .

Because these documents may become obsolete, one should contact the FAA APO organization for current guidance. At present, we suggest contacting Stefan Hoffer (202- 267-3309) at APO. Another source of information is the ASD-400 Chief Scientific and Technical Advisor for Investment Analysis and Operations Research, David Chin.

b) Compute the net present value (NPV) of the benefits using the standard methodology and the current, official FAA and Office of Management and Budget (OMB) discount rate(s).

c) Unfortunately, the official document for discount rates, OMB Circular A-94, http://www.whitehouse.gov/OMB/circulars/a094/a094.html , does not present sufficient, clear guidance. It therefore is recommended that one use APO guidance provided in the document cited above, *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, FAA-APO-98-8, June 1998, (or later). Other APO documents may be useful. For a listing of these, go to http://api.hq.faa.gov/apo_pubs.htm . For a list of OMB guidance circulars, consult http://www.whitehouse.gov/OMB/circulars/index.html .

12. Risk analysis.

The risk analysis related to benefits should be an independent effort. However, the Risk Analysis Team will require documentation on the data and methodology used by the Benefits Team and will need to have access to members of the Benefits Team, Cost Team, Safety Assessment Team, and the PT. **It is, therefore, important that care be taken in maintaining the data used in the benefit analyses and in adequately documenting the methodologies and assumptions used.** Any concerns and/or uncertainties that surfaced during the benefit analysis should also be documented. Failure to maintain information required by the Risk Analysis Team may delay the completion of the Investment Analysis. The information below is provided to assist the Benefits Team in preparing the material needed for the Risk Analysis portion of the Investment Analysis.

Among the areas that the Risk Analysis Team will evaluate are the following:

a) Benefit Identification

i) Are the same benefits claimed by other programs? (Is there double counting?)

ii) Has a major benefit area been omitted?

iii) Are some of the benefits attributed to the program unrealistic? (Will the program REALLY be able to deliver them?)

> Are the benefits dependent on the existence of factors, such as other, non-completed programs, that may not be present at the time the benefits are supposed to be realized?

b) Benefit estimation

i) What assumptions were used in the benefit estimation and are they justified?

ii) How sensitive are the benefit estimates to changes in the assumptions?

iii) How reliable and appropriate are the data that were used.

iv) Were the benefit estimation techniques used appropriate and adequate, and did they account for all major factors needed to achieve the benefits?

v) Is the benefit analysis straightforward or tortuous?

vi) Were all calculations, including NPV calculations, done correctly, using standard FAA, DOT, and OMB values?

vii) Are the qualitative descriptions of non-quantifiable benefits reasonable.

viii) Are any estimates of cost avoidance reasonable, justifiable, and thorough. (Have all new expenses required to achieve the cost avoidance been included?)

c) The risk that the project may have unintended, adverse consequences.

The report, *Risk Assessment Guidelines for the Investment Analysis Process* is a good source of information. Other documents that contain information on risk are *Federal Aviation Administration Acquisition Management System* and *Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development*.

D. POST-IMPLEMENTATION BENEFIT ASSESSMENT

Once a safety project has become operational, someone (the GAO, a Senator, or possibly the FAA itself) may be interested in assessing its impact: Has it reduced accidents and saved lives? Are the benefits it has achieved as great as were claimed for it? (Did the FAA play "fast and loose" with the benefit estimates?)

Some Federal agencies, such as the DOT National Highway Traffic Safety Administration (NHTSA) and the recreational boating division of the U.S. Coast Guard, have been performing formal, post-implementation benefit assessments for over 20 years. The FAA, however, has seldom performed such assessments. The General Accounting Office (GAO) has suggested that the FAA perform such assessments, and at the time of this writing, the FAA is developing a formal process for doing so.

Irrespective of the specifics of any formalized process, however, the essence of a post-implementation assessment of the benefits of a project is the use of appropriate metrics (e.g., accident and fatality counts and rates) and statistical methods.

Because the FAA does not have a significant history of performing post-implementation benefit assessments, it does not have documents detailing the methodology for doing these assessments. Consequently, the ASD-430 document *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis* has an extensive section on this methodology, and in particular on statistical methods for use in post-implementation benefit assessment. Rather than reproduce that material here, the reader is referred to that document.

APPENDIX A
BENEFIT ANALYSIS
"RULES of CONDUCT"

The following rules and principles should be satisfied by any properly executed benefit estimation project. The number of rules may appear excessive, but they really are just common sense, and so should be reasonably easy to satisfy. As a benefit analysis progresses, it would be prudent to periodically review these rules and principles to ensure that the analysis is on track and to reduce the potential for later grief.

