U.S. Department of Transportation

Federal Aviation Administration

Report to Congress

Child Restraint Systems

Volume I

Washington, DC 20591

May 1995

**Report of
the Secretary of Transportation
to the United States Congress
Pursuant to Section 522 of the Federal
Aviation Administration Authorization
Act of 1994, P.L. 103-305**

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This report was prepared in response to Section 522 of Public Law 103-305, a 1994 amendment to the Airport and Airway Improvement Act of 1982. The law requires the Secretary of Transportation to study the impact of mandating the use of Child Restraint Systems (CRS) for children under the age of two on scheduled air carrier aircraft. The primary issues analyzed in the study include the efficacy of CRSs currently approved for use in air carrier aircraft, and the impacts of required use of CRSs (which occupy a passenger seat) on air carrier passenger volume, costs to families traveling with infants, and fatalities and injuries.

Infants under 2 years old are currently permitted to travel aboard aircraft in an unsecured manner on the laps of accompanying adults. Current airline general practice is to allow these infants to fly free of charge. Although the FAA encourages and actively promotes the use of effective CRSs for infants in air transportation, their use is not mandatory and most infants now travel on the laps of adults. To analyze the economic and safety impacts of a CRS mandate, an analytical framework was developed, based on several premises:

- If CRSs become mandatory, infants will require the use of passenger seats, making them unavailable for other full-fare passengers.
- Costs will be associated with implementing a CRS mandate. These costs will affect air carriers, air passengers traveling with children under two, and possibly other passengers as well. One or more of these groups will either absorb or share the additional costs.
- Higher air travel charges for families traveling with infants, if implemented, will reduce demand for air travel for some families. These families may divert to other modes of transportation or may forego their trips completely.
- Increased costs and/or revenue loss may affect the profits of air carriers.
- Air travelers who divert to other modes of transportation will be subject to the higher mortality and injury rates associated with those modes.

Just prior to the enactment of PL 103-305, the FAA completed laboratory testing of a representative group of CRSs. Other key parameters used in this study, however, such as the sensitivity of travel choices of families traveling with infants to possible increased fares associated with CRS use, and estimates of fares that air carriers may charge for CRSs are not well established. Information on these and other topics relevant to the questions posed by the Congress was obtained by a review of pertinent literature and data; conducting five panel discussions with academic, industry, and government experts, and soliciting public comments through a *Federal Register* notice. Data available from previous studies and aviation industry and government sources suggest likely impacts if use of CRSs is made mandatory. However, except for efficacy issues, results of this study are only estimates and are not based on data derived from surveys, experiments, or tests. In an effort to examine uncertainties associated with these estimates, the study includes sensitivity analyses related to key parameters.

Study results are as follows:

- <u>EFFICACY OF CHILD RESTRAINT SYSTEMS</u>: Of the categories of CRSs tested, only the aft-facing types, typically used for infants under 20 pounds, performed well. Of the eight forward facing carriers tested, only two met accepted head impact criteria limits. The installation of alternative anchor points on three of the forward-facing carriers tested resulted in a dramatic improvement of these carriers. Booster seats failed to prevent head impact and presented a potential safety threat because of crushing forces related to seat-back breakover. Harness-type systems permitted excessive forward head and body movements, followed by violent rebounding, and the belly belt failed to prevent head impact and permitted the occupant to be crushed between the adult and the forward seat. An effective CRS is considered to be one that provides at least the same level of protection to an infant that a lap belt provides to an adult or a child large enough to use a lap belt. To improve the efficacy of CRSs, modifications must be made to either the CRS designs or the manner in which they are installed or attached to the aircraft seat. Despite the deficiencies with respect to the use of most current CRSs types in air carrier aircraft, it was assumed for the purposes of completing this study that fully effective CRSs would be available in the future.

- <u>AIR CARRIER PASSENGER VOLUME</u>: Families with infants traveling on aircraft are believed to be extremely sensitive to changes in the cost of airline tickets. Any extra cost imposed on families traveling with infants is expected to decrease air carrier passenger volume. For example, if families traveling with infants are charged the full noninfant airfare for the infant passenger, an overall yearly average of approximately 27 percent are estimated to continue traveling by air, an average of 20 percent would still travel but divert to another transportation mode, and 53 percent would forego their trip. At the other extreme, if families incur no additional costs, they would not divert to other modes of transportation. This behavior is based on the economic principle of price elasticity of demand, which states that the amount of service purchased (in this case air travel) will decrease if the price of the service (airfares) increases.

- <u>FAMILY TRAVEL COSTS</u>: The potential increase in family-travel costs includes the additional purchase of infant tickets and of aircraft-effective CRSs for families not currently owning them. The general policy of airlines is to charge for any seat reserved for occupancy by an infant, although most airlines do not prevent an infant from being placed in a vacant seat during cruise flight. Individual families would incur the greatest costs when air carriers charge airfares for infants at the same rate currently charged for non infants. Based on average trip distance, the additional cost to a family traveling with an infant in this case would be about $200, with a total estimated annual cost of $109 million for this segment of air traveler.

- <u>FATALITIES AND INJURIES</u>: The impact of a CRS mandate on fatalities and injuries depends on the efficacy of CRSs being used and on the number of air travelers who divert to other transportation modes. Fatality and injury rates for automobile transportation are significantly higher than those for scheduled air carriers. Air crash fatalities of infants are a rare event although well-reported when they occur. The study estimates that, even if fully-effective CRSs become available, a CRS mandate would prevent a maximum of 5 infant fatalities in air transportation over the next 10 years. Mandating the use of currently available CRSs would probably prevent only 2 or 3 infant fatalities over 10 years. However, mandating CRSs could result in added air fare costs to passengers with infants. In this event, any added cost would cause some of these passengers to divert to other modes of transportation. Any safety improvement from mandating CRSs on airplane flights will be offset by additional fatalities that would occur on the highways, assuming air carriers charge parents for passenger seats in which to place CRSs. In the worst case, when families are charged the full fare for infant tickets, the shift to other transportation modes is estimated to result in a net increase of about 82 infant and adult fatalities over 10 years. Major and minor injuries follow the same pattern, but at elevated levels, because the automobile injury rates are much higher than the fatality rates. Increased fatalities and injuries occur even when infant fares are discounted. If infant fares are set at only 25 percent of full ticket fares, there will still be a net increase of about 17 infant and adult fatalities over ten years. Any charge at all for infants will result in fatalities and injuries (for infants and non-infants) because of FTU diversions from air travel.

- <u>IMPACT ON AIR CARRIERS</u>: For seats reserved for CRSs, air carriers may opt to charge full fare, no fare, or a discounted fare. Air carrier revenues under a range of scenarios were estimated balancing gains from parents electing to pay infant fares against losses resulting from diverted passengers who elect not to pay infant fares. Airlines may also incur recurring costs and nonrecurring costs for the acquisition and maintenance of air carrier-provided CRSs and for updating and maintaining air carrier reservation systems to accommodate reserved seats for infants. Unless airlines pass the costs on to passengers in the form of higher air fares, the combination of higher costs and potential lower revenues associated with mandatory use of CRS may result in a net decrease in airline profits. Based on study results, air carriers may actually lose substantial revenues if full fares are always charged for a seat reserved for CRS use, because of resulting extensive diversion of whole families from air travel. This finding, however, is based on a presumption that families traveling with infants are extremely sensitive to the price of air travel and the assumed size of those families. There may be circumstances when families are less sensitive to changes in air travel cost, such as holidays and other peak periods. The finding of potential revenue loss associated with new charges to families traveling with infants also reflects past circumstances of the air transportation industry, which has been characterized by moderate excess capacity relative to total demand. This is subject to change. United States commercial air carrier passenger enplanements, which have averaged only 1.5 percent annual growth during the preceding four years, were up 8.2 percent in 1994, the largest growth since 1987. The FAA forecasts relatively strong growth to continue for at least three more years (over 5 percent per year) which could result in higher load factors and increasing reluctance on the part of air carriers to offer deep discounts to infants. If strong demand exists in the future, airlines may be able to offset revenue lost to family diversions with new passengers entering the market.

1. INTRODUCTION AND BACKGROUND

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This study was mandated by Public Law 103-305, a 1994 amendment to the Airport and Airway Improvement Act of 1982. In the words of the law, the Secretary of Transportation is to conduct a study, "on the availability, effectiveness, cost, and usefulness of restraint systems that may offer protection to a child carried in the lap of an adult aboard an air carrier aircraft or provide for the attachment of a child restraint device to the aircraft."

These issues relate to the central question of whether the Federal Aviation Administration (FAA) should require by regulation that infants under two years of age (hereinafter referred to as "infants") be secured in air carrier aircraft, or whether those traveling with infants should continue to have the choice of securing their infants in a restraint system or holding infants unsecured on their laps.

Infants are currently permitted to travel aboard air carrier aircraft in an unsecured manner on the laps of accompanying adults. Infants traveling by air can also be placed in an approved Child Restraint System (CRS), a term referring to the seat holding the infant, which is anchored to the surrounding structure. Individual air carriers exercise discretion in the amount they charge for infants transported either on laps or in CRSs.

The FAA encourages and actively promotes the use of effective CRSs for infants in air transportation, but to date has stopped short of requiring them. This is primarily because several previous studies suggest that if families are charged for infant air travel, many would shift to less safe ground transportation systems, resulting in a net increase in overall fatalities and injuries [Apogee, 1990 and 1993; Windle and Dresner, McKenzie and Lee].

Overall, U.S. air carriers have a superb safety record—one that has improved over time and now ranks among the best in the world. Air carrier incidents are infrequent; accidents are rare; and the risk of passenger injury or death associated with this mode of transportation is low. However, if an aircraft accident does occur, unsecured or improperly secured infants may face a higher risk of death than adequately secured passengers.[1]

As directed by Congress, this study examines the following topics:

- The efficacy of CRSs currently approved for use in air carrier aircraft (Chapter 3)
- The impact of a CRS requirement on air carrier passenger volume (Chapter 4)

[1] Results of the Civil Aeromedical Institute study (see Chapter 3) demonstrated that some forward-facing CRSs allowed higher than acceptable head impacts with the seat in front of the infant. For children who are large enough to use the standard seat belts, this is not an issue.

- The direct cost to families of requiring air carriers to provide CRSs and infants to use them (Chapter 5)
- The impact of a CRS requirement on fatalities and fatality rates of infants and adults traveling by air, automobile, or other modes of transportation (Chapter 6).

This chapter summarizes:

- Past and present regulations relevant to CRSs
- History of aircraft accidents involving infants
- Results of previous studies on CRSs
- Current air carrier practices regarding CRSs.

1.1 PAST AND PRESENT REGULATIONS AND DIRECTIVES RELEVANT TO CRSs

CRS regulations and related documents fall into two groups: those relevant to the CRS (that is, the actual restraint) and those relevant to the structural environment surrounding the CRS (that is, the aircraft passenger seat).

1.1.1 CRS Policy, Regulations, and Standards

CRSs were initially regulated by the now defunct Technical Standard Order (TSO) C100, issued by the FAA. This TSO was followed by the Federal Motor Vehicle Safety Standard 213 (FMVSS-213), Child Restraint Systems; Federal Aviation Regulations (FARs) 91.107, 121.311, 125.211, and 135.128; Advisory Circular (AC) 91-62A, Use of Child Seats in Aircraft; Flight Standards Information Bulletin (FSIB) Number 92-23, Miscellaneous Operational Amendments, Air Carrier Cabin Safety Operations Provisions; and a public information FAA leaflet, Child/Infant Safety Seats Recommended for Use in Aircraft. The following briefly describes the above items:

- ***TSO C100***, issued in 1982, was the first regulation defining FAA performance standards for CRSs used in an air carrier aircraft environment. The standard covered the following:

  - Systems that met FMVSS-213 requirements (as amended in 1980)
  - Systems that met a 16 times the force of gravity, 22 feet-per-second dynamic test using a representative aircraft seat fixture. (A list of CRSs meeting the test was provided in the order.)

  Based on the recommendation of a U.S. Department of Transportation (DOT) report, TSO C100 was withdrawn in 1985 when FMVSS-213 was amended to include a roll over test.

- ***FMVSS-213***, Child Restraint Systems, initially defined the National Highway Traffic Safety Administration's (NHTSA) performance standards for portable, as well as built-in CRSs, sold for use in automobiles driven in the United

States. The fixtures, procedures, impact conditions, and pass-fail criteria that should be used in testing CRSs seeking approval under the standard are also specified. In 1985, a roll over test supporting the use of CRSs in an air carrier aircraft environment became a requirement of FMVSS-213. Following this amendment, FMVSS-213 became the solitary standard for CRSs used in all transportation modes. At the discretion of the airline operator, any CRS labeled as meeting FMVSS-213 could be allowed aboard.

- ***FAR Sections*** 91.107, 121.311, 125.211, and 135.128 (14 C.F.R. §§ 91.107, 121.311, 125.211, and 135.128), were amended in 1992 to permit the use of a CRS if it is appropriately labeled, the child to be placed in the seat is accompanied by his or her parent or designated attendant, the CRS is capable of being secured to a passenger seat, and the child does not exceed the weight limitations for the device. In addition, the amendments prohibit, during air transportation, the use of CRSs that position children on the lap or chest of adults.

- ***Advisory Circular (AC)91-62***, Use of Child/Infant Seats in Aircraft, specifies limitations (for example, seat location, proximity to accompanying adult) governing the use of CRSs in air carrier aircraft. This AC was amended in 1992 to AC 91-62A, Use of Child Seats in Aircraft, to define certain types of CRSs that are approved under FMVSS-213 or under the standards of the United Nations that should not be used in an air carrier aircraft. These CRSs position an infant on the lap or chest of an adult seated in a passenger seat. In 1994, FMVSS-213 was amended to prohibit the use of belly belts.

- ***FSIB Number 92-23***, Miscellaneous Operational Amendments, Air Carrier Cabin Safety Operations Provisions, contains the same information as AC 91-62 and is published concurrently with AC 91-62 and the amended FARs.

- ***FAA Leaflet,*** Child/Infant Safety Seats Recommended for Use in Aircraft, is a quick reference guide for the general public. It has been widely distributed to the public and discusses how to ensure that CRSs are acceptable for aircraft use; questions to ask air carriers when making reservations; and the proper use, location, and maintenance of CRSs.

Several Federal policies identify standards associated with CRSs, specify minimum requirements, define testing standards, and describe what constitutes their proper utilization in several modes of transport, including airplanes. In general, any CRS that meets the performance standards defined by FMVSS-213 may be used in aircraft.

1.1.2 CRS Structural Environment Regulations

In the 1980s, the FAA began a separate regulatory activity aimed at improving the performance criteria for aircraft passenger and crew seats. By 1988, the FAA adopted regulations defining performance standards for assessing occupant protection from crash injuries as well as the structural performance of the seat and restraint (that is, lap belt) system. These regulations specify dynamic horizontal and vertical impact test conditions and pass-fail criteria.

However, aircraft seat performance regulations focus only on noninfant occupant injury protection. Current regulations do not stipulate requirements for aircraft seats to accommodate CRSs, or for aircraft passenger seat performance testing to assess injury protection for occupants secured in CRSs installed in these seats.

1.2 HISTORY OF AIRCRAFT ACCIDENTS INVOLVING INFANTS

In evaluating the safety of infants traveling by air, the size of the population at risk and the extent of the risk must be addressed. Therefore, the FAA identified aircraft accidents and incidents involving infants from 1978 to the present. FAA representatives met with representatives of the National Transportation Safety Board (NTSB) and analyzed those accidents involving infant fatalities and injuries to reach consensus on injury and fatality statistics appropriate for this study. Exhibit 1-1 summarizes the FAA and NTSB findings. The accidents include those that occurred during regularly scheduled air carrier service under FAR parts 121 and 135.

EXHIBIT 1-1
Infant Fatalities and Injuries Sustained in Survivable Air Carrier Incidents (1978 to 1994)

Item	Number Sustained	Number Determined as Preventable If a CRS were Used
Fatalities	9	5
Major injuries	4	4
Minor injuries	8	4 to 6

Source: FAA and NTSB

11.013.94-36

Based on this data set, infants have a greater risk of sustaining fatalities than adults (actual fatality rates are presented in Section 2.2.2), but have a lower risk of sustaining injuries. The results do not recognize survivable accidents in which an infant was involved but was not hurt. Because incidents involving infants in such accidents were not recorded, they could not be included in the review. Also, the analysis did not include any incidents involving parts 121 or 135 accidents occurring outside the United States, part 129 foreign air carriers, or nonsurvivable accidents. Finally, these data are historical; past incidents are not necessarily a precursor for the future.

1.3 RESULTS OF PREVIOUS STUDIES ON CRSs

The sections below briefly describe previous studies on the impact of CRS use in the aviation environment.

1.3.1 An Impact Analysis of Requiring Child Safety Seats in Air Transportation
Apogee Research Inc., 1990

In 1990, the FAA contracted Apogee Research to analyze the impact of requiring CRSs for infants traveling by air [Apogee 1990]. This analysis examined the potential safety consequences of mandatory CRS use on air carrier aircraft and the economic costs to air carriers and families with children under two years of age. Family travel behavior was considered under several scenarios that included short and long trips, hotel-based travel, and visits with relatives. The analysis reached the following conclusions under the scenario where infants were charged full fare:

- Costs would increase at an average of $185 per trip for families continuing to fly with infants.
- Families would experience an increased average annual cost of $252 million and air carriers would gain $119 million annually in revenues.
- The higher cost of air travel could cause approximately 17 percent of families that would have flown to either divert to other modes of travel or forego travel.
- The expected number of fatalities for infants traveling by air would decrease (0.4 infant deaths would be prevented in the first year after the regulation was implemented). However, the expected number of infant and noninfant family member fatalities would increase overall as some families chose to travel by automobile (there would be 2.0 additional deaths due to diversion to automobile travel in the first year after the regulation was implemented).
- The expected number of adult and infant injuries would increase significantly. For example, in the first year after the regulation was implemented, the number of net serious injuries (the difference between the change in air and the change in automobile injuries) would increase by 4.8 and the number of net minor injuries by 217.6.

The following assumptions were incorporated into the Apogee analysis:

- Infants make up about 1 percent of all commercial enplanements.
- Parents who are charged for their infants in airline seats using CRSs incur the same costs as for children between the ages of 2 and 12, who were assumed to be charged two-thirds of an adult fare.
- The cost of foregone travel or of fatalities from increased local, or stay-at-home, travel for diverted trips was not included.

1.3.2 Analysis of Options for Child Safety Seat Use in Air Transportation
Apogee Research Inc., 1993

In 1993, the FAA contracted Apogee Research to update their 1990 impact analysis [Apogee 1993]. The FAA also asked Apogee to enhance the analysis by considering a number of alternatives to mandatory CRS use. To consider such alternatives, Apogee examined five scenarios, each of which made varying assumptions concerning the cost of infant tickets to families as well as who was responsible for purchasing CRSs—airlines or families. Also, one scenario incorporated costs associated with reprogramming airline reservation systems to accommodate the need for advance CRS reservations and restrictions on CRS seat placement.

Conclusions of the 1993 analysis were as follows:

- Mandatory CRS implementation would increase the total number of fatalities and injuries and also increase costs to the traveling public. Fatality and injury increases result from the diversion of families from air to automobile travel.
- The cost of mandatory CRS implementation on the traveling public would be significant; however, fare discounts by air carriers could discourage trip diversions and reduce net fatalities.
- Requiring air carriers to hold the seat adjacent to a traveling parent or guardian—unless the plane is full—rather than mandating CRS use, would realize 95 percent of the safety gains at very low system costs, that is, the cost to reprogram reservation systems.

Because of different assumptions made in this study, no direct comparison of fatalities, injuries, or cost estimates is possible between this and the 1990 study.

1.3.3 Mandatory Child Safety Seats in Air Transportation: Do They Save Lives? *University of Maryland, 1990*

A study was conducted at the University of Maryland in 1990 [Windle and Dresner]. The assumptions made in performing that study were generally similar to those in the first Apogee analysis. Although the final results differed to a certain extent, the overall conclusion was consistent with the Apogee results: mandating CRSs for infants traveling by air would increase the total number of fatalities because of passenger diversion from air to automobile travel, which has higher fatality rates.

1.3.4 Ending the Free Airplane Rides of Infants: A Myopic Method of Saving Lives *Cato Institute, 1990*

A study conducted by McKenzie and Lee was published as a Cato Institute briefing paper (No. 11, August 1990). Their study concluded that a child restraint mandate that resulted in increased family air travel costs could endanger more children than it would save if the increased cost of air carrier travel put more families on the highways. They did not suggest the amount air carriers would charge nor did they show the elasticity of demand. Their research showed that if one-third of all families who chose not to fly at higher fares diverted to automobile travel, they would drive an additional 185 million miles each year. This increase could translate into more than 175 disabling injuries and almost 5 additional highway deaths each year.

1.3.5 FAA Civil Aeromedical Institute Study

In 1994, the FAA Civil Aeromedical Institute (CAMI) evaluated the performance, or "efficacy," of portable CRSs and standard passenger seat lap belts in restraining child anthropomorphic test dummies (ATDs) during dynamic impact testing. The testing program, conducted at CAMI facilities in Oklahoma City, examined four portable CRS types currently certified for use in aircraft -- booster seats, forward-facing carriers, aft-facing carriers, and harness restraints. Belly belts, which were made impermissible by the aforementioned 1992 amendments to the FARs, were also tested. As a result of this evaluation, CAMI concluded that the performance of aft-facing carriers (designed for children under 20 pounds) in dynamic testing was satisfactory. CAMI test results revealed that the performance of lap belts in restraining a representative three-year-old child ATD provided mixed results: both of the tests designed to measure HIC (head injury criteria) resulted in head strikes by the ATD against the front of the passenger seat it occupied, and one head strike was above acceptable HIC mandated for new airplanes. Further, only two out of eight forward-facing carriers tested without anchor point modification met acceptable HIC limits. The performance of booster seats, harnesses, and belly belts was unsatisfactory. Specific conclusions by type of CRS are detailed in Chapter 3. The CAMI report is provided in Appendix F.

1.4 CURRENT AIR CARRIER PRACTICES REGARDING CRSs

Current regulations do not require that infants traveling by air be restrained in a CRS. However, some parents traveling with infants bring their own CRSs on board. If the flight crew confirms that the CRS meets the requirements of FMVSS-213 (see

Section 1.1.1) is not broken, and is capable of being properly secured to the aircraft passenger seat, the parents may use it as long as the child does not exceed the specified weight limit for the restraint system. Sometimes, an air carrier's policy allows parents who have not purchased a seat for their infants to use an empty seat at no cost; however, this option is available only when the airplane has spare seating. When parents choose not to pay for infant tickets and if no seats are available, parents must seat infants in their laps, and the CRS is typically placed in the airplane's baggage compartment.

One area this study examined was the costs associated with a CRS requirement. What the costs will be and who will bear them depend mainly on air carrier pricing practices. Based on conversations with the Air Transport Association (ATA) and on statements by air carrier representatives, it appears that air carriers generally do not discriminate in pricing between adults and children under the age of 12. Fares charged for reserved seats occupied by children are the same as adult fares. However, air carriers sometimes offer discounts for children under the age of 12, in conjunction with special promotions or during periods of low travel demand. Nonetheless, the specific pricing policies that air carriers will adopt for infants if CRSs are required are not known. However, the air carriers made two points. The first is that they want the option to charge infant fares; the second is that market forces will play a strong role in determining what, if any, charges are made.

1.5 REPORT ORGANIZATION

The report is organized in two volumes. Volume I contains Chapters 1 through 8. Chapter 1 introduces the background of the study. It includes the Congressional request for the study, past and present regulations, history of aircraft accidents involving infants, results of previous FAA studies, and current air carrier pricing practices. Chapter 2 describes the methodology followed in conducting the study. Chapters 3 through 7 respond to each of the questions contained in the Congressional request for the study. Specifically, Chapter 3 presents the study's findings on CRS efficacy. Chapters 4 through 7 present the study's findings on the impact a CRS requirement will have on air carrier passenger volume, family travel cost, fatalities and injuries, and air carrier costs, respectively. Chapter 8 summarizes the major findings of the study.

Volume II contains eight appendices that provide supplementary information. Appendix A lists acronyms used in the report; Appendix B describes expert panel discussions held to collect information at the inception of the study; Appendix C contains the FAA *Federal Register* notice and submitted responses; Appendix D presents survey data related to CRS recurring and nonrecurring costs; Appendix E contains historical air carrier and automobile safety data; Appendix F contains the CAMI study report; Appendix G reviews the technical literature used to develop estimates for the price elasticity of demand values and the analytical method that implements them; and Appendix H lists key data sources and technical journals reviewed to support this study.

2. STUDY METHODOLOGY

2. STUDY METHODOLOGY

In conducting the CRS study, a combination of qualitative and quantitative approaches were used to obtain data and estimate economic and safety impacts. Material was gathered and reviewed by numerous individuals and entities. The Department's study team consisted primarily of staff from the Office of Aviation Policy, Plans, and Management Analysis; Office of Aviation Medicine; Aircraft Certification Service; and Flight Standards Service. The team was assisted by a contractor, Booz, Allen and Hamilton, Inc., who provided technical and computer modeling support.

2.1 QUALITATIVE APPROACHES FOR INFORMATION GATHERING

To ensure this study incorporates the most current information available, the following qualitative approaches were used to collect data:

- Panel discussions
- *Federal Register* notice solicitation of public comments
- Literature review.

The information gathered through these methods forms the foundation for this study. Further details regarding each method of inquiry are provided below.

2.1.1 Panel Discussions

The FAA conducted discussions with panels of experts on issues related to CRS regulation for three purposes:

- To provide relevant information
- To determine other sources of relevant information
- To check the validity of assumptions that would be incorporated into the analysis.

Participants in these discussions included representatives from the air carriers, the CRS industry, academic institutions, professional associations, advocacy groups, and government agencies. Panel sessions on the following five subject areas were conducted in the Washington, D.C., area:

- Infant and adult mortality rates for air and automobile travel
- Price elasticity of demand and forecasts for air and automobile travel
- The efficacy of child restraint systems
- Air carrier operational issues
- Air carrier costs and potential pricing issues.

Before the panel meetings, panel members received background information that included reports from three previous studies [Apogee 1990 and 1993; Windle and

Dresner]; information regarding survivable aviation accidents involving infants; results c a literature search on price elasticities of demand; internally derived estimates of the number of infant passengers on airplanes; and estimates of distances families would typically consider driving instead of traveling by air.

In each panel session, the assumptions and results of previous studies were firs summarized to provide a baseline for discussion. Panelists presented their ideas or opinions regarding each assumption or result. The panel facilitator did not attempt to reach a consensus—only to obtain all the opinions of the expert panelists on each topic covered. In the time allotted, the facilitator encouraged further discussion and elaboration of ideas presented by panelists. The panel discussions are summarized as follows:

- **Mortality rate** panelists reviewed the assumptions used by previous studies to estimate mortality rates for air and automobile travel, discussed methodologies for improving the estimates, and provided guidance for obtaining the most current sources of applicable data. A common theme of the session was that even though mortality rates for automobiles are decreasing annually, they are still many times higher than aviation mortality rates.

- **Price elasticity** panelists considered the values of the elasticity parameters used in previous studies and the methods to improve these parameter values. Specifically, they discussed the magnitudes of the elasticities in terms of passenger segmentation by trip purpose, trip length, and passenger income. In general, many participants believed that demand for air travel is elastic and may be more elastic than previously thought.

- **Efficacy** panelists focused on the results of the recent CAMI CRS testing. Those results and their implications were the basis for further discussion. Suggestions to enhance safety through potential CRS and airplane seat modifications were also presented. In summary, aft-facing CRSs performed the best in testing; other CRSs generally performed poorly.

- **Operational issues** panelists discussed the potential impacts of mandatory CRS use on air carriers. Main topics were the impact to air carrier reservation systems; the additional training requirements for gate agents, flight attendants, and maintenance personnel; and the need to educate the public regarding changes to air carrier policies and procedures. The main theme of the discussion was that mandating CRSs could significantly impact operations. Air carriers requested that these impacts be minimized.

- **Cost impact** panelists discussed the same topics as the operational issues panel, but examined those issues in terms of the financial burden that a CRS mandate might place on air carriers. Major cost impacts would result from retrofitting aircraft to incorporate the alternate anchor points and modifying the reservation systems.

Appendix B contains a description of each session, including the agenda, a list of participants, and a summary of the discussions.

2.1.2 Federal Register Notice

The FAA also solicited public comments regarding child restraint systems by publishing a Notice of Study and Request for Comments in the *Federal Register* (59 Fed. Reg. 53768) on October 26, 1994. This publication established Docket 27941 at the FAA. The docket was officially closed on November 11, 1994. The notice posed the following four questions.

- What cost might air carriers incur if the use of CRSs were required by regulation?
- For a family traveling with infants, what is the price elasticity of demand for air travel?
- What are the profiles of families who drive with infants? What are the profiles of families who fly with infants?
- What are the infant and adult mortality rates for air travel, automobile travel, and other modes of transportation?

The FAA received four comments. Each of the comments stated that an infant restrained by a CRS would be safer than a lap-held infant. Comments differed in their recommended approaches for developing effective CRSs for aviation use. For example, one respondent recommended developing a new CRS around the current airplane seat configuration; another recommended modifying both the CRS and the airplane seat to maximize the potential safety benefits. However, none of the comments specifically addressed any of the four questions published in the *Federal Register*. (See Appendix C for a reprint of the *Federal Register* notice and comments received.)

2.1.3 Literature Review

The time schedule established by Congress for this study precluded conducting original research to develop the values of price elasticity estimates, the average number of people traveling as a family, mortality rates for all transportation modes, the mode choice distribution of diverted passengers, and the probability that an infant could displace a full fare passenger. Therefore, the FAA conducted a thorough external literature search to gather the most current and reliable information available for the topics listed below. In total, over 50 data sources and technical journals were obtained from various university on-line databases, government libraries, and transportation association publications. (See Appendix H for a complete reference bibliography.)

- **Price elasticity of demand for different types of air travelers**. Many studies on price elasticities of demand segment air travelers either by trip distance, trip purpose, or passenger income levels. For air travelers in general, a wide range of price elasticity estimates were published. Appendix

G reviews the price elasticity literature; Section 2.2.2 discusses the process used to determine the estimates for the analysis. Generally, price elasticity estimates for business travelers are less elastic than for nonbusiness travelers; estimates for high-income passengers are less elastic than for low-income passengers; and estimates for travelers taking long trips are less elastic than for travelers taking short trips. However, none of the research identified price elasticity values specific to family travel units (FTUs)—families traveling by air with infants. Therefore, the price elasticity relationships described above were used to estimate the price elasticities for FTUs.

- **The number of people in a family travel unit**. The U.S. Census Bureau presents data on the number of families by income class, with children under the age of 18, and with children under the age of 6; the number of married-couple families; and the number of children in the U.S. by age. The size of the average family, including the number of infants in different income levels, was not directly available. Survey results from the U.S. Travel Data Center provide data on travel party sizes of different incomes taking trips of different lengths. The data from these sources were used to determine the number of passengers in an average FTU.

- **Injury and fatality rates for all transportation modes**. Extensive historical data regarding airplane and automobile accidents and casualties were obtained from NTSB and NHTSA. These data were used to develop casualty rates for air and automobile travel. The limited historical information available for buses and trains were used to develop casualty rates for these alternative transportation modes.

- **Transportation mode choice for diverted passengers**. The literature provided values for the proportions of travelers who, once diverted from air travel, would either use another mode of transportation or would forego their trips. U.S. Travel Data Center survey results were then used to distribute the diverted travelers among automobile, bus, and rail travel.

- **The probability of passenger displacement ("bumping")**. Several studies focused on situations in which high air carrier load factors resulted in high passenger spill rates. These spill rates, also termed "bumping," were used in the analysis to predict the number of full fare passengers who might be bumped by infants occupying airplane seats.

The detailed analyses used to develop these parameter values are described in Section 2.2.2.

2.2 QUANTITATIVE APPROACH FOR THE BENEFIT/COST ANALYSIS

Estimates of the costs and benefits under different sets of assumptions were produced to determine which sets of assumptions have the least adverse economic and safety impact. The estimates were based on the following premises:

- If the FAA mandates use of CRSs, then associated costs may be incurred. Air carriers, FTUs, and non-FTUs (all air passengers who are not FTUs) could separately or collectively absorb the additional cost.

- From the air carrier standpoint, a higher cost could result in a lower profit. Also, if airplane seats were reserved for infants at reduced prices, air carriers could suffer reduced revenues when infants displace passengers paying a higher fare. Air carriers may decide to charge higher fares as a way to pass costs on to air travelers.