General Requirements

Guiding Principles

- Safety must not be compromised.
- There must be a documented cause and effect (temporal) relationship between the investment and the benefits.
- Economic Benefits must be achievable in monetary terms by specific entities.
- Benefits should not be double-counted.
- Check for disbenefits that might result from the investment. For example, a project that increases terminal capacity also may have the potential of increasing the likelihood of a collision, particularly if it involves some technical risk.
- The documentation for each IA should include a complete description of the benefit estimation methodologies, the computations, and the data used.
- Documentation, data bases, and models should be retained for future use. Electronic versions should be archived so they don't disappear with departing staff or contractors.
- Plans for a post-implementation assessment of the actual benefits should be included in the IA, and should be implemented after the project is operational.

Reference case

- The reference case in year x should be "what the system would be in year x if we did not make this change" (and kept the same maintenance, etc.)

Metrics Guidance

- The Metrics should be useable and measurable during modeling, operational trials and in-service operations.

- The Metrics should be in units of measurement that are useable in business cases by either or both Service Providers and Airspace Users

- Each metric should be clearly and completely defined. Any assumptions implicit in the definition of the metric should be made explicit and the potential ramifications of the assumptions should be described.

- Wherever possible metrics should be those already accepted. Other metrics should include a full explanation of the reasoning for their choice.

- There may be a choice of metrics available to measure a benefit category. (For example, for Safety one might use fatalities per million departures or fatal accidents per million flight hours.) In such cases, one should choose the metric most appropriate for the operational environment and project being studied. The ramifications of using other metrics should also be presented.

- If a metric (e.g., a safety metric) incorporates an exposure unit (e.g., flight hours, departures) as part of its definition, the definition and source of the exposure values shall be provided, and the ramifications of the use of different exposure units and any vagaries in the exposure values should be described.

Quantification Guidance

- Methods of measurement should, whenever possible, be objective and incorporate statistical methodology.

- If subjective methods of measurement are used for the quantification of a metric, they should not be the only measurement of that metric, and the subjective method should be adequately described and justified.

- Whenever different methodologies are used to quantify a metric in different phases of a program (e.g., modeling and operations), the relationships among the methods and the ramifications of the differences should be described to enable formal comparison of the measurements obtained.

- The source(s) of the data used to obtain the metric values, any deficiencies in the data, and algorithms for computing metric values shall be documented.

- For frequently used metrics and when possible, an easily accessed, current file should be maintained of the data used to generate the metric values.

- For frequently used metrics and when possible, the algorithm(s) used to generate the metric values should be automated.

- Wherever possible, the metric quantification methodologies should be based on those already developed.

APPENDIX B
DATA SOURCES

There are a multitude of data sources available for performing aviation-related analyses. In the following pages, we present brief descriptions of many of them, along with contact persons. Note however, that contacts can quickly become out of date. In particular, any listed SETA contacts are or shortly will be obsolete because of the transition to a new contractor. Corrections and revisions will be greatly appreciated.

DATABASE NAME	RESPONSIBLE OFFICE	DATABASE DESCRIPTION and CONTACT
ADA	APO-130	Aviation Data Analysis System - Includes Air Traffic Activity forecasts. Carlton Wine, 202-267-3350.
AFEIS		Air Facilities Executive Information System - Available to Division and Regional Managers. Contains outages and staffing information. Similar to EXIS. Rick Ford, AAF-60, 202-267-8970.
AFTECHNET		This web site contains daily reports on all scheduled and unscheduled outages that occurred in the NAS in excellent detail - http://aftechnet.faa.gov/ns.htm
ADOC		Airport Direct Operating Costs – Includes aircraft type and aircraft category costs by airborne hour and block hour costs. Data inputs are based on carrier submitted on Form-41.
ASAS		Aviation Safety Analysis System
ASQP	DOT	Airline Service Quality Performance - Developed to support a DOT report on airlines' on-time performance. Data elements include departure, arrival, and elapsed flight times as shown by (1) OAG, (2) carriers' reservations systems, and (3) carriers' actual performance. ASQP shows selected differences among the three sources, such as departure delay and elapsed time difference. However, it lacks the more detailed time and delay records of other databases. David Bennett, AAS-1, 202-267-3053. Gloria Laurie, DOT.
ASRS	ASY-200	Aviation Safety Reporting System - Contains operational errors, pilot deviations, and other air traffic problems voluntarily reported by pilots and controllers. ASRS data are used to identify deficiencies and discrepancies in the NAS so that these can be remedied by appropriate authorities, support policy formulation and planning for (and improvements to) the NAS, and strengthen the foundation of aviation human factors safety research. Tom Kossiaras, ASD-110, 202-358-5574.
ATADS	APO-110	Air Traffic Activity Data System – Provides operational count for Air Traffic Facilities. Nancy Trembly, APO-110, 202-267-9942.
ATOMS	ATM-300	Air Traffic Operations Management System – Provides regular count of air traffic operations and operations delays by minutes or more for all aircraft.
CBAS	ASD-420	Cost-Benefit Analysis System - Contains information on present and future costs and benefits of CIP projects to users and FAA. Brad Loomis, SETA, 202-651-2414.