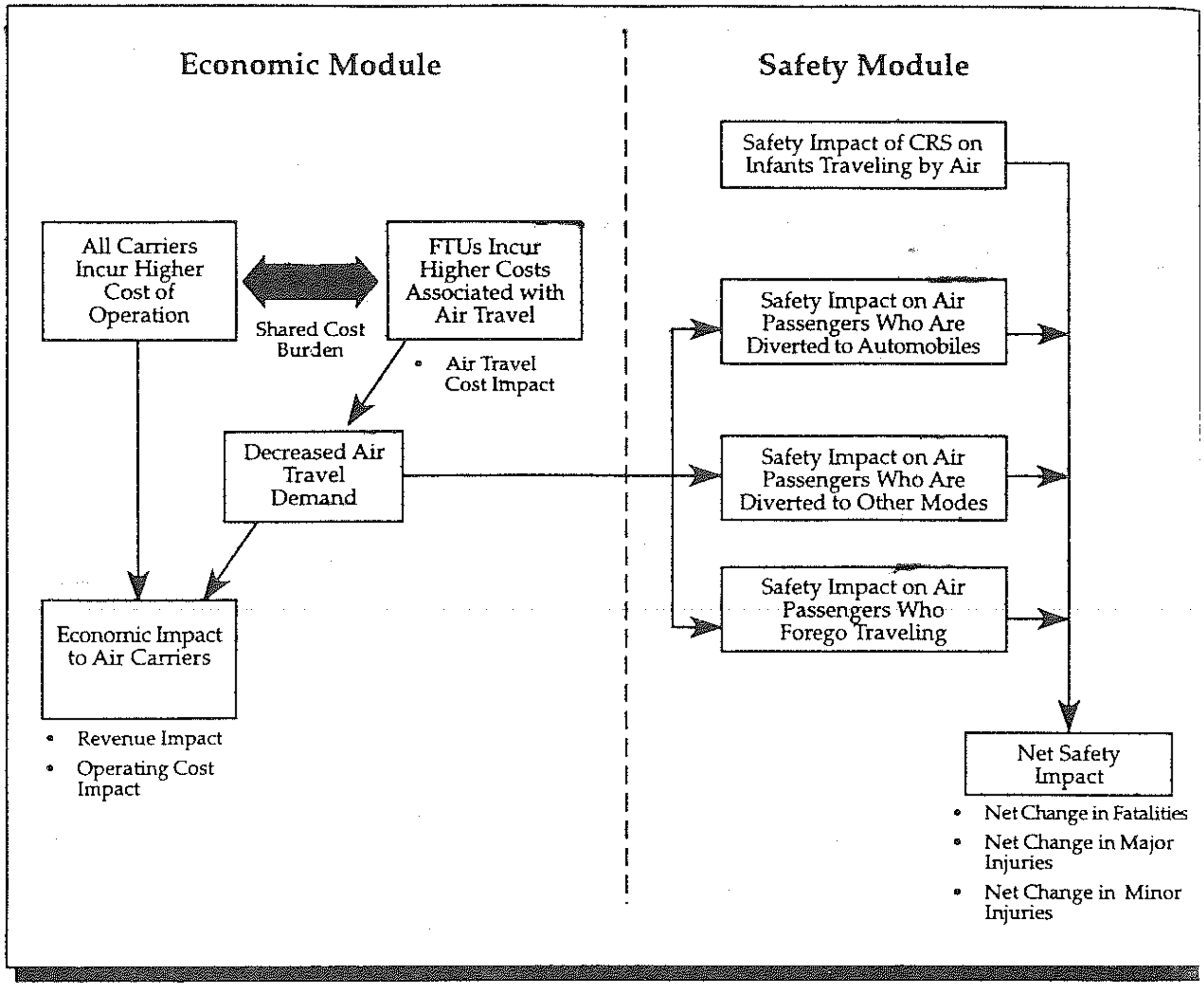
- If higher ticket prices were charged to air travelers, some air travelers would divert to other transportation modes or may decide to forego travel.

- If air travelers divert to other modes of transportation, those passengers would be subject to the higher fatality and injury rates inherent in other transportation modes. The occurrence of accidents when diverted air passengers travel by other transportation modes may offset the increase in aviation safety resulting from mandated use of CRSs.

2.2.1 Structure of the Analysis

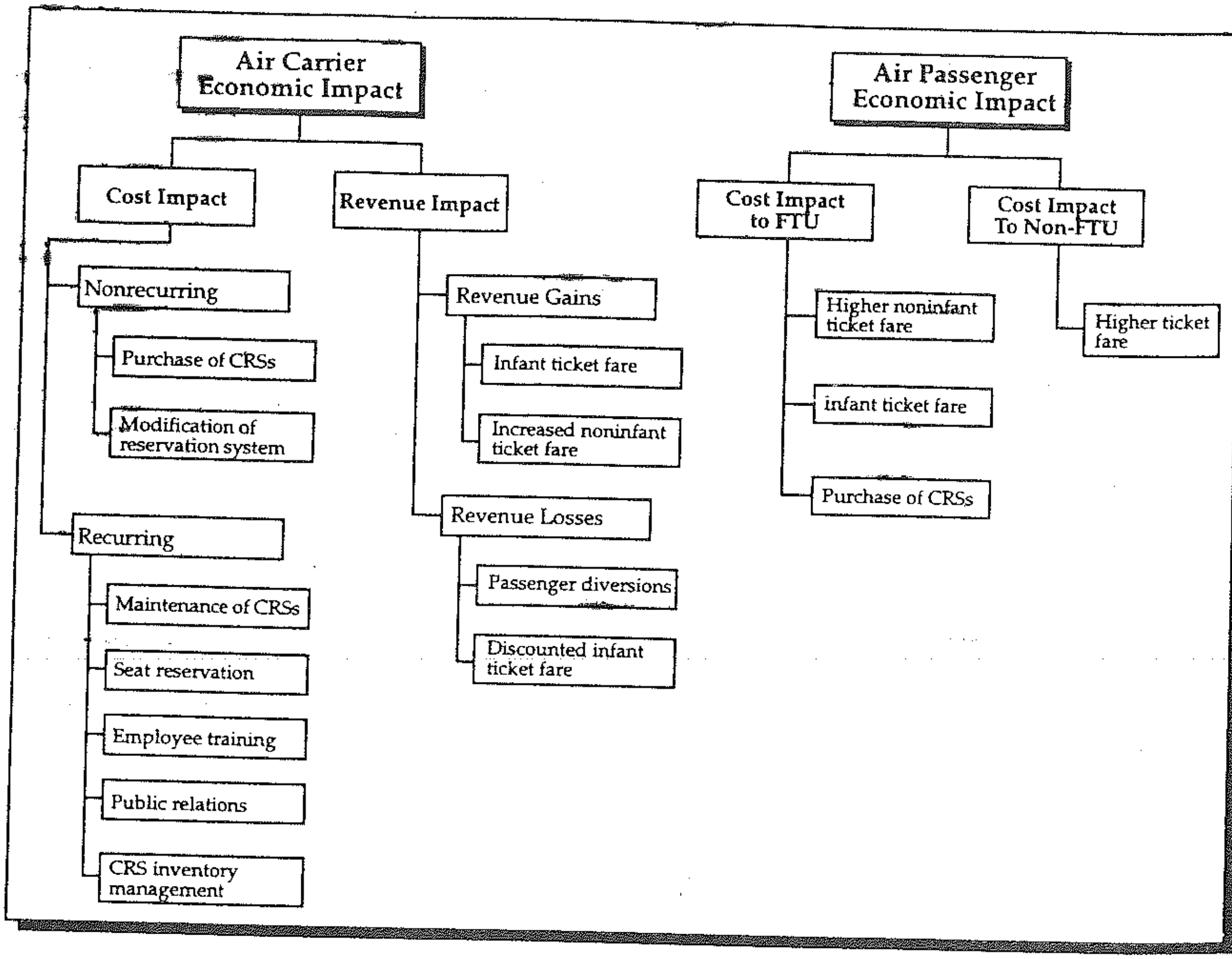
The analysis considered the cost and safety impacts for seven feasible scenarios concerning use of CRSs in aircraft of major and commuter air carriers. The analysis estimates safety benefits in terms of fatalities and injuries prevented by use of CRSs. Passengers and air carriers may experience cost increases if CRS use is mandated. The analysis consists of two major modules, the Economic Module and the Safety Module, as summarized in Exhibit 2-1. A discussion of each module follows.

EXHIBIT 2-1
Child Restraint System Benefit/Cost Analysis



- **Economic Module**. The Economic Module projects the impact of costs and revenues on air carriers and the impact of costs on air travelers depicted in Exhibit 2-2. Air travelers respond to price increases by reducing their air travel (air passenger price elasticity). Decreased air travel affects the air carrier revenue stream. Major outputs of this module are the economic impacts to air carriers, the cost impacts to air travelers, and the number of diverted passengers resulting from decreased air travel demand.

EXHIBIT 2-2
CRS Economic Impact Module



Air carrier cost increases can be categorized as either recurring or nonrecurring costs. Additional nonrecurring costs are for initially acquiring CRSs and modifying the computer reservation systems. The additional recurring costs are for maintaining the CRSs and updating the reservation systems.

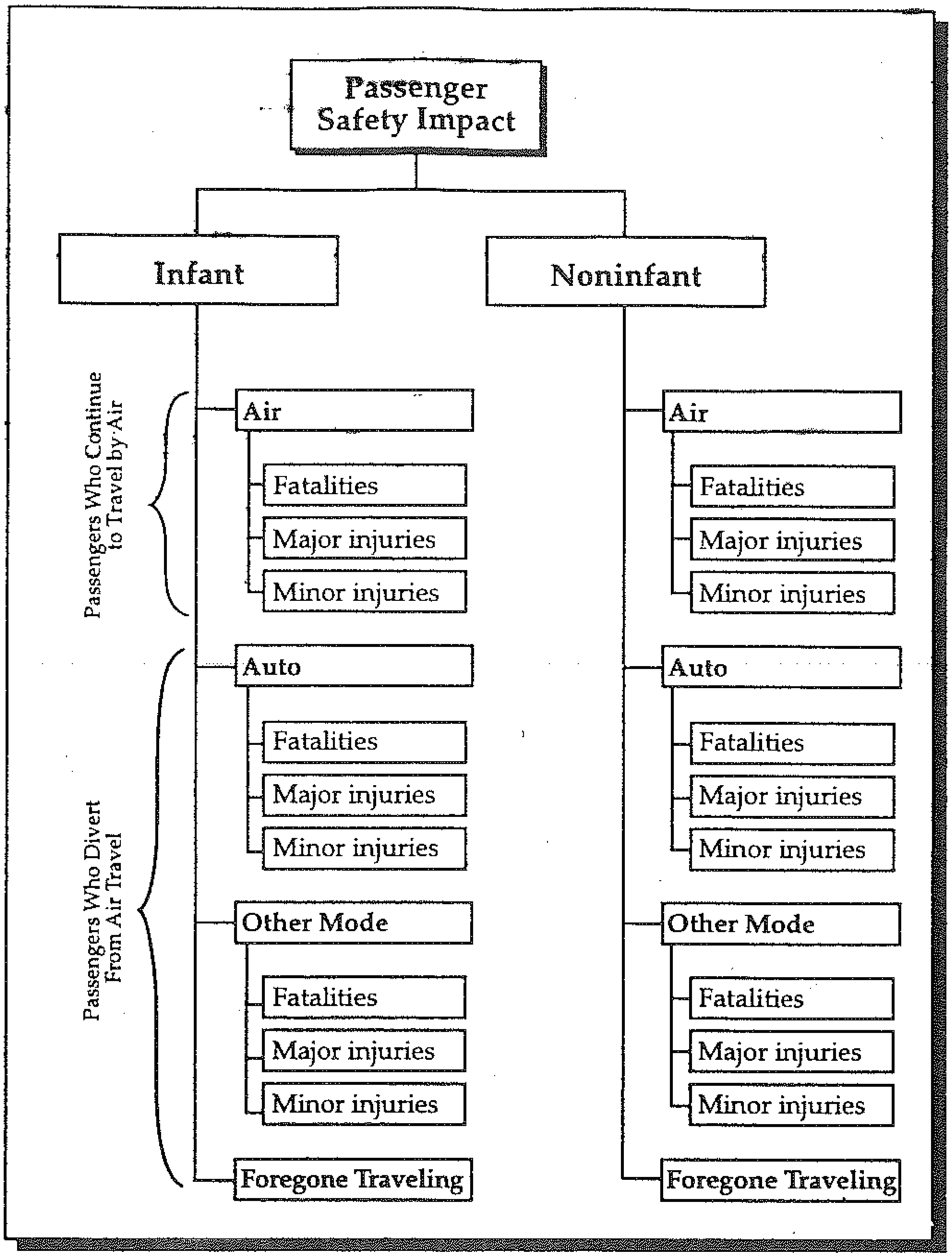
Air carrier revenues may also be affected. The air carriers receive increased revenue by charging for traveling infants. Also, air carriers could pass costs on to all paying passengers, which would result in increased fares for noninfants. In both cases, the impact of negative revenue may result from passengers diverting from air travel because of air fare increases. In addition, if infant tickets are offered either for free or at reduced fares, the difference between the infant ticket price and the price of the ticket for the noninfant passenger, who was displaced by the infant, is a loss in air carrier revenue.

The net economic impact to air carriers is the increased revenue from infant ticket receipts and increased air fares caused by air carrier pricing responses minus the lost revenue, the recurring costs, and the nonrecurring costs.

To allocate costs properly, air passengers are segmented into two groups: FTUs and non-FTUs. Higher air fares for noninfants could result for both groups if air carriers choose to recover their costs by increasing air fares for all passengers. However, the assumptions consider only the costs to FTUs—infant ticket fares and the CRS purchase costs.

- **Safety Module**. The Safety Module calculates the number of infant fatalities and injuries that CRS use on airplanes could prevent. The module also distributes the diverted passengers across several transportation modes, including the category of foregone travel. Based on fatality and injury rates related to the different transportation modes and on the volume of traffic using each mode, the number of infant and noninfant fatalities and injuries are calculated using differential fatality rates. Finally, the analysis combines the number of infant fatalities and injuries prevented in the air with the total number of additional fatalities and injuries resulting from traveling by other modes of transportation to produce the net fatality and injury impacts. Exhibit 2-3 illustrates the safety impacts captured by the Safety Module.

EXHIBIT 2-3
CRS Safety Impact Module



The analysis was developed to quantify economic and safety impacts under the following seven scenarios. These scenarios reflect a range of possibilities for sharing the CRS and infant ticket costs between the air carriers and the passengers.

- **Scenario 1—the baseline case (no CRS mandate)**. The adult accompanying the infant may either hold the infant on his or her lap—the infant travels at no cost—or may purchase a ticket so the infant can occupy a separate seat. An infant may also be placed in a vacant adjacent seat at no cost if that seat is available. Scenario 1 provides a benchmark against which the other scenarios are compared.

- **Scenario 2—the air carrier provides a separate seat for the infant at no cost; the FTU provides the CRS.** The seat is guaranteed for the infant and will not be sold to a full fare customer. A small percentage of full fare passengers will be bumped from flights that are filled. Some of those bumped passengers will forego traveling. The family brings its own CRS, which it most likely purchased for automobile travel.
- **Scenario 3—the air carrier provides a separate seat for the infant at no cost; the air carrier provides the CRS.** This scenario differs from Scenario 2 in that the air carrier provides the CRS for the infant's use instead of the FTU bringing its own.
- **Scenario 4—the FTU reserves a separate seat for the infant at no cost on a space available basis; the FTU provides the CRS.** A family member can reserve an adjacent airplane seat for an infant's use on a space available basis. The air carrier reservation system will block that adjacent seat until the airplane becomes completely booked. At that time, the air carrier sells the infant's seat to the next full fare passenger and the infant travels on its guardian's lap. The family brings its own CRS, which it most likely purchased for automobile travel.
- **Scenario 5—the FTU pays the full fare for an infant ticket; the air carrier provides the CRS.** This scenario is the first that requires the family to purchase a ticket for the infant at the noninfant ticket price to reserve the seat in which the CRS will be placed. The airline provides the CRS, which the infant will use for the duration of the flight.
- **Scenario 6—the FTU pays the full fare for an infant ticket; the FTU provides the CRS.** This scenario differs from Scenario 5 in that the FTU brings its own CRS, which it most likely purchased for automobile travel.
- **Scenario 7—the FTU pays a percentage of the full fare for an infant ticket; the FTU provides the CRS.** This scenario provides three possible infant ticket cost sharing plans in which the FTU and the air carrier share the infant travel cost. That is, the infant air fare is a fraction of the noninfant fare. These cost share values represent possible strategies that air carriers might use to defray the cost of the seat the infant will occupy without requiring the family to pay the full fare for the infant. The family brings its own CRS, which it most likely purchased for automobile travel.

For each scenario, the default pricing response is zero; air carriers absorb all costs. It is not known if air carriers would choose to pass costs on to all passengers.

2.2.2 Key Input Parameters

In this analysis, certain key parameters significantly affect the results. The nine key parameters, their descriptions, and the methodology used to determine their values are as follows:

- **Price elasticity of demand for air passengers**. The price elasticity of demand for air travel is a measure of air travelers' response to variations in the cost of air travel. This parameter measures the percentage change in air passenger departures resulting from a one percent change in air carrier ticket prices. Price elasticity values are negative because, in general, price and quantity demanded are inversely proportional—in this instance, if the air fare increases, the demand for air travel will decrease (all other factors remaining constant).

  For this analysis, a two-step approach was used to determine the appropriate price elasticities of demand. First, the FAA sought opinions from a panel of experts on the price elasticity of demand—with respect to ticket price—for air travelers. Appendix B summarizes the main points of discussion. Generally, different passenger groups exhibit different responses to air fare increases. The three categories that were discussed for segmenting passengers are:

  - Trip purpose (business and nonbusiness)
  - Trip distance (long distance and short distance)
  - Passenger income (high income and low income).

  Although panelist opinions varied on the price elasticity estimates and ranges of estimates for each passenger group, some general relationships were identified. For example, panelists stated that nonbusiness travelers generally exhibit a more elastic response to changes in ticket prices than business passengers. Also, the panelists agreed that travelers taking short trips exhibit a more elastic response to air fare changes than passengers taking long trips. Finally, the panelists stated that low-income passengers show a more elastic response to air fare changes than higher-income passengers.

  Panelists also stated that air fare price elasticity estimates should be in the elastic range (less than -1.0), and that, over time, air travelers may have become more sensitive to air fare increases than was previously thought. One panelist suggested this change may be a result of passengers' trained expectations of periodic fare wars, prompting them to wait for discounted fares before purchasing tickets.

  The panel discussion provided information on the types of passenger segmentations to consider and on the relative differences between the demand elasticities for each group. The panel discussion was also useful because no published studies classified air travelers into the groups this study addressed. Based on the panel information, the FAA decided that elasticity estimates were needed for the following eight categories of air travelers:

- Nonbusiness traveler
  - Short distance trip
    - Low-income traveler[1]
    - High-income traveler
  - Long distance trip
    - Low-income traveler
    - High-income traveler
- Business traveler
  - Short distance trip
    - Low-income traveler
    - High-income traveler
  - Long distance trip
    - Low-income traveler
    - High-income traveler

For the purposes of this study, only the price elasticity estimates for nonbusiness travelers will be discussed in detail because only FTUs, which are a subset of the nonbusiness travelers, are assumed to be affected by increases in infant ticket prices in this analysis. Appendix G includes a description of the business traveler price elasticity estimates.

The second step was to obtain reasonable elasticity estimates for each of the above individual passenger groups. Two options were considered in completing this task. First, primary research could be conducted to obtain the appropriate elasticity estimates for each of the eight segmentations identified. This approach was not considered feasible because of the time constraints imposed on this study.

The next option, and the one selected for completing this work, was to review the existing literature describing the price sensitivity of U.S. air travelers to variations in air fares. The approach used to estimate the price elasticities used in this study was based on the literature review and panel discussions. The four price elasticity estimates shown in Exhibit 2-5 are those used in this analysis. The average, weighted by percentage of FTUs in each passenger

1 Passengers are grouped by income levels to differentiate between their price sensitivities. This grouping is not to be confused with income elasticities, in which consumers' incomes are changed (with all other variables held constant) and their behavioral responses to those changes are measured.

category, is -1.6. However, the four specific price elasticity estimates—not their weighted average—were used in all calculations.

The four estimates range from -1.3 to -2.3, depending on the passenger group. The spectrum of price elasticities used to develop the estimates for this analysis came from the studies summarized in Appendix G. Key findings from this literature review are:

- Ten studies of the U.S./North American air travel market were used as the starting point for determining price elasticity estimates for the traveler groups.
- Of these ten studies, seven segmented air travelers by trip purpose; three segmented them by distance; and one segmented them by income level. One of the studies did not segment the travelers. (The number of studies does not total to ten because one study segmented travelers into all three groups and is counted three times.)
- Price elasticity values ranged from -0.6 to -4.5 for different types of passengers. This wide range of estimates is based on differing assumptions, time periods, and data.

Of the ten studies on air fare price elasticities, seven did not apply to this study for several reasons—either they focused on narrow, niche markets; they did not specify passenger groupings; or the panelists believed the study results may not have been applicable. Also, many of the studies were relatively old—five of them were based on prederegulation data—and their elasticity estimates may be understated if the price elasticities of air travelers truly have been increasing over time. The three remaining studies provided information to develop price elasticity estimates for the four nonbusiness travel groups. None of the studies provided elasticity estimates specific to families or families traveling with infants. Appendix G describes the ten studies and the rationale for using or not using each study in this analysis.

The price elasticity estimates presented by these studies are point elasticities. These point elasticities, by definition, prevail only for particular points on the demand curve. Thus, these elasticity estimates can only be used to accurately estimate quantity changes for small changes in air fares. To estimate changes in demand for large increases in air fare experienced by FTUs under specific scenarios, specific assumptions were made on how elasticity values change over the price range of interest. This study assumes linear demand curves, which imply a greater elasticity as the price increases. This is consistent with views expressed in the panel discussions and is believed to be more realistic than one of constant elasticity because of the large changes in price considered in this study.[2] Separate curves were

[2] The FAA does not believe that the price elasticity of demand for air travel by FTUs is constant throughout the possible range of prices. A priori, it seems more reasonable that the price elasticity of demand varies over the

calculated for each of the 10 years included in this study—these curves having the elasticities discussed in this chapter at the point of forecast demand.

The following table summarizes the applicable price elasticity studies and the associated price elasticity estimates.

EXHIBIT 2-4
Applicable Price Elasticity of Demand Studies

Author and Article	Focus of Study	Value (or range of values)
Oum, Gillen, & Noble, "Demands ... in Airline Markets," 1986.	Economy, standard Economy, discount	-1.23 to -1.36 -1.50 to -1.98
Abrahams, "... Model of Air Travel Demand," 1983.	Florida vacation city-pairs Hawaiian-West Coast city-pairs Eastern medium-haul city-pairs	-1.98 -1.68 -1.22
Straszheim, "Airline Demand Functions ... Pricing Implications," 1978.	Economy, peak period Economy, average Economy, standard Economy, promotional Economy, high discount	-1.92 -1.48 -1.12 -2.74 -1.82

It was not possible to assign price elasticity values from the literature directly to the specific passenger segmentation groups identified for this study. Therefore, the FAA used its professional judgment to determine which price elasticity values listed in Exhibit 2-4 applied to this analysis. First, nonbusiness air traveler groups were ranked from the highest to the lowest price elasticity magnitudes as follows:

possible range of prices -- more elastic at high fares, less elastic at low fares. This is characteristic of a linear demand function. Previous studies of the demand for air transportation which specified a constant price elasticity within a given market segment, estimated a wide range of elasticity values. This suggests that elasticity is not constant over the range of possible prices and may therefore be more appropriately represented by a linear function.

Non-linear, constant price elasticity of demand curves are, a priori, not considered realistic models of consumer behavior at the extrema of possible prices (the curve is a hyperbola, asymptotic to both axes). Such functions suggest that there will always be a consumer no matter how high the price and that at some low price, consumers will buy an infinite amount of a product or service. An assumption of constant price elasticity demand functions by economists is probably caused more by convenience in calculations rather than the accuracy of portraying consumer behavior.

- Low-income traveler taking a short trip
- Low-income traveler taking a long trip
- High-income traveler taking a short trip
- High-income traveler taking a long trip

The most price-sensitive nonbusiness passenger (low-income, short trip) probably would purchase tickets at high discount or promotional economy fares. One study provided a high discount economy price elasticity of -1.82 and a promotional economy price elasticity of -2.74 [Straszheim]. The average of these two values, -2.3, was the value assigned to this type of passenger.

The second most price-sensitive nonbusiness passenger (low-income, long trip) probably would purchase tickets at discount economy fares. Oum, Gillen, and Noble found that the price elasticity for discount economy travelers was between -1.50 and -1.98. Also, Abrahams found that the price elasticity was -1.98 for Florida vacation city-pairs. This estimate was assumed to apply to these travelers because Florida is a popular vacation destination for many families, and it represents a trip length of over 500 miles from most major U.S. metropolitan locations. The average of these three values is -1.8 and was assigned to this type of passenger.

The next most price-sensitive nonbusiness travelers (high-income, short trip) probably would travel at somewhat more costly economy rates because of their higher income—average economy fares or during peak periods because of their higher income. Straszheim provided an average economy price elasticity of -1.48 and a peak period economy price elasticity of -1.92. The average is -1.7 and was assigned to this type of passenger.

The least price-sensitive nonbusiness travelers (high-income, long trip) probably would travel at the highest economy rates. Two studies provided standard economy price elasticities of -1.12 [Straszheim] and -1.23 through -1.36 [Oum, Gillen, and Noble]. Also, Abrahams provided a price elasticity of -1.68 for Hawaiian-West Coast city-pairs, which was applicable because it represented a long distance trip that might be dominated by higher income travelers. Abrahams also calculated a price elasticity of -1.22 for eastern medium-haul city-pairs, which was considered because most medium-haul trips are more than 500 miles and this lower price elasticity is representative of higher-income travelers. The average of these five values is -1.3 and was assigned to this type of passenger.

The price elasticity values used for FTU travelers used in this study are summarized in Exhibit 2-5.

EXHIBIT 2-5
Price Elasticity of Demand Estimates for FTU Travelers and Percentage of FTU Enplanements

Travel Distance (One Way)	Annual Household Income Less Than $40,000	Annual Household Income Greater Than or Equal To $40,000
Less than 500 miles	-2.3 (4.5% of FTU enplanements)	-1.7 (4.4% of FTU enplanements)
Greater than or equal to 500 miles	-1.8 (46.4% of FTU enplanements)	-1.3 (44.7% of FTU enplanements)

Source of price elasticity estimates: Oum, Gillen, and Noble; Abrahams; Straszheim.
Source of passenger percentages: U.S. Travel Data Center

The simple average of the four FTU price elasticity estimates is -1.8; the weighted average is -1.6. Because the most price-sensitive passengers only comprise 4.5 percent of FTU enplanements (0.5 percent of all enplanements), the highest price elasticity value of -2.3 contributes very little to the FTU air traveler price sensitivity.

These estimates may be conservative because many of them are not based on up-to-date data. If the panelists' observations are correct that air fare price elasticities have been increasing over time, then the actual price elasticities could be greater than those listed above. These estimates were developed from the best information available for the grouping of air travelers identified as being most affected by changes in air fares.

The business traveler price elasticity values are approximately 50 percent of the nonbusiness elasticity values, but those values were not used in this study because fare increases are assumed to be limited to FTUs. Appendix G describes the sources The business traveler price elasticity values are approximately 50 percent of the used to determine this relationship and the resulting business traveler price elasticity estimates.

The elasticity estimates used in this analysis assumes that the average FTU size is 3.17 individuals including one infant (See following discussion). However, in some situations, the price elasticity of demand of a small family (e.g., one adult, one small child and one infant) may be much more inelastic and therefore FTUs may be much less willing to divert to automobile transportation than FTUs with older children.

The analysis also assumes that FTUs will be equally willing to travel at any time during the year and therefore the elasticity would only vary by distance and FTU income. In some situations, FTUs with school age children and an infant may only be able to travel during spring and Christmas break. The parents would be unwilling to take their children out of school during other times of the school year. Consequently, the price elasticity of demand for airfare may be much less sensitive during school breaks and much more elastic during other times of the year.

During Christmas, Thanksgiving, and certain other periods of the year , the demand for passenger seats may exceed the supply. This situation suggests that air carriers would be likely charge full adult fares for passenger seats for use of a CRS. At other times of the year, it is assumed that air carrier charges for infant travel would result in significant diversion to highway travel with an associated increased risk of injuries and fatalities. However, during holiday peaks, diversion may not be possible for many families; they would instead forego travel, which would reduce the potential benefits of a mandatory CRS requirement.

The distance break at 500 miles differentiating a short from a long trip coincides roughly with the maximum driving distance a FTU might cover without the added cost in money and time for an overnight stop. Thus, if the dollar cost of the short trip appears excessive to the FTU, the automobile alternative is more feasible than for a long trip that would include the cost of a night's meals and lodging as well as an extra day's driving. It is reasonable that for long trips more than short trips FTUs electing not to fly because of the added fare would forego the trip entirely. Trip distance is thus to some extent a surrogate for feasibility of an alternative mode.

Families traveling with infants constitute a small fraction of total air travelers, so that general air travel price elasticity may not fully capture special characteristics of families with infants. Families with school age children as well as infants may be limited to traveling during school breaks like Thanksgiving, Christmas, or Easter, and thus be unable to divert to more time-consuming alternative modes. Similarly, where the FTU composition might be a single adult with one or more small children, driving for extended periods may be impractical. For either of these cases, the "short" trip break point may be considerable less than 500 miles.

- **The number of people in an FTU**. This parameter is defined as a family traveling by air on a nonbusiness trip, accompanied by at least one child under two years of age. Data were not available to determine the average size of a family with an infant. As an estimate, census data [U.S. Census Bureau] were used to determine that the average size of a family in the United States, with children under 18 years of age, was 3.17. That value was used to estimate the average size of a family with one infant.

To differentiate the FTU by income level, survey data [U.S. Travel Data Center] that segmented air travel party sizes by income were used to develop the percentage of high-income travel parties and low-income travel parties. This relationship (51 percent low income and 49 percent high income) was applied to the mean value of 3.17; the results of this analysis yielded the parameter values listed in Exhibit 2-6.

EXHIBIT 2-6
Number of Air Passengers per FTU

	Number of Air Passengers by FTU Annual Income	
	Less Than $40,000	Greater Than or Equal to $40,000
Infants	1.00	1.00
Noninfants	2.12	2.22
Total	**3.12**	**3.22**

11.013.94-0

Source: U.S. Travel Data Center 1993 Travel Market Report; U.S. Census Bureau: Families By Size and Presence of Children, 1993

- **Number of Infant Enplanements**. The estimate of infant enplanements was derived from a combination of air carrier surveys and industry experience, as discussed during the operational issues panel session; U.S. Travel Data Center survey results; and a sampling of passengers at Washington National Airport. Each survey was done independently and converged on infant enplanements equaling approximately 1 percent of air passenger enplanements. The 1994 FAA Aviation Forecast was used as the source of data for enplanements from 1995 through 2004. Exhibit 2-7 displays these enplanements and the subsequent 1 percent values used for infants.

EXHIBIT 2-7
Enplanement Forecasts

Year	Total Enplanements (millions)	Infant Enplanements (millions)
1995	500.8	5.0
1996	520.3	5.2
1997	541.8	5.4
1998	563.3	5.6
1999	586.5	5.9
2000	606.2	6.1
2001	628.2	6.3
2002	650.0	6.5
2003	671.9	6.7
2004	695.0	7.0

Source: FAA Aviation Forecasts 1994-2005

The independent surveys used to obtain the number of infant enplanements were not comprehensive. The real number of infant enplanements may differ significantly from the values used in this study. To improve the accuracy of this parameter, either national surveys of air passengers must be conducted or air carriers must report the numbers of enplaned infants per flight.

- **Fatality and injury rates for all transportation modes.** Current and projected fatality and injury rates were developed for four modes of transportation—airplane, automobile, bus, and rail. The rates used in this analysis are for airplanes and automobiles (separately), and for bus and rail, (combined). Both bus and rail are considerably safer than automobiles, but current indications are that little diversion to these modes would occur. Thus, no significant loss of accuracy is involved in combining them. These parameters are defined as the number of infant and noninfant fatalities and injuries per a measurement unit specific to the transportation mode, as described below.

  – *Aviation fatality and injury rates.* The bases for these key parameters were historical fatality and injury data. These parameters were computed per flight operation (takeoffs and landings) rather than overall miles traveled in accordance with the opinions of several aviation safety experts and academic studies [Pickrell, 1992; Sivak]. A three-step process was used to compute the probabilities of sustaining aviation fatalities and injuries.

First, the probability of a flight operation resulting in a survivable accident[3] and the probability of a passenger being in such an accident were calculated from the NTSB's historical accident information (1978 to 1993) and the FAA's operations data. Accident data used are shown in Exhibit 2-8. Because lap-held infants were not required to be listed on passenger manifests for most of the years covered by the NTSB data, these statistics may not include all the infants actually involved.

EXHIBIT 2-8
Historical Aviation Casualty Data for Commercial Air Carriers (1978-1994)

Number of Survivable Accidents	Number of Passengers Involved In Survivable Accidents	Number of Fatalities		Number of Major Injuries		Number of Minor Injuries	
		NonInfant	Infant	NonInfant	Infant	NonInfant	Infant
281	19,046	824	9	601	4	1,642	8

11.013.94-13

Source: NTSB Database

Second, the conditional probability was determined for a passenger being killed, given that a survivable accident occurred. Finally, the probability of an infant being killed given the occurrence of a survivable accident was computed. The infant enplanements as a fraction of total enplanements (as independently determined by several air carriers) and the case-by-case accident evaluations conducted by the NTSB and the FAA were used to determine this probability (see Appendix E). Because this evaluation determined that five of the nine infant fatalities might have survived if they had used CRSs, it was possible to compute the probability of infant fatalities both with and without any restraint device.

The same process was used to determine rates for major and minor injuries, after accounting for the FAA and NTSB finding that, of the five infants that would have survived by using CRSs, three would have sustained major injuries; one would have sustained minor injuries; and one would have received no injury. The probabilities of passengers being

3 In this study, the only aviation accidents of interest are those involving fatalities and injuries. Nonsurvivable accidents are not relevant because CRSs would not improve infant safety in those circumstances.

killed or injured when converted to mortality rates per 10 million enplanements are shown in Exhibit 2-9.

EXHIBIT 2-9
Rate of Passengers Sustaining Fatalities and Injuries in Air Carrier Aircraft
(Per 10 Million Enplanements)

Casualty Type	Rate of Infant Casualties		Rate of Noninfant Casualties
	Without CRS	With CRS	
Fatality	1.616	0.718	1.480
Major Injury	1.571	1.178	2.360
Minor Injury	1.851	1.152	3.798

Source: Booz·Allen & Hamilton analysis of NTSB data from 1978-1994

Two aspects of this exhibit are noteworthy: The infant fatality rate significantly decreases when the infant is secured in a CRS and the fatality rate is greater than the major injury rate for an infant who is not secured in a CRS.

It was conservatively assumed that these rates would remain unchanged over the 10-year period considered. However, advances in aviation technology may continue to improve air travel safety in the future.

– *Automobile fatality and injury rates.* The bases for these key parameters were historical fatality and injury rates per 100 million passenger miles, which are the standard units of measurement used by the Federal Highway Administration (FHWA), NHTSA, and other Government agencies. NHTSA provided data for intercity travel over the last 73 years. Unlike the aviation fatality and injury rates, these parameters did not have to be derived for infants and noninfants because the NHTSA explicitly keeps records of these statistics.