DATABASE NAME	RESPONSIBLE OFFICE	DATABASE DESCRIPTION and CONTACT
CODAS	APO-130	Consolidated Operational Delay & Analysis System - A combined database of enhanced traffic management system (ETMS), airline service quality program (ASQP), and NOAA weather information. CODAS supports non-real-time analyses and projections of delays. Carlton Wine, APO-130, 202-267-3350.
COPS	ABC	Cost Performance System (COPS) - A data warehouse and decision support information system which allocates total FAA O&M appropriation costs to the field facilities, and associates these costs with workload and performance measures. Phillip Schaeffer, ABC-200, 202-267-9537 and ASD-430.
EDB		Engineering Data Base – End-state FAA system locations showing latitudes, longitudes, controlling ACF, antenna height, source/sink of functional interface, and specific subsystem connectivity. Terry Snyder, ARS-10, 202-366-9674 or Jim Novaco, SETA, 202-651-2271.
EIS	AAT	Air Traffic Executive Information System - Air Traffic version of EXIS. Larry Silvious, ATX-430, 202-267-7120.
ETMS	Volpe Center	Enhanced Traffic Management System - A database containing flights for which flight plans were filed and includes flight departure and arrival messages. It is available at the Volpe National Transportation Systems Center (Volpe Center) in Cambridge, MA. Tommie Tyson, AUA-500, 202-233-5052. Nancy Kalinowski – ATA-200.
EXIS	ABC-100	Executive Information System - Provides detailed concise demographic view of the FAA as compared with the national civilian labor force. Figures are broken down by line of business, as well as in terms hiring, promotions, and region. The Office of Business Information and Consultation updates information quarterly and at year's end. EXIS information is accessible to headquarters and regional management team members. Steve Hopkins, ABC-100, 202-267-7120.
F&E BSL	ASD-300	Facilities & Equipment Financial Baseline - Contains the financial baseline of F&E costs for current CIP projects. Dave Stuecheli, SETA, 202-651-2152.
FLAPS		FAA LINCS Architecture Pricing System – Provides the firm, fixed price cost of all Leased Interfacility NAS Communications System (LINCS) circuits and many other contract line item numbers (CLINs) for all ten years of the contract.
FMF &PFF	AOP-200	Facility Master File and Pre-Commission Facility File – Sub-element databases from the FSEP module of MMS, containing information on equipment and systems of FAA facilities from pre-construction through decommissioning. Ann Delaney, AOP-200, 202-267-3266 or Charlotte Powell, AOP-200, 202-267-3266.
FSEP	AOP-200	Facility, Service, and Equipment Profile - Database is described in FAA Order 6000.5C. It includes sub-elements, FMF and PCFF. Ann Delaney, AOP-200, 202-267-3266 or Charlotte Powell, AOP-200, 202-267-3266.
FSRDB	AND-140	Facility/Subsystem Requirement Database - Comprehensive listing of incoming CIP NAS subsystem component characteristics. The data elements collected include power, HVAC, environmental, dimensional and subsystem configuration data. Data on deployed CIP subsystems is migrated continually from the FSRDB to a separate but similar characteristics database as subsystems are installed fully. Dr. Sophia Ashley, AND-140, 202-358-5283.