The extensive intercity traffic data show a steady decrease in automobile fatality and injury rates over the 73-year period; a trend analysis was performed to project these rates for the period 1995 through 2004 (see Appendix E). Furthermore, the NHTSA also provided a methodology to account for the increase in safety that CRSs provide to infants relative seat belts.

Exhibit 2-10 provides the fatality and injury rates associated with automobile travel for the year 1995, the starting point for this study. Results of the trend analysis were used to compute these rates from th historical data. Similar values were incorporated into the analysis for e of the 10 years considered. Consistent with the historical trend, automobile safety increases steadily over this period. Use of CRSs dramatically improves the safety of infants; infant casualty rates are approximately 34 percent lower than the corresponding noninfant rates.

EXHIBIT 2-10
Fatality and Injury Rates for Intercity Automobile Travel—1995
(By Passenger Type)

Passenger	Casualty Rates (Per 100 Million Passenger Miles)		
	Fatality	Major Injury	Minor Injury
Noninfant	0.521	0.947	23.874
Infant	0.343	0.624	15.721

Source: NHTSA

This study made no assumptions regarding a step-change in safety because of the advent of the air bag use in cars—a phenomenon that is likely to improve automobile safety further.

The automobile fatality and injury rates for infants used in this analysis represent average infant experience rates without distinction as to whether or not the infant was properly carried in a CRS. That is, the rate is calculated by adding all infant fatalities (injuries) regardless of whether the infant was in a CRS and dividing it by 100 million passenger miles. Every State in the United States requires that infants be fastened in CRSs while traveling in an automobile, but the laws may not be fully observed and there is evidence that not all infants in motor vehicles CRSs are properly belted in place. Therefore, if there was full compliance with these laws and proper CRS usage, the infant fatality rates observed would decrease from present levels. However, the FAA expects that those FTUs who divert to automobiles would comply with State CRS laws at the same level of compliance as the general population. Thus, the use of CRSs in automobiles would probably not improve with diversion of air travel FTUs to automobiles.

- *Bus fatality and injury rates.* NHTSA also provided bus fatality data for intercity, 3-axle bus occupants for the period 1990 through 1993. The fatalities were converted to a rate of fatalities per vehicle mile based on operational data obtained from the *Bureau of Transportation Statistics 1993 Annual Report*. This rate was then expressed in terms of passenger miles based on data from the *1993 Transit Passenger Vehicle Fleet Inventory Report*, published by the American Public Transit Association (APTA). The bus fatality rate per passenger mile was 42 times lower than the rate for automobiles. This ratio was then applied to the projected automobile fatality and injury rates to obtain projections for the bus mode.

- *Train fatality and injury rates.* The Association of American Railroads provided train fatality rates. The train fatality rate was approximately 20 times lower than the bus fatality rate. The quantitative analysis combines the bus and rail modes into a single category called "other." Because the bus fatality rate was significantly higher than the rail fatality rate, the bus fatality rate was conservatively adopted for the "other" transportation mode category. These rates are displayed in Exhibit 2-11.

EXHIBIT 2-11
Fatality and Injury Rates for Intercity Bus and Rail Travel

Passenger	Casualty Rates (Per 100 Million Passenger Miles)		
	Fatality	Major Injury	Minor Injury
Infant and Noninfant	0.010	0.019	0.477

Source: NHTSA, APTA

- **Mode choice distribution**. The mode choice is represented by distributing diverted passengers into three categories—those continuing to travel by automobile, by bus or rail, or those who forego travel completely. Bus and rail are combined because the proportion of travelers choosing these modes as primary transportation is very small (less than 4 percent) even after they are combined [U.S. Travel Data Center]. It was assumed that the proportion of travelers choosing these modes after diverting from air would be no greater than 4 percent and that no improvement in analytical accuracy would be gained by treating them as distinct categories.

The mode choice distribution was determined through a two-step process. The first step was to determine the proportion of the diverted passengers who would continue their trip by other transportation modes and the proportion who would forego traveling. One study [*Directions*] provided air travel modal substitution indices for four distance categories. The average values of the modal substitution indices were 0.72 for short distance trips and 0.22 for long distance trips. For example, of the travelers who divert from short trips by air, 72 percent will continue their trip by an alternate transportation mode. The other 28 percent would forego traveling.

The second step was to distribute the diverted passengers who continue to travel by other transportation modes across those modes. The 1993 Travel Market Survey[4], conducted by the U.S. Travel Data Center, provided proportions of passengers traveling by ground transportation. According to this survey, 96 percent of passengers travel by automobile and 4% travel by bus and rail. These percentages were applied to the diverted passengers continuing their trips. For example, of the 72 percent of diverted travelers continuing their trip by other modes, 96 percent of them continue their trip by automobile (which is 69.1 percent of all diverted travelers). The resulting mode choice distribution used in the analysis is depicted in Exhibit 2-12.

EXHIBIT 2-12
Mode Choice Distribution

Air Passenger Trip Distance (one way)	Modes of Transportation to Which Air Passengers Divert		Forego Traveling
	Automobile	Bus and Rail	
Less than 500 Miles	69.1%	2.9%	28.0%
Greater than or equal to 500 Miles	21.1%	0.9%	78.0%

Source: *Directions: The Final Report of the Royal Commission on National Passenger Transportation*, 1992; U.S. Travel Center Data 1993 Travel Market Report

4 The Travel Market Survey is conducted annually. In the 1993 survey, more than 18,000 households were contacted and more than 5,000 responded.

The above table shows that automobiles are the most common alternative to air travel for diverted passengers planning trips less than 500 miles. Bus and rail modes are seldom selected alternatives for any distance.

- **Probability of passenger displacement ("bumping").** Placing infants in CRSs occupying passenger seats, instead of holding them on laps, would reduce the number of seats available for non-FTU passengers. In Scenarios 2 and 3 where all infants are placed in CRSs at no charge to FTUs, the number of round trip seats available for non-FTU passengers would be reduced by 1,991,612 per year (the average number of annual FTU trips). However, because most flights are not full, most of the potentially impacted non-FTU travellers would be either accommodated on the same flight or on an alternative flight. Thus, the impact on airline volume and revenue is limited to "bumped" passengers who cannot be so accommodated.

A two-step approach was taken in this analysis to estimate bumped passengers. The first step was to statistically estimate the number of non-FTU passengers not accommodated on their first choice of flights by infants occupying passenger seats. The second step was to assume that one acceptable alternate flight was available, and then statistically estimate the number that could not be accommodated on the second choice flight. The residual unaccommodated passengers at the end of the second iteration was adopted as the estimate of the number of "bumped" passengers in this study.

Using this approach, it was estimated that, over ten years, about 11,000 non-FTU passenger round trips per year would divert from air transportation in Scenarios 2 and 3. Proportionately fewer would be diverted in Scenarios 5 through 7C because of fewer infants occupying passenger seats.

The probability of non-FTU passengers not being able to be booked on a given flight (spill) as a result of infants was estimated using a method generally consistent with behavior described in prior studies of the phenomenon (Swan; Kraft et al; Brumelle, et al). The probability of spill was estimated from a function which defines probable demand relative to airplane capacity.

The demand for air travel was assumed to be normally distributed, the mean of which was the average load factor. The probability of demand exceeding the capacity of an aircraft can be calculated based on this distribution. Variations in the probability of excess demand can be calculated to reflect changes in aircraft capacity. In turn, changes in aircraft capacity can be used to simulate the effect of using an aircraft seat to accommodate a CRS for an infant hitherto transported on the lap on an accompanying adult.

Thus, standard statistical techniques were used to determine the fraction of demand that cannot be accommodated because of a reduction in seat capacity caused by CRS placement which increases the probability of spill. FAA estimates that, under the existing case of infants being held on laps, as many as 7.1 percent of potential air travelers may not book on a specific flight and either book on an alternative flight or divert to another mode of travel or cancel their trip. With the increased demand for passenger seats resulting from all infants being provided seats for CRSs at no cost (Scenarios 2 and 3), the FAA believes this probability would rise. For purposes of this study, the new probability of spill was approximated to be 7.5 percent.

- **Costs related to CRSs**. These costs include acquiring CRSs and recurring maintenance costs associated with them. In some of the analysis scenarios, the air carriers are required to procure CRSs for passenger use. Results of a rental car company survey of CRS costs were used to estimate the acquisition and maintenance costs of CRSs. Purchase and maintenance costs were averaged across the 20 locations surveyed. Appendix D contains the data from that survey. The result was an average purchase cost of approximately $50.00 per CRS and an average annual maintenance cost of $17.50 per CRS. Both costs were incorporated into this analysis.

- **Reservation system costs**. This parameter consists of the costs required to update the air carrier reservation systems to accommodate the additional requirements of a CRS regulation. .During a panel meeting, participants estimated that the initial cost to modify the air carrier reservation system to accommodate potential CRS requirements could range from $125,000 to $1 million per reservation system. For the United States air carrier industry, the cost would range between $500,000 and $4 million. The upper end of the range is used is this analysis to account for any other additional non-recurring costs that the FAA may not be aware.

  Recurring costs for system maintenance, staff training, and additional time needed to accommodate CRS requirements would also result. For instance, the panel participants discussed the recurring costs of making reservation system modifications to accommodate frequent updates because of air fare changes. Other recurring costs would result from modifications to the reservation systems to accommodate aircraft seating configuration changes—or the ability to handle equipment changes such as replacing a wide body with a narrow body aircraft for a specific flight. Another significant recurring cost would be caused by modifying the reservation systems to accommodate booking CRS-specific seats across all air carrier reservation systems. Currently, not all air carriers and travel agencies can determine which seats are available on other air carriers because they do not have access to all the carriers' seat maps. Other potential recurring costs might include the added time to make each reservation. For example, it will take additional time for reservation agents to ask callers if they are traveling with an infant. For those passengers who are, it would take the reservation agent more time to confirm that CRS-ready seats were available on specific flights.

In addition to modifying the reservation systems and the associated maintenance costs, other recurring costs could result from training new reservation agents, gate agents, flight crews, and maintenance personnel to handle the particular CRS requirements.

To calculate an approximate reservation system recurring cost, a worst-case assumption was that the annual system maintenance and modification cost would equal the initial system cost of $4 million. This cost was divided by the approximately 200 million reservations projected for 1995 to equal $0.02 per reservation. The total number of reservations were used instead of only the FTU reservations because the system would have to differentiate between all passengers, determine if seats were available next to adults with infants, and determine which aircraft seats could accommodate CRSs. For instance, CRSs may be allowed in specific areas of aircraft, such as window seats only or in the last rows of the aircraft. Each of these restrictions varies by aircraft type and air carrier configuration. To capture other recurring costs, which are not known at this time but were discussed above, the recurring cost was increased to $0.03 per reservation. These methodologies for estimating costs and the resulting dollar values were discussed with industry experts who concurred that the estimates were reasonable.

- **FTU air fares**. A four-step process was used to estimate FTU airfares. First, the FAA assumed that all FTUs made round trips. The 1993 O&D Plus compact disc, read-only memory (CD ROM) data base [*Origin and Destination*] was used to determine the cost for one-way trips in two distance categories—less than 500 miles and greater than or equal to 500 miles. The O&D Plus data base is composed of 10 percent ticket sample data (recorded on Form 41) for large air carriers and Form 298-C data from regional and commuter operators. Data base queries for these two distance categories resulted in average one-way ticket prices in 1993 of $88 for trips less than 500 miles and $173 for trips greater than 500 miles. Second, the rate of constant dollar domestic yield change, as forecasted by the FAA, was used to project the ticket prices for the period from 1995 through 2004. Third, the FAA used a ratio of approximately 2.5 to 1 to determine the difference between business and nonbusiness ticket prices [Stephenson and Fox]. The results gave one-way 1995 individual ticket prices of $54.78 ($109.56 round trip) for nonbusiness trips less than 500 miles and $107.70 ($215.40 round trip) for nonbusiness trips greater than or equal to 500 miles. Fourth, the round trip estimates were then weighted by the percent of families taking short trips (8.91 percent) and the percent of families taking long trips (91.1 percent), yielding a weighted average 1995 air fare of $205.98. This procedure was repeated for the years 1996 through 2004. The average air fare for the time period from 1995 through 2004 was estimated at $201.46.

2.3 STUDY ASSUMPTIONS AND LIMITATIONS

In the process of quantifying the economic and safety impacts to air passengers, it was necessary to limit the scope of the analysis. First, it was not possible to capture all cost and safety input parameters in the time allotted for this analysis. For example, no estimates were available for many potential costs to air carriers because some of the information required is confidential. Also, most information and data used for the quantitative analysis were gathered from previous government and academic research. Because researchers from different topic areas produced the information, it sometimes had to be modified to fit the specific needs of this project. Occasionally, the data and information were incomplete and had to be extrapolated to meet the needs of this study. Finally, some impacts were difficult to quantify mathematically; therefore, they were not included in the analysis, but they will be discussed where appropriate. The following assumptions and limitations must be considered in any interpretations of the analysis results:

- Air travel price elasticity values were determined from markets similar to the ones modeled, but they may not be entirely representative of the average U.S. market.
- The price elasticity of demand for FTUs is equal to the price elasticity of demand for nonbusiness travelers. FTUs that divert from air travel do so as a family unit; business and non-FTU nonbusiness travelers divert as individual passengers.
- Price elasticity estimates used in this analysis are point estimates. As such, they can only be used to accurately estimate changes in demand for small price increases. For larger price increases considered in this study, specific assumptions must be made about the demand curve. This study assumes linear demand curves, which imply greater elasticities as prices increase.
- The point elasticity estimates were used to derive the slope of the linear curves and estimate the change in demand and revenue following increases in air fares resulting from mandating CRS use. However, demand will become more elastic as price increases (for a linear demand curve, the elasticity value prior to the price increase will be different (less negative) than the value after the price increase). For this reason, the elasticity estimates used in this study should be thought of as "initial" elasticity estimates reflecting the elasticity value at the starting point on the demand curve prior to the increase in price.
- To more accurately estimate the number of infant enplanements, either national surveys of air passengers must be conducted, or air carriers must report the number of enplaned infants per flight.

- The enhanced safety factors applied to CRS use are based on the assumption that an effective CRS exists and would be used by infants in both air and automobile transportation. At present, not all approved CRSs performed well in testing. It is expected that these problems may be solved in the future.

- All FTUs would use CRSs that they already own for the scenarios requiring them to provide their own CRSs for air travel.

- Several potential costs to air carriers were difficult to quantify and were not captured in this analysis. These costs include those associated with potential departure delays; increased logistics management costs; and the cost of training flight crews, gate agents, and reservation agents in new regulations and procedures pertaining to a CRS mandate.

- To estimate economic impacts of the CRS mandate, air fare for children between the ages of 2 and 12 was equal to the air fare for adults categorized as nonbusiness travelers. However, the analysis has three scenarios in which fractions of the noninfant ticket fare are used.

- No attempt was made to quantify costs of inconvenience to air travelers foregoing travel.

- To determine fatality and injury impacts caused by diversion to other modes of transportation, it was assumed that diverted passengers continued to travel the same distance they had planned to travel by air.

- Safety results do not include fatalities and injuries for passengers who decided to forego traveling.

- Only incidents involving fatalities and injuries on U.S.-based major and commuter air carriers occurring within U.S. territory were considered in the development of the aviation mortality rates.

- Noninfant passengers, who were bumped by infants, diverted to other modes of transportation or decided to forego their trip in the same proportions as diverted FTUs.

- Costs are discounted at 7 percent over 10 years.

- Some FTUs currently pay for a passenger seat to ensure that their infants may fly next to them in a CRS. This analysis does not estimate the revenues that airlines would lose by giving away seats they currently sell to families with infants. If as many as 10 percent of FTUs currently do this at full fare for their infants, airlines would experience a loss of about $40 million (1,991,612 infants * $201.46 per round trip * 10 percent = $40.12 million) per year. We have not included any estimate of this lost revenue in the tables associated with this study because there is insufficient data available on the extent that FTUs are now paying for passenger seats.

- This analysis estimates the price elasticity of demand along demand curves for four homogeneous groups of non business travelers. As discussed later, the non-business travelers are divided by income and by travel distance. Information on the price elasticity of demand characterized by month of year, holiday season, school vacation, or high density routes were not available. Families, therefore, who travel during school holidays probably exhibit much more inelastic demand than typified in the analysis. This group of travelers, traveling during holidays, may be much more willing to incur additional air fare costs than they would at other times of the year.

- In every scenario, regardless of whether FTUs pay for passenger seats, there are some non pecuniary costs, such as inconvenience, that have not been captured. For example, in scenario 4, if all passenger seats are sold and there are no cancellations, then passengers who bring infants have to stow the CRSs they brought on board, either in an overhead storage bin or below with checked baggage, possibly delaying flight departures. Also, there is not total assurance that seats will be available for infants under Scenario 4, which may increase parent anxiety.

The above assumptions and limitations must be considered when interpreting the results of this analysis.

3. FINDINGS—CHILD SAFETY RESTRAINT EFFICACY

3. FINDINGS—CHILD SAFETY RESTRAINT EFFICACY

To evaluate whether CRSs offer levels of impact protection equal or superior to those passenger seats required by the FAA for newly certificated aircraft passenger seats, CAMI conducted a series of impact tests. In these tests, CRSs meeting current Department of Transportation (DOT) requirements for use in aircraft were subjected to the same dynamic test conditions specified for adult seats (44 feet per second, triangular deceleration pulse 16 times the force of gravity with a 90 millisecond rise time). To perform the tests, CAMI used typical current air carrier seats to hold the CRSs that restrained a variety of sizes and designs of anthropomorphic test dummies (ATDs). The ATDs simulated children 6 months, 2 years, and 3 years old (although current regulations and air carrier policies only address infants under 2 years of age).

3.1 TYPE OF CRSs TESTED

A variety of CRS designs are currently available. A representative sample of the following designs were tested:

- Aft-facing carriers
- Forward-facing carriers[1]
- Booster seats
- Harness restraints
- Belly belts
- Conventional lap belts.

Aft-facing carriers are designed for very young children who weigh less than 20 pounds. These restraints are often one application of a popular CRS, called a "convertible carrier." A convertible carrier is initially installed as an aft-facing carrier and is used for very young children. All aft-facing devices are mounted in a seat so that the child faces the rear of the vehicle. The neck musculature of very young children precludes their facing forward and, in most aft-facing carriers, the child rides in a semi-reclined position. As the child grows, using aft-facing carrier becomes impractical because the back of the seat prevents the availability of adequate space for the child's legs. Also, the child's musculature development allows the use of a forward-facing seat design.

Most forward-facing carriers are designed for children who weigh between 20 and 40 pounds. To avoid purchasing a new CRS when their children reach 20 pounds, parents often use convertible carriers. When the child exceeds 20 pounds, the device is turned around from its aft-facing mode. The angle of the seat pan and seat back are adjusted; the same device can be used in the forward-facing mode until the child reaches 40 pounds.

1 This category includes those convertible carriers that can be changed from aft-facing to forward-facing carriers to accommodate a child weighing more than 20 pounds.

Even after reaching 40 pounds, a child needs an appropriate restraint device when riding in a motor vehicle. For these larger children, two types of booster seats are available. A first type of booster seat is the backless child restraint system, which is a shield-type booster seat that consists of a platform on which the child sits to raise the child to a higher level. A shield fits over the front of the device; the child's legs are below the shield and the head is above the shield. The vehicle seat belt is routed around or through the shield. In an impact, restraint is provided because the child's abdomen and thorax contact the padded shield. However, these types of booster seats do not have back supports to provide protection from objects that may strike the child from behind. This design feature may be crucial in aviation applications because of the breakover feature of most aircraft seats currently in service. The second type of booster seat is the belt-positioning seat, which has a back to provide back protection for the child occupant. Belt-positioning booster seats require the use of the lap and should portions of the vehicle belt system. Because commercial aircraft are not equipped with shoulder belts, these seats are required to be labelled not for use in aircraft.

The three designs described represent the majority of available devices. However, CAMI also studied three other CRS designs: harness restraints, belly belts, and conventional lap belts. Harness restraints consist of a belt harness worn by the child. The harness has a path in the back of the device through which the vehicle's seat belt is routed. These devices are intended for children who can sit facing forward on their own. The second type of device, the "belly belt," is classified for use only on aircraft. The belly belt consists of a supplemental seat belt wrapped around the child and through the parent's seat belt. The child sits on the parent's lap. This design is intended for all children who can be held on the parent's lap. The design was decertified by NHTSA in 1994 for use in automobiles or for aviation use in the United States. It is, however, certified for use in the United Kingdom by the British Civil Aviation Authority. The final CRS design is the conventional lap belt available in all aircraft seats. Because an automobile seat belt is not designed or appropriate to restrain a small child, important differences between aircraft and automobile seat belts may make aircraft seat belts effective for a child large enough to use a booster seat.

3.2 TEST FIXTURE DIFFERENCES—AUTOMOBILE AND AIRCRAFT

The test fixture specified for use in certifying CRSs for both automotive and aircraft applications represents typical automotive applications, but important differences exist between aircraft seats and automobile seats. Seat belt anchors in an automobile are located so that the seat belt interface with the CRS is at a significantly different angle than that found with aircraft seat belts. Significant differences also exist between aircraft seat belts and automobile seat belts regarding the location, size, and design of the seat belt buckle. In a typical economy seating configuration in a commercial air carrier aircraft, the amount of free space in front of a child in which the head can flail without impacting some part of the seat ahead is only 22 inches measured from the cushion reference point (CRP). However, this dimension, referred to as the head strike envelope, is 32 inches (28 inches from the CRP) in the automotive-based government standard.

Another difference between aircraft and automobile seats is a feature called seat back breakover. A forward force applied to the top of the seat back in an airplane will cause the seat back to rotate forward. This feature is not an impact protection feature; it is a maintenance consideration that makes it easier for air carriers to remove, install, and store seats. However, a child seated in an aircraft seat with an adult sitting in the row behind will be subjected to a second impact when the seat back breaks over and exerts force on the child's back because of the impact of the adult and the seat back. The test fixture used for DOT's certification standard does not feature seat back breakover. The CAMI testing was based on the worst case survivable crash scenario. There could be instances when some breakover seats might not breakover.

3.3 CAMI STUDY RESULTS

The CRSs that were tested provided varying degrees of performance. Summaries of test results follow:

- Aft-facing carriers performed well, protected the child, and fit in the aircraft seat.
- The CAMI study found significant problems with 6 of 8 forward-facing and convertible carriers in the forward-facing orientation, including:
  - None prevented head impacts when a seat back in the forward row was locked to prevent its breakover. Instruments on the ATDs indicated a high probability of a serious head injury with most devices.
  - Routing the seat belt through the CRS was difficult. Buckling and unbuckling the seat belt was also difficult with convertible carriers. Therefore, some configurations may not be attachable to aircraft seats.
  - Investigation of alternative anchor points in the aircraft seat resulted in dramatic improvement in the impact protection performance of a selected sample of forward and convertible carriers that faced forward. When alternative anchor points were used, all CRSs that could be attached in this manner performed well and prevented head contact during testing.
- Backless booster seats performed poorly. Their significant problems include the following:
  - They did not prevent head impact.
  - Passing the belt through the devices presented significant problems and frequently made it impossible to attach the booster seat to the aircraft seat properly.

- Seat back breakover represented a potential safety threat because of the high force exerted on the abdomen.

- Harness-type systems performed poorly. Unacceptable forward head and body excursion was followed by violent rebounding back into the seat.

- The belly belt performed poorly. Not only did the belly belt fail to prevent head impact, but a child "restrained" by a belly belt would be crushed between the parent and the seat back of the row in front of them. Exertion of force on the abdomen and the resulting risk of abdominal injury were observed, and instruments on the ATD indicated a high probability of a serious head injury.

- Children large enough to use conventional aircraft seat belts were adequately restrained. While they were not protected from seat back breakover, the resulting force exerted on the abdomen was significantly less than that observed with booster seats.
  - There was no head contact with the row of seats in front of the child.
  - The child must be large enough that the parent can tighten the seat belt properly. In CAMI testing, the 3-year old, 33-pound size ATD was an adequate size.

3.4 POTENTIAL EFFICACY IMPROVEMENTS

Based on the CAMI study, aft-facing carriers work well. Children large enough to use a booster seat are large enough to be restrained by the conventional aircraft passenger seat lap belt. The CAMI study suggests that children of a size suitable for a booster seat are better protected by the aircraft seat belt because the head does not contact the seat back in front of the child and less force is exerted on the child's abdomen. Therefore, potential efficacy improvements that would result in devices suitable for use in an aircraft seat should target children too large for an aft-facing carrier and too small to use the aircraft seat belt alone.

The challenge to CRS designs for use in aircraft arises from two significant differences between aircraft seats and automobile seats. In an aircraft, the seat belt anchors are located much farther forward than in an automobile. Approximately one third less space exists for the head of the child to flail before it impacts with an interior fixture. As a result of this anchor point placement, the CRS pitches forward on the seat until tension in the aircraft seat belt is attained and restrains the CRS. Coupled with the significant reduction in aircraft space, this problem represents a design challenge that no device currently available can meet without resulting in some type of head injury (provided the seat back in front of the infant does not break over). Four potential changes to improve efficacy are:

- Modification to existing CRS designs
- Modification of existing aircraft seats
- Potential new design concepts
- Increase the pitch between the rows of seats.

The advantages and disadvantages of these four approaches are discussed in detail in the next section.

3.4.1 Modifications To Existing CRS Designs

To ensure that all forward-facing CRS perform well in aircraft, designers should consider modifying the seat belt path through the device. This modification should ensure that the seat belt restrains the device as soon as possible upon deceleration and minimizes the distance the CRS can pitch forward before the seat belt produces adequate tension restraint forces. Many current CRS designs, based on the anchor locations of the motor vehicle test fixture used to certify them, assume that anchors in motor vehicles are considerable rearward of their location in an aircraft seat. Producing a CRS suitable for an aviation application will require considerable CRS redesign to route the aircraft seat belt and help ensure the structural integrity of the CRS under impact loads. Given that this design is a new type and, as a result, will require considerable development and testing time, the development cost and delay in availability will be considerable. At the efficacy panel session, representatives from CRS manufacturers stated that it typically takes from 120 to 140 weeks after a design is finished to design the manufacturing equipment and procedures needed. Thus, the design and production of an aircraft-specific CRS will take between 4 and 5 years. The time required to produce significant numbers and make them available to the flying public is difficult to estimate, but is likely to be 5 to 6 years after an aircraft design standard is available.

The cost of such a device might be prohibitively high. The low cost of current CRSs arises from their mass production. When development costs are spread over hundreds of thousands of units, these costs become insignificant. However, modifications to current CRS designs for aircraft use could be an a costly development effort for a limited market. As a result, rather than costing from $40 to $100 per unit, an aviation-suitable CRS may cost the consumer considerably more.

3.4.2 Modifications To Existing Aircraft Seats

In its study, CAMI made a simple modification to the aircraft seats used in the tests. Although simple in the testing environment, the alteration could be expensive and time consuming in the operational environment. This modification installed a second set of seat belt anchors on the hinge that reclines the aircraft seat. Installation of this alternative anchor point improved the angle for the aircraft seat belt anchors and dramatically improved the performance of all forward-facing carriers tested. The alternative anchor points might improve the performance of the harness belt systems, but these systems were not tested with the alternative anchor point. Alternative anchor points are only suitable for forward-facing and convertible carriers used in the forward-facing mode and would not function properly with aft-facing carriers, booster seats, or belly belts.

CRS manufacturers and consumer activists have recommended requiring alternative anchor points in air carrier seats. These groups point to the millions of devices being used by the public and their perception of the much faster implementation time needed to install alternative anchor points. However, the cost of certification of the new design and the expense of retrofitting fleets of aircraft would be significant.

Because of emergency evacuation considerations, CRSs are usually installed only in window seats. Therefore, potentially two seats per row (in each window location) would require the modification. Because of the normal wear and tear to air carrier seats, they tend be changed on a regular basis. Thus, seats with alternative anchor points could be installed more quickly than an aviation-suitable CRS could be produced.

The alternative anchor is not suitable for use by someone restrained only by the seat belt. Use of an alternate anchor point would also require use of a different size seat belt for the CRS. Because current FAA regulations require that a certified aviation mechanic remove and replace seat belts, qualified mechanics would have to attach the shorter seat belts to the alternate anchor point when a CRS was installed and then remove them at the conclusion of the trip. The cost and disruption of having the FAA-required, certified mechanic at both ends of a trip to change the seat belts could be prohibitive to the air carriers. In addition, ensuring that the belts had been attached to the proper location and that passengers were not using inappropriate seat belts would require new procedures. For example, alternative seat belts of a bright, distinctive color that flight attendants would immediately notice could be used; flight attendants would require training to evaluate the proper use of the belts. This proposal, therefore, involves additional costs for the air carriers. Aviation mechanics may have to be available at both ends of the trip. Air carriers would have to modify flight attendant training and provide additional equipment—suitable colored belts of the appropriate lengths.

A second important consideration in altering anchor points relates to the certification basis for the seat. The FAA must approve all components in an aircraft. If a modification, such as adding an alternative anchor point, is made to a component, the organization making the modification must show the FAA that the component continues to meet airworthiness standards. The cost and administrative burden of requiring recertification of each seat modified by the installation of alternative anchor points may be substantial.

If the FAA removed the requirement to recertify seats when the alternative anchors were installed and allowed flight attendants to change seat belts between two locations, some of the burden of complying with this choice would be alleviated. Air carriers still might have to contend with labor union contracts that prohibited cabin crew from changing seat belts. Assuming that these labor problems could be resolved, the air carriers would still have to bear the cost of modifying the appropriate number of seats. The air carriers would also have to stock the needed belts and modify their cabin crew training to include instruction on how to identify and change the alternative belts. There would then be a transition period when some, but not all, of the air carriers' fleet would be modified and some, but not all, of the cabin crews had received the necessary training.

3.4.3 Potential New Restraint Device Designs

Industry frequently responds to problems by developing new techniques and devices. Although it is difficult to predict what new restraint technology might emerge, three possibilities merit discussion. Integrated child seats similar to those pioneered on Chrysler minivans and the ISO FIX system are two new child restraint technologies that may apply to aircraft. A third possibility would be to separate the motor vehicle and aircraft certification test procedures to develop a CRS that would perform better in the aviation environment.

An integrated child seat (an aircraft seat with the child restraint built in) could be folded out of the way when not needed, and an adult passenger could then sit in the seat. With this type of device, parents could not use their child restraints, and air carriers would have to equip their aircraft with these seats. Also, adult passengers sitting on the folded child seat might not be as comfortable as they would be in a regular aircraft seat. Cabin crews would require training on how to fold and unfold the child restraint. Such a system would most likely provide superior protection because it would be integrated with the frame of the seat and would not depend on seat belts and their anchors. An integrated child seat would require a significant development effort and would have to meet all FAA airworthiness requirements. For several years, the Centers for Disease Control (CDC) had a topic in their Small Business Innovative Research (SBIR) solicitation seeking an aviation-suitable child restraint device. Among the proposals submitted was one to build an integrated seat suitable for use in an aircraft cabin. But based on the small number of children at risk in airplane accidents and their limited budget, CDC was unable to fund this topic.

An integrated child seat offers superior protection because the child is tightly coupled to the seat frame. A consortium of automobile organizations in the United States and Europe have tried to develop a system called ISO FIX. This may be considered an excellent system in the future, but it cannot be expected to solve current problems in a timely manner. In the ISO FIX system, the CRS is not attached to the vehicle seat with seat belts. Instead, a mechanism mechanically attaches the CRS to the vehicle seat frame. This easily operated mechanism allows for forward- and aft-facing designs, tightly couples the CRS to the vehicle structure, and provides optimal restraint. When the ISO FIX design is completed, designers can develop an aircraft seat with the ISO FIX mechanism, and parents can then install their own CRSs, which must have the appropriate ISO FIX hardware, in an aircraft seat. An ISO FIX system in an aviation setting would be immune to the problems of forward-facing carriers not performing well with aviation seat belt anchors.

The problem with ISO FIX is in its implementation. ISO FIX CRSs will not work if the vehicle seat (automobile or aircraft) is not equipped with the ISO FIX mechanism. There is no incentive for parents to purchase ISO FIX CRSs because automobiles are not currently equipped to be compatible with them. Also, families already own other CRSs that are incompatible with ISO FIX mechanisms. The cost of redesigning aircraft seats would be significant; air carriers will not redesign seats to accommodate ISO FIX systems until the majority of traveling families own ISO FIX-compatible CRSs. Therefore, it is unlikely that ISO FIX will receive wide acceptance in the U.S. any time soon.

Another approach could be to separate the test procedures for motor vehicle use, aircraft use, or both and to define dynamic test procedures for an aircraft CRS standard based on the work done by CAMI. This might result in a CRS that performs better in the aircraft environment. However, the market for aircraft-specific CRSs is relatively small and might not support the design and development costs.

3.4.4 Change the Pitch Between Seat Rows

The CAMI testing demonstrated that the problem with six of the eight forward-facing carriers was that head strikes exceeded the maximum acceptable levels. If the distance between the aircraft seat row was increased, then a greater clearance for infant head motion would exist. This could result in more of the current forward-facing carriers that could meet the existing HIC.

This option was not discussed in the efficacy or the operational issue panel meetings. The option presents a significant burden to the air carriers in two respects. First, the cost of modifying the aircraft seating configuration for the entire fleet could be high. Second, the aircraft would have reduced passenger capacity because at least one row of seats would have to be removed to extend the pitch between seat rows. Consequently, air carriers could not market as many seats with their current fleet sizes.

4. FINDINGS—THE IMPACT ON AIR CARRIER PASSENGER VOLUME

4. FINDINGS—THE IMPACT ON AIR CARRIER PASSENGER VOLUME

If the costs to air passengers are increased, some passengers will divert from air travel to alternative modes of transport or forego travel completely. The expectation of passenger diversion is based on the economic principle of price elasticity; that is, demand for air travel services will decrease as ticket prices are increased. The mandatory use of CRSs, then, could increase passenger costs because of additional fares for infant tickets, potential increases to noninfant air fares, and the need for some families to purchase CRSs. Also, bumping of passengers by infants will impact passenger volume.