DATABASE NAME	RESPONSIBLE OFFICE	DATABASE DESCRIPTION and CONTACT
LIS		LIS Engineering Database System - Maintains repair history for FAA Depot repaired items and maintains current information on modification records, performance data records, repair specification, manufacturer's information, and test equipment application. Ken Towery, Manager, NAILS Management Division, FAA Logistics Center, 405-954-4212 or Ellen Brinson, AND-340, 202-358-5040.
MMS		Maintenance Management System – All failure that have at least 1 minute duration, including NAPRS reports that have reliability and availability facility information by scheduled and unscheduled cause codes.
NAIMS	ASY-100	National Airspace Incident Monitoring System - Details of near mid air collisions, runway incursions, and causal factors. Bob Toenniessen, ASY-100, 493-4248 or Larry Randall, ASY-100, 493-4251.
NAPRS		National Airspace Performance Reporting System - Facility and services reports on scheduled and unscheduled outages, operational availability, operational delays and causes of delays. No longer considered a database. It is a set of requirements for what should be in Maintenance Management System (MMS). Frank DeMarco, AOP-200, 202-267-7359.
NASDAC		National Aviation Safety Data Analysis Center - Provides rapid automated access to a unique database that integrates commercial and government information, accident and incident data, aircraft-specific information, international safety recommendations, airport and navigational aids, and safety trend analyses. With a data storage capacity exceeding 300 billion bytes of information, the center houses one of the world's most extensive collections of aviation data. The center is staffed with analysts who are available to assist customers with NASDAC automation tools and data sources. FAA Headquarters, Room 1006, 800 Independence Ave. SW, Washington, DC, 202-483-4247.
NCDC	National Climatic Data Center	National Climatic Data Center database includes surface observation data, hourly weather updates of airports, and other useful aviation-related weather data.
NFDC	ATM-610	National Flight Data Center (OK City) – Contains "structural" information on the NAS, such as location of airports and navaids. Marie Killian, 202-267-5906.
NMNS	ASD-130	NAS Mission Need Statement Database – Source of information on description and status of every MNS throughout the FAA. Users of the database can view general information about the MNS (e.g. MNS Number, Title, Summary, and Status), as well as JRC and TSARC information (both past and future). Users may choose to print from a selection of existing reports. Gail Rollins, ASD-130, 202-358-4922.
NPIAS		National Plan of Integrated Airport Systems Database - Used by GAO to produce "Airport Development Needs Estimating Future Costs", Report No. GAO/CREDO-97-99 of April 8, 1997. Larry Kiernan, APP-400, 202-267-8784.
NTSB AAD	NTSB	NTSB Aviation Accident Database - Provides characteristics of all accidents, including the sequence of events, that occurred in the US airspace and summary narratives of each accident. Summary data available from Stan Smith. General telephone number, 202-314-6000; Public inquiries, 202-314-6551.

DATABASE NAME	RESPONSIBLE OFFICE	DATABASE DESCRIPTION and CONTACT
OAG	APO-130	Official Airline Guide - Official airport schedules of airline arrivals and departures. The OAG contains information on the flight's airline, flight number, arrival and departure cities, arrival and departure times, frequency of flight, connections, class of service, type of aircraft, number of stops and more. Gary Mihalik, 202-267-3347.
ODMS		Operational Data Management System
OPSNET	ATO-200	Operational Performance System Network – Used for air traffic delays and aircraft operations counts reporting. The planned evolution of the OPSNET is to include all radar terminal facilities and automated flight service stations (AFSS) and will include reporting requirements such as staffing and facility performance summaries. More information can be found in FAA Order 6040.15C (Titled: NAPRS). Larry Dixon, ATO-200, 703-925-3129.
PCFMF & PCPFF	AOP-200	PC versions of Facility Master File (FMF) and Pre-Commission Facility File (PFF). Ann Delaney, AOP-200, 202-267-3266 or Charlotte Powell, AOP-200, 202-267-5928.
PMAC	ASD-400	Performance Monitoring and Analysis Capability - A data analysis tool that provides accessibility to airline operations data in a PC environment. The PMAC system includes OAG, ASQP, CODAS, TAF, NCDC, and other data. Dan Citrenbaum, ASD-430, 202-358-5442. URL: http://www.faa.gov/opsresearch/pmac.htm
Reuters Aviation Database	Commercial	Reuters Aviation Database - Provides historical information from Airlines Form 41 fillings and the OAG. Allows for simple programming to create tables or database subsets of specific information from the Database. Includes operational, financial, personnel (e.g. number of flight crew, maintenance personnel, etc.) data.
RIMS	ARS	Requirements Information Management System - A comprehensive life cycle planning and data-tracking tool with four integrated modules: CIP Project Management, Budget Requirements Tools, Historical Cost, and Budget Planning. Rosanne Marion, ARR-200, 202-366-6934.
SDRS	ASY-100	Service Difficulty Reporting System - General aviation malfunction and defect reports and AC mechanical report. Bob Toenniessen, ASY-100, 202-493-4248 or James Hallock, VOLPE NTSC, 617-494-2199.
T-100 Airline Cost Data		Form 41 that includes carriers reporting costs by aircraft type – most of this information is applied by APO and reflected in FAA-APO-98-8, Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs.
TAF	APO-110	Terminal Area Forecasts – 10-year forecasts of aviation activity at 873 airports in the U.S. by category of flight, i.e., air carrier, air taxi, general aviation. Dan Taylor, APO, 202-267-3302.
TIMS		Telecommunications Information Management System - Assists network planning, budget analysis, circuit engineering. Franklin Corpening, AOP-600, 202-267-9202.
TIS		Tower Information System - Provides graphical interface to "virtual database". Four paths to extract information: Airport, Equipment, Operations, and Tower. Information includes emplanements, tower details, future layout, current layout, runway list, runway details, equipment list, equipment details, equipment changes list, equipment changes details, equipment delivery, delays, operations, etc.