Among the alternatives considered in this analysis, the most beneficial outcome—in terms of preventing fatalities and injuries and maintaining air carrier revenue—was achieved when the least number of passengers diverted from air transportation. This occurred in Scenario 4, when the FTUs reserved CRS aircraft seats at no cost and provided their own CRSs. The result was that no passengers were expected to divert from air travel.

4.1 RESULTS

Exhibit 4-1 shows the impact to FTU air travel volume for each of the seven scenarios, as defined in Section 2.2.1. The average passenger volume output results are grouped according to the number of passenger round trips diverted to other transportation modes (automobile, bus, or rail); the number foregoing travel as a result of increased costs; and the number of passengers continuing to travel by air.

Generally, the impact of a CRS mandate on air passenger volume varied widely across the scenarios considered. This variation is driven primarily by the extent to which the costs of complying with such a mandate are transferred to the traveling public. Specifically, the output ranges from no FTU diversions under Scenarios 1 through 4 to a total of 73.4 percent of the FTU passengers diverting under Scenarios 5 and 6. The large number of diversions under Scenarios 5 and 6 includes 53.3 percent of passengers foregoing their travel plans and 20.1 percent diverting to other transportation modes. Results of Scenarios 7A, 7B, and 7C range between the minimum and maximum values. The next section explains these variations.

EXHIBIT 4-1
Projected Changes in FTU Air Travel Volume[1]
(Annual Number of Round Trips, Averaged Over 1995-2004)

Scenario	Divert to Auto and Other Modes	Forego Trip	Continue to Travel by Air	Total
1. Base Case -- No mandate	0 (0.0%)	0 (0.0%)	1,991,612 (100%)	1,991,612 (100%)
2. Air carrier provides seat at no cost, FTU provides CRS	0 (0.0%)	0 (0.0%)	1,991,612 (100%)	1,991,612 (100%)
3. Air carrier provides seat at no cost, air carrier provides CRS	0 (0.0%)	0 (0.0%)	1,991,612 (100%)	1,991,612 (100%)
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0 (0.0%)	0 (0.0%)	1,991,612 (100%)	1,991,612 (100%)
5. FTU pays full fare for infant ticket, air carrier provides CRS	400,343 (20.1%)	1,062,306 (53.3%)	528,963 (26.6%)	1,991,612 (100%)
6. FTU pays full fare for infant ticket, FTU provides CRS	400,343 (20.1%)	1,062,306 (53.3%)	528,963 (26.6%)	1,991,612 (100%)
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	304,401 (15.3%)	798,341 (40.1%)	888,870 (44.6%)	1,991,612 (100%)
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	202,934 (10.2%)	532,227 (26.7%)	1,256,451 (63.1%)	1,991,612 (100%)
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	101,467 (5.1%)	266,114 (13.4%)	1,624,031 (81.5%)	1,991,612 (100%)

11,013.34-16

4.2 ANALYSIS OF RESULTS

The changes in FTU air passenger volume and the underlying reasons for these changes are summarized in Exhibit 4-2. No FTUs divert to other modes of transportation under Scenarios 1, 2, 3, and 4. FTUs incur no additional costs under these scenarios because infants continue to fly for free and all the FTUs are assumed to own CRSs. However, minor non-FTU diversions occur under Scenarios 2 and 3, which are caused by infant passengers who "bump" noninfant passengers on full flights, causing some of those passengers to cancel their trip or divert to other transportation modes.

[1] Air travel volume is based on the number of FTU round trips. To measure the change in enplanements as normally reported in FAA statistics, the figures in this table can be converted by multiplying them by 2.17 (the average number of people per FTU, 3.17, minus 1—the infant is not normally counted as an enplanement) and by the number of enplanements per round trip (2.73). For example, the average annual number of FTU round trips is 1,991,612. This is equal to (1,991,612)x(2.17)x(2.73) = 11,790,342 enplanements.

Scenario 4 results in no impact on passenger volume because FTUs incur no costs. Moreover, noninfant passengers are not bumped because infants are provided seats only on a space-available basis. Infant fatalities and injuries increase slightly because lap-held infants were calculated to have higher mortality rates than secured infants. This is discussed fully in Chapter 6.

EXHIBIT 4-2

Reasons For Projected Changes in Air Passenger Volume

(Annual Number of Enplanements, Averaged Over 1995-2004)

Scenario	Reason for Change		Net Change
	FTU Diversions From Air Travel	Infant Bumps Passenger (Non-FTU Passengers Only)	
1. Base Case -- No mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	0	-30,030	-30,030
3. Air carrier provides seat at no cost, air carrier provides CRS	0	-30,030	-30,030
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0	0	0
5. FTU pays full fare for infant ticket, air carrier provides CRS	-8,664,873	-8,056	-8,672,929
6. FTU pays full fare for infant ticket, FTU provides CRS	-8,664,873	-8,056	-8,672,929
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-6,532,754	-13,535	-6,546,289
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-4,355,167	-19,135	-4,374,302
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-2,177,587	-24,731	-2,202,318

11.013.94-17

Scenarios 5 and 6 impact the volume of air carrier passengers the most because, under these scenarios, the FTUs are required to pay the full noninfant fare for infants. For a family of two adults and one infant, this represents an approximate cost increase 50 percent over the base case. This increase causes significant passenger diversions because of the highly elastic nature of the FTUs' demand for air travel.

Scenarios 7A through 7C display a range of diversions that increase proportionately to infant ticket price increase. The price of the infant ticket decreases in 25 percent increments for Scenarios 7A through 7C. The number of FTU diversions caused by the decreasing infant ticket price correspondingly decreases. However, the number of non-FTU diversions caused by passenger bumping increases. The diversions associated with bumped passengers increase because as the infant ticket price is reduced, more FTUs will continue to travel by air. As more FTUs travel by air, the number of infants traveling by air also increases; therefore, more non-FTU passengers are likely to get bumped.

Scenario 4 results in least impact to passenger volume because no passengers divert to other transportation modes. Scenario 4 presents significant benefit to FTUs because the infant seat is reserved on a space-available basis; however, this may sometimes result in less preferred flight times or infants being transported in the lap of accompanying adults.

4.3 SENSITIVITY ANALYSIS

Analyzing the effects of changes in the values of input parameters on air passenger volume is important. Changes in the air carrier passenger volume affect other facets of the analysis; both air carrier revenues and safety impacts are highly dependent on the number of passengers diverting from air travel. The following input parameters were varied to evaluate the resulting impact on the number of air travelers:

- Infant enplanements as a percentage of total enplanements
- Percent of FTUs who must buy a CRS
- Initial price elasticity of demand.

In analyzing the sensitivity of air passenger volume for the first two parameters, two scenarios were used to represent the best and worst outcomes. Scenario 4 represented the best case with the least change in passenger volume; Scenario 6 represented the worst case. Under Scenario 4, passengers do not divert to other modes of transportation; hence, passenger volume is unaffected by either the number of infants or CRS ownership. Thus, a detailed sensitivity analysis for this scenario was unnecessary. Results under Scenario 6—the worst case—are displayed in Exhibit 4-3.

Changes in infant enplanements as a percentage of total enplanements produced proportional variation in air passenger volume. As the infant enplanement proportion changed by 10 percent, the number of diverting passengers also changed by 10 percent. Proportional changes occur for any change in the value of this parameter because it is assumed that each FTU has exactly one infant. Therefore, as the ratio of infants to total air passengers increases, the number of FTUs will increase by that same percentage as will the diversions under Scenario 6.

EXHIBIT 4-3
Sensitivity Analysis for FTU Air Passenger Volume Impacts

Parameter	Change in Parameter Value	Change in Net FTU Passenger Diversions: Scenario 4 FTU Reserves Seat at no Cost, FTU Provides CRS	Change in Net FTU Passenger Diversions: Scenario 6 FTU Pays Full Fare for Infant Ticket, FTU Provides CRS
Infant enplanements as a percentage of total enplanements	-10%	N/A	-10.0%
	10%	N/A	10.0%
Percent of FTUs who must buy a CRS	+5%	N/A*	+2.3%
	+10%	N/A**	+4.7%

11.013.94-25

* The percentage change is not applicable, but the average annual number of diversions changes from 0 for 0% of FTUs buying CRSs to 334,156 for 5% of FTUs buying CRSs.

** The percentage change is not applicable, but the average annual number of diversions changes from 0 for 0% of FTUs buying CRSs to 668,313 for 10% of FTUs buying CRSs.

In this study, it is assumed that all FTUs own CRSs. However, assuming some percentage of FTUs must buy CRSs causes variation in passenger diversions under Scenario 6. The number of passengers diverted changed at almost 50 percent of the rate of the change in this input parameter value. A 5 percent increase in the percent of FTUs who must buy a CRS caused a 2.3 percent increase in passenger diversions. The reason for this relationship is that CRSs cost much less than full air fare. All FTUs are affected by the full air fare under Scenario 6, but only 5 percent or 10 percent of the FTUs see a price increase from CRS purchases. In addition, that price increase is a fraction of the airfare increase, so the diversion rate of change is less than the rate of change of FTUs purchasing CRSs. Changing the percentage of FTUs who must buy CRSs had a much greater effect on diversions under Scenario 4. This effect occurs because under Scenario 4, FTUs do not have any travel costs associated with CRSs; hence, no diversions occur if they already own CRSs. Assuming as little as 5 percent of the FTUs must purchase CRSs causes large diversions because the cost of a CRS is a significant price increase for each of the FTUs affected.

With respect to price elasticity of demand, this study generally is premised on FTUs being extremely sensitive to changes in airfare (demand is elastic with respect to price). However, some economic studies discussed in Chapter 2 and Appendix G concluded that demand may be less sensitive to price. Further, the Air Transport Association comments, in response to the *Federal Register* notice soliciting information for this study, suggested that FTUs may not alter their travel behavior in response to mandating use of CRSs. Thus, it is worthwhile to explore the impact of changing assumptions from an elastic demand to unitary demand to an inelastic demand. An expanded sensitivity analysis was performed for the price elasticity parameter. Exhibit 4-4 shows the results.

EXHIBIT 4-4
Price Elasticity of Demand Sensitivity Analysis
Annual Number and Percent of Total FTUs Diverted (Averaged over 1995-2004)

Scenario	Baseline *† Point Elasticities	Initial Point Elasticities Set to -1.0	Initial Point Elasticities Set to -0.8
1. Base Case - No CRS mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	0	0	0
3. Air carrier provides seat at no cost, air carrier provides CRS	0	0	0
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0	0	0
5. FTU pays full fare for infant ticket, air carrier provides CRS	1,462,648 (73.4%)	918,658 (46.1%)	734,927 (36.9%)
6. FTU pays full fare for infant ticket, FTU provides CRS	1,462,648 (73.4%)	918,658 (46.1%)	734,927 (36.9%)
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	1,102,742 (55.4%)	688,994 (34.6%)	551,195 (27.7%)
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	735,161 (36.9%)	459,329 (23.1%)	367,463 (18.5%)
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	367,581 (18.5%)	229,665 (11.5%)	183,732 (9.2%)

* See Exhibit 2-5 for baseline price elasticity estimates.
† These point elasticities characterize the initial point on the linear demand curve. As the cost to FTUs increases, the demand becomes more elastic. Section 2.2.2 and Appendix G provide further discussion of the properties of demand elasticities.

Exhibit 4-4 displays the impact to FTU passenger diversions for three significantly different price elasticity values. Only FTU diversions are shown because FTUs are the passenger group most affected by infant air fare increases. Under Scenarios 2, 3, and 7 there is also a small amount of diversion resulting from infants bumping noninfant passengers, which is not included in Exhibit 4-4.

Even with substantially lower elasticities, significant diversions exist in Scenarios 5 through 7. However, the magnitude of those diversions decreases as the price elasticity values decrease. This relationship, which does not include bumping diversions, is approximately linear.

5. FINDINGS—THE IMPACT ON FAMILY TRAVEL COST

5. FINDINGS—THE IMPACT ON FAMILY TRAVEL COST

This chapter discusses the potential impact of a CRS mandate on family travel cost. These costs include additional infant ticket fares and the potential acquisition cost of CRSs for families currently without them. The cost of infant tickets is subject to the discretion of air carriers. Generally, most air carriers charge the same price for infants occupying a separate seat as charged for adults. However, air carriers may offer promotions for free or discounted seats for infants. This information was obtained from panel discussions and telephone inquiries to air carrier representatives, including reservation agents and Government affairs representatives. Air carriers are expected to set infant fares according to market conditions. Full fares for infants are likely to prevail during peak hours and holiday periods.

Because laws require the use of CRSs for automobile travel and because these same CRSs can be used in aircraft, FTUs are generally considered to own acceptable CRSs for use on aircraft. Hence, no marginal cost to FTUs for CRS purchase is expected. If such purchases were to occur, however, the unit cost is estimated at $50. As discussed in Chapter 2 and Appendix D, this cost was obtained from a rental car company survey. Rental car company information was used because their experience in purchasing, renting, and maintaining CRSs for passenger use is similar to what would be expected for air carrier use.

The scenario that minimized costs to families in this analysis was when air carriers were assumed to provide the aircraft seat and the CRS for infant use at no charge (Scenario 3). In this scenario there were no added costs to families. The greatest average annual cost to all families, estimated at $137 million, is associated with charging 70 percent of an adult fare for infants.[1]

The FAA is assuming in this analysis that the price sensitivity of demand for air travel by FTUs does not vary during the year. Therefore, air travel price elasticity is a function of only the cost of air travel, the distance traveled, and the income of the FTU. However, the FAA is aware that FTUs with school age children are less likely to travel during the school year than during the summer. When they do travel during the school year, they will most likely travel during a break period (Easter, Thanksgiving, and Christmas). These FTUs may be more sensitive to price during the long summer months than during the short school breaks. School breaks also tend to occur during peak demand periods for air travel when the demand for passenger seats may exceed the supply. During these periods of peak demand, the air carriers are more likely to charge for seats used by CRSs. Parents would be more likely to pay the extra charge during these periods, and, even if particular parents choose not to pay the extra charge, the air carriers could still sell the passenger seat to someone else. During these peak demand periods, some parents would still choose to divert to automotive travel if the distance is short enough rather than pay the extra cost to travel by air.

[1] None of the variants of Scenario 7 is set at exactly 70% of the noninfant fare. Permutations of Scenario 7 were produced by varying the infant ticket price until the maximum family cost was determined.

Many others, however, would forego travel. The latter decision would have the effect of reducing the assumed safety benefits of mandating CRSs.

5.1 RESULTS

Exhibit 5-1 summarizes the impact to family travel costs under the seven scenarios, as defined in Section 2.2.1. This impact is measured both in terms of the combined additional cost for all FTUs that continue air travel and the additional round trip air travel cost per FTU. The exhibit also lists the number of passengers who divert from air travel or continue air travel, thus depicting the relationship between family travel costs and passenger diversions.

EXHIBIT 5-1
Projected Changes in Family Travel Cost–1995 Dollars
(Averaged Over 1995-2004)

Scenario	Annual Round Trips of FTU Air Passengers		Additional Cost of Travel per FTU Continuing to Fly (Per Round Trip)	Additonal Annual Cost to FTUs Continuing to Fly	Net Present Value (Discounted over 10 Years)
	Diverted from Air Travel	Continue to Travel by Air			
1. Base Case-No CRS mandate	0	1,991,612	-	-	-
2. Air carrier provides seat at no cost, FTU provides CRS	0	1,991,612	-	-	-
3. Air carrier provides seat at no cost, air carrier provides CRS	0	1,991,612	-	-	-
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0	1,991,612	-	-	-
5. FTU pays full fare for infant ticket, air carrier provides CRS	1,462,648	528,963	$201.46	$109,177,476	$754,379,679
6. FTU pays full fare for infant ticket, FTU provides CRS	1,462,648	528,963	$201.46	$109,177,476	$754,379,679
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	1,102,742	888,870	$151.09	$136,074,138	$940,226,579
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	735,161	1,256,451	$100.73	$127,254,068	$879,282,859
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	367,581	1,624,031	$50.36	$81,896,022	$565,874,000

Generally, the impact of CRS use on family travel costs varies widely across the scenarios considered and depends on the extent to which the costs are transferred to the FTUs. Additional annual FTU round trip costs range from no cost, under Scenarios 1 through 4, to a maximum of more than $136 million under Scenario 7A. The additional round trip cost for individual FTUs ranges from no cost to $201.46, with the maximum value occurring in Scenarios 5 and 6. The next section explains the variations in these results.

5.2 ANALYSIS OF RESULTS

The FTUs incur no additional costs while traveling by air under Scenarios 1 through 4, because infants continue to travel for free under each of these scenarios. Furthermore, it is assumed that all families with infants already own CRSs; therefore, they do not incur expenses for purchasing CRSs.

The most significant cost impact on individual FTUs occurs under Scenarios 5 and 6. Because the FTUs pay the full price of an adult ticket for infants under those scenarios, the cost impact to the FTUs is simply the average cost of an adult ticket. The only difference between these two scenarios is that, under Scenario 6, FTUs must provide the CRSs. Because it is assumed that the FTUs already own them, no increased cost to FTUs results from the purchase of CRSs; both scenarios produce identical results.