DATABASE NAME	RESPONSIBLE OFFICE	DATABASE DESCRIPTION and CONTACT
TTS+	AOP-100	Trouble Tracking System Plus reports failure/outage events from the NMCC for FAA facilities, a subset of the MMS – CSSI through AOP-100.
WIS	AFZ-200	Workload Information System - Provides maintenance staffing data for facilities. Barbara Froome, AFZ-200, 202-267-3203.

APPENDIX C
The NEED to CATEGORIZE the ACCIDENTS ¾
An EXAMPLE of SIMPSON'S PARADOX

In the text, emphasis was placed on disaggregating the analyzed accidents into categories and evaluating the benefits of each separately. One reason for doing this is that different types of operations and sizes of aircraft carry different numbers of passengers and hence are likely to experience different benefits resulting from a safety project.

Another reason for this is related to problems encountered when there are strong interrelationships among factors such as the effectiveness of a product, the circumstances of its use, and the results of its use. The following example provides a dramatic example of such a problem…one which at first you may find hard to believe — until you check the numbers for yourself.

This example actually occurred some years ago during a study of the effectiveness of increasing the use of life jackets in recreational boating. To simplify the example illustrative rather than actual numbers are used.

The situation is this: In recreational boating some people fall in the water. Some are wearing life jackets and some are not. Some drown and some survive. A basic question is, "how effective are life jackets in preventing the drowning of someone who falls in the water?" The following tables (using illustrative, not real, numbers) show what can happen if cases are unwisely combined.

In each table cell, the denominators are the number of people who fell in the water and the numerators are the number of these people who survived.

	Adults	**Children**
Wearing life jacket	$\frac{99}{100} = 99\%$	$\frac{250}{300} = 83\%$
Not wearing life jacket	$\frac{980}{1000} = 98\%$	$\frac{200}{300} = 67\%$

As is readily apparent, one has a better chance of survival wearing a life jacket than not wearing a life jacket, whether one is an adult or a child.

Suppose we had not separated the accidents into adult and child classes. Then we would have the following table (obtained by adding the numerators and denominators in the above table).

	People
Wearing life jacket	$\frac{349}{400} = 87\%$
Not wearing life jacket	$\frac{1180}{1300} = 91\%$

According to this table, one has a better chance of surviving a dunking if one **doesn't** wear a life jacket!

Hey! What's going on here???

The reversal we see here is the result of two factors:

- There are strong interrelationships between the three categories
  - Adult – child
  - Wearing – not wearing
  - Survival – Non-survival

- There are large differences in the numbers of adults and children (the denominators)

Simply put, children are less likely to survive than adults, but are more likely to be wearing life jackets. These dependencies together with the wide differences in the numbers of adults and children cause the apparent paradox.

The same difficulties were found with several other variables, including gender and severity of weather.

In general, it is safe to aggregate (combine) categories of one type if the categories' counts are not strongly associated with the counts in other types of categories.

APPENDIX D
REFERENCES

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Web Sites for Other Useful Information

Aviation Glossary : http://172.27.164.125/CATS/Search/default.cfm?SG=TRUE

FAA Architecture home page: http://www.nas-architecture.faa.gov .

This page has links to several pages including the must-see *Capability Architecture Tool Suite (CATS)*. Note that the version of CATS accessible from the home page may be different from the private FAA page, http://172.27.164.125/cats/

The *FAA National Aviation Research Plan* (formerly the *RE&D Plan*): http://172.27.164.125/CATS/Tutorials/NARP.htm

The *NAS Blueprint*: http://172.27.164.125/CATS/Tutorials/Blueprint.htm

Other Architecture-related documents: http://172.27.164.125/CATS/Tutorials/Other-Intro.htm

Useful APO publications, data bases, and information may be found at http://api.hq.faa.gov/apo_pubs.htm and at http://www.apo.data.faa.gov/

OMB guidance circulars: http://www.whitehouse.gov/OMB/circulars/index.html