Under Scenarios 7A through 7C, round trip ticket costs per infant are 75 percent, 50 percent, and 25 percent, respectively, of the average adult ticket price. However, the highest annual round trip air travel costs to all FTUs collectively (that is, the total cost impact to traveling families) is incurred under Scenario 7A. This result appears to be an anomaly because the greatest round trip cost per FTU occurs under Scenarios 5 and 6. Two opposing factors contribute to this result. First, the price of an infant ticket increases linearly—that is, in 25 percent increments of the adult ticket price. On the other hand, as ticket prices increase, the number of air passengers decreases.[2] The maximum annual cost—infant ticket price multiplied by the number of FTUs traveling by air each year—occurs at 70 percent of the adult ticket cost (at a cost of $137 million). The infant ticket price in Scenario 7A (infant tickets are 75 percent of the adult fare) is closer to the 70 percent rate than the price in Scenario 7B (50 percent); therefore, Scenario 7A results in the maximum cost to all FTUs.

No cost impact to FTUs was quantified for Scenarios 2, 3, and 4. However, these various scenarios may impose some costs. Scenario 4 assumes a space-available basis for infant travel; that is, an FTU may not be able to use a CRS if seats are unavailable for traveling infants (infants may be transported on their parents' laps or the FTUs may have to travel during a less-preferred time). If all passenger seats are sold, passengers with infants would have to stow the CRSs they brought on board or check them as baggage, and some delayed flights may result. Similarly, under Scenario 2 it is assumed that FTUs already own CRSs; if not, families that do not currently own CRSs may experience cost impacts. Therefore, the best-case scenario

[2] Because this study uses a price elasticity of -2.3 for certain FTUs, the effect of charging an additional fare results in complete diversion of this most sensitive category of FTUs.

for FTUs is Scenario 3 where infants are guaranteed a reservation at no cost and the air carrier provides the CRS.

5.3 SENSITIVITY ANALYSIS

To assess changes in the values of input parameters on family travel costs the following input parameters were varied and the resulting impact was evaluated:

- Infant enplanements as a percentage of total enplanements,
- Percent of FTUs who must buy a CRS, and
- Initial price elasticity of demand.

Scenario 6 represents the worst case for individual FTUs in terms of additional cost per round trip. Exhibit 5-2 shows the results from varying assumptions concerning infant enplanements and CRS ownership—calculated in terms of net present value (NPV)—under Scenario 6.

EXHIBIT 5-2
Sensitivity Analysis for FTU Cost Impacts

Parameter	**Change in Parameter Value**	**Change in the NPV of Family Travel Costs** Scenario 6 FTU Pays Full Fare for Infant Ticket, FTU Provides CRS
Infant enplanements as a percentage of total enplanements	-10%	-10.0%
	+10%	+10.0%
Percent of FTUs who must buy a CRS	+5%	-4.0%
	+10%	-8.3%

As noted in Chapter 4, changes in total infant enplanements cause proportional impacts on FTU cost. As the infant enplanement proportion increased by 10 percent, the total cost to FTUs also increased by 10 percent. This result occurs because as the number of infants traveling by air increases, the total FTU population, and hence cost, rises in direct proportion.

Ironically, assuming some proportion of FTUs must buy CRSs actually reduces the annual cost to all FTUs traveling by air because the increased cost of air travel causes some FTUs to divert. The additional cost of CRS purchases for FTUs continuing to travel by air is outweighed by the reduction in FTU costs associated with diversions. In other words, when an FTU diverts from air travel, it has no air travel costs. The net effect is an overall reduction in total FTU costs.

Changes in the price elasticity of demand cause the greatest variation in family travel costs and are directionally opposite to the changes in elasticity. For example, a decrease in the value of price elasticity results in an increase in total cost to all FTUs.

Exhibit 5-3 shows the sensitivity analysis results for assumptions of unitary and inelastic price elasticity under all seven scenarios, compared with the baseline of price elasticity estimates used in this study. As the price elasticity estimate is decreased from that used in this analysis (weighted average of -1.6) to unitary elasticity (-1.0) to an inelastic value (-0.8), family travel costs increase substantially. Because their sensitivity to changes in price decreases, more families continue to travel after air fares increase. The result is that families as a group pay more for air travel.

The average FTU size used in this study is slightly over three individuals including one infant. Price elasticity of demand is likely to be fairly sensitive to actual size and composition of the FTU. For example, the price impact on FTUs with two infants under two years old would tend to have a higher elasticity (divert from air travel more readily if charged infant fare). On the other hand, single parent FTUs would probably be less elastic because the option of driving alone with infants is less feasible. This study finds that total FTU travel costs and consequently air carrier revenues are sensitive to variations in price elasticities as shown in Exhibits 5-3 and 7-5. Air carriers experience net revenue losses until infant fares are lowered to about 50 percent of full fare even with an inelastic initial point value of -0.8. Further evidence suggesting airlines believe that highly elastic behavior is the actual case is the fact that air carriers are free now to charge fares even for lap-held infants but choose not to do so. It appears reasonable that if it were profitable for the carriers to charge for infants, then they would.

FTU costs estimated in this study are based on the assumption that virtually no families today are paying fares to assure the availability of passenger seats in which to install CRSs. To the extent that some FTUs may be paying for such seats, FTU travel cost increases associated with mandating CRSs are overestimated. No adequate data exist concerning this issue. Anecdotal evidence supports the view that relatively few families purchase seats for their infants. The impact of this factor on FTU costs would be linear. For example, if 10 percent of FTUs currently purchase passenger seats, then FTU travel cost increases and air carrier revenue losses due to diversion and bumping would be reduced by 10 percent from values shown in the tables.

EXHIBIT 5-3
Price Elasticity of Demand Sensitivity Analysis
NPV of Change in Family Travel Costs—1995 Dollars
(Averaged over 1995-2004; Millions of Dollars)

Scenario	Baseline * ** Price Elasticities	Initial Point Elasticities Set to -1.0	Initial Point Elasticities Set to -0.8
1. Base Case - No CRS mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	0	0	0
3. Air carrier provides seat at no cost, air carrier provides CRS	0	0	0
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0	0	0
5. FTU pays full fare for infant ticket, air carrier provides CRS	$754.4	$1,491.5	$1,746.8
6. FTU pays full fare for infant ticket, FTU provides CRS	$754.4	$1,491.5	$1,746.8
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	$940.2	$1,358.0	$1,501.7
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	$879.3	$1,065.0	$1,128.8
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	$565.9	$612.3	$628.3

* See Exhibit 2-5 for baseline price elasticity estimates.
** These point elasticities characterize the initial point on the linear demand curve. As the cost to FTUs increases, the demand becomes more elastic. Section 2.2.2 and Appendix G provide further discussion of the properties of demand elasticities.

6. FINDINGS—THE IMPACT ON FATALITIES AND INJURIES

6. FINDINGS—THE IMPACT ON FATALITIES AND INJURIES

This chapter discusses the impact a CRS mandate would have on fatalities and injuries. The primary purpose of such a mandate is to enhance the safety of infants during air travel. The following premises have been incorporated into the analysis:

- The use of some types of CRSs can reduce infant fatalities and injuries sustained in air carrier accidents and incidents. (Chapter 3 discusses these findings.)
- Air carriers may charge up to the full fare for seats encumbered by CRSs. This action would increase the cost of air travel for families with infants. (Chapter 5 discusses these impacts.)
- Increases in the cost of air travel may cause some families with infants to divert from air travel to other transportation modes or to cancel their trips. (Chapter 4 discusses impacts to passenger volume.)
- Air travel is safer than travel on other modes of transportation. For example, on a 500-mile trip, an unrestrained infant has a 1.6 out of 10 million probability of dying in a survivable air carrier accident For a 500-mile automobile trip, an infant has a 17.2 out of 10 million chance of dying in a survivable automobile accident. The chance of dying in an automobile accident increases with distance, while the rate for air carriers is considered less dependent on distance.
- Therefore, the net impact of mandatory use of CRSs on fatalities and injuries should be estimated as the net change resulting from the following effects:
  - Reduced aviation fatalities and injuries resulting from CRS use
  - Reduced aviation fatalities and injuries because of decreased air passenger enplanements resulting from higher costs of air travel
  - Increased fatalities and injuries resulting from the diversion of air passengers to other modes of transportation.

If air carriers choose not to charge for seats encumbered by CRSs, then an estimated 4.9 fatalities, 2.1 major injuries, and 3.7 minor injuries could be prevented over the next 10 years.

If air carriers elect to charge the full fare for seats encumbered by CRSs, then an additional 82.2 fatalities, 160.4 major injuries, and 4,785.2 minor injuries are estimated to occur over the next 10 years.

The air carriers may decide to charge for infant seating only during peak periods such as the holiday season. Unfortunately, automotive travel may be more hazardous during the school breaks (particularly Thanksgiving and Christmas) than during the summer months. There are more people on the roads during the holiday season, more of these drivers are intoxicated than at other times of the year, and the weather conditions are more harsh. For these reasons, the FAA believes that it has under-estimated the highway fatalities and injuries that would result when people divert to automotive travel during these periods. If the air carriers charge for infants to fly during peak periods (as a result of the FAA mandating the use of CRSs), then highway fatalities and injuries may be much higher during these period than could be estimated by prorating the above FAA estimate for only the portion of the year covered by the peak period, holiday season. On the other hand, many families choose air travel during holidays because automotive travel is not practicable given the short holiday time constraint. Thus, for those families unwilling to pay for infant travel that have tight time constraints during the holidays, relatively more will simply forego travel during these periods. This could offset some of the increase in fatalities and injuries.

6.1 RESULTS

A summary of the quantitative output for fatality and injury impacts is shown in Exhibits 6-1 through 6-3. Exhibit 6-1 shows the impacts on infant fatalities and injuries; Exhibit 6-2 lists the impacts to noninfants; and Exhibit 6-3 shows the net safety impact to all passengers for each of the seven scenarios (as defined in Section 2.2.1). The total fatalities and injuries for the 10-year period considered in this study (1995 to 2004) and the net impacts are provided for each transportation mode.

Generally, the impact of a CRS mandate on travel safety varies across the scenarios considered. This variation is primarily driven by the extent to which air passengers divert to other modes of transport. Over a 10-year period, the infant fatalities range from 4.9 fatalities prevented under Scenarios 2, 3, and 4 to 19.6 additional fatalities under Scenarios 5 and 6 (Exhibit 6-1). The noninfant fatalities range from zero in Scenario 4 to 62.6 additional fatalities under Scenarios 5 and 6 (Exhibit 6-2). The total fatalities range from 4.9 fatalities prevented in Scenario 4 to 82.2 additional fatalities under Scenarios 5 and 6 over 10 years (Exhibit 6-3). [1]

The prevented infant fatalities for Scenarios 2, 3, and 4 are not identical. Scenario 4 is slightly less safe than Scenarios 2 or 3 because a small proportion of infants are displaced to the laps of noninfant guardians traveling with them when the airplane is full. Specifically, infant fatalities prevented in Scenarios 2 and 3 are actually 4.88; in Scenario 4, it is 4.86; both numbers round to 4.9.

The point at which the number of infant fatalities is exactly zero results from a permutation of Scenario 7. This occurs when the infant ticket price is set to 20.0 percent of the noninfant air fare. However, at this infant ticket rate, 12.8 noninfant fatalities result from diversions to other modes of transportation projected to occur over 10 years. There is no point at which the noninfant fatalities will equal zero. Even if there is no cost for infant tickets, 0.2 noninfant fatalities are projected over 10 years as a result of diversions caused by bumping. As soon as the infant ticket fare exceeds 0 percent of the noninfant air fare, the number of fatalities resulting from diversions to other modes of transportation increase.

Major and minor injuries follow the same pattern as fatalities, but the magnitude of impact is much higher. The net major injuries range from -2.1 to 160.4; the net minor injuries range from -3.7 to 4,785.2 across the various scenarios (Exhibit 6-3). The point at which the number of infant major injuries is exactly zero is when the infant ticket price is set to 4.9 percent of the noninfant air fare. However, at that infant ticket price, 6.1 noninfant major injuries occur.

[1] At present, most forward-facing CRSs are not fully effective. These seats are used primarily by infants over one year of age. If these infants represent half of the infants who travel, then mandating the use of currently available CRSs at this time might only prevent between two to three infant fatalities over 10 years.

EXHIBIT 6-1
Projected Changes in Infant Fatalities and Injuries
(Totaled Over 1995-2004)

Scenario	Infant Fatalities			Infant Major Injuries			Infant Minor Injuries		
	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case: No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	-4.9	0.0	-4.9	-2.1	0.0	-2.1	-3.8	0.0	-3.8
3. Air carrier provides seat at no cost, air carrier provides CRS	-4.9	0.0	-4.9	-2.1	0.0	-2.1	-3.8	0.0	-3.8
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-4.9	0.0	-4.9	-2.1	0.0	-2.1	-3.7	0.0	-3.7
5. FTU pays full fare for infant ticket, air carrier provides CRS	-5.0	24.6	19.6	-2.3	44.8	42.5	-3.9	1,129.3	1,125.4
6. FTU pays full fare for infant ticket, FTU provides CRS	-5.0	24.6	19.6	-2.3	44.8	42.5	-3.9	1,129.3	1,125.4
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-5.0	18.6	13.6	-2.2	33.7	31.5	-3.9	850.5	846.6
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-4.9	12.4	7.5	-2.2	22.5	20.3	-3.8	567.0	563.2
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-4.9	6.2	1.3	-2.2	11.2	9.0	-3.8	283.5	279.7

Note: "Diversions to Other Modes" account for the fatalities and injuries of infants who are diverted.

EXHIBIT 6-2
Projected Changes in Noninfant Fatalities and Injuries
(Totaled Over 1995-2004)

Scenario	Noninfant Fatalities			Noninfant Major Injuries			Noninfant Minor Injuries		
	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case -- No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	-0.1	0.3	0.2	-0.1	0.5	0.4	-0.1	13.1	13.0
3. Air carrier provides seat at no cost, air carrier provides CRS	-0.1	0.3	0.2	-0.1	0.5	0.4	-0.1	13.1	13.0
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. FTU pays full fare for infant ticket, air carrier provides CRS	-18.3	80.9	62.6	-29.2	147.1	117.9	-47.0	3,706.7	3,659.7
6. FTU pays full fare for infant ticket, FTU provides CRS	-18.3	80.9	62.6	-29.2	147.1	117.9	-47.0	3,706.7	3,659.7
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-13.8	61.0	47.2	-22.0	110.9	88.9	-35.5	2,794.5	2,759.0
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-9.2	40.8	31.6	-14.7	74.1	59.4	-23.7	1,867.3	1,843.6
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-4.6	20.5	15.9	-7.4	37.3	29.9	-11.9	940.2	928.3

Note: "Diversions to Other Modes" account for the fatalities and injuries of noninfants who are diverted. Scenarios 2 and 3 include diversions of bumped passengers.

EXHIBIT 6-3
Projected Changes in All Fatalities and Injuries
(Totaled Over 1995-2004)

Scenario	Total Fatalities			Total Major Injuries			Total Minor Injuries		
	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case -- No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	-4.9	0.3	-4.6	-2.2	0.5	-1.7	-3.9	13.1	9.2
3. Air carrier provides seat at no cost, air carrier provides CRS	-4.9	0.3	-4.6	-2.2	0.5	-1.7	-3.9	13.1	9.2
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-4.9	0.0	-4.9	-2.1	0.0	-2.1	-3.7	0.0	-3.7
5. FTU pays full fare for infant ticket, air carrier provides CRS	-23.3	105.5	82.2	-31.5	191.9	160.4	-50.9	4,836.1	4,785.2
6. FTU pays full fare for infant ticket, FTU provides CRS	-23.3	105.5	82.2	-31.5	191.9	160.4	-50.9	4,836.1	4,785.2
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-18.8	79.6	60.8	-24.3	144.6	120.3	-39.3	3,644.9	3,605.6
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-14.2	53.1	38.9	-16.9	96.6	79.7	-27.5	2,434.3	2,406.8
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-9.5	26.7	17.2	-9.6	48.6	39.0	-15.7	1,223.7	1,208.0

Note: "Diversions to Other Modes" account for the fatalities and injuries of passengers who are diverted. Scenarios 2 and 3 include diversions of bumped passengers. Numbers are rounded and totals from Exhibits 6-1 and 6-2 may not exactly sum to the above values.

6.2 ANALYSIS OF RESULTS

Exhibit 6-4 summarizes the projected changes in net fatalities and injuries and the underlying reasons for these changes. Because the study assumed that a CRS mandate will always increase the safety of infants traveling by air, the values for fatalities and injuries sustained by infants traveling by air are always negative. However, these values also incorporate the improvement in air safety resulting from infant diversions. These diversions "improve" air safety in the sense that infants that no longer travel by air are no longer subject to an aviation fatality or injury.

EXHIBIT 6-4
Reasons For Projected Changes in Fatalities and Injuries
(Totaled over 1995-2004)

Passengers	Reason for Change	Fatalities (By Scenario)								
		1	2	3	4	5	6	7A	7B	7C
Infant	CRS used on airplane	0.0	-4.9	-4.9	-4.9	-1.3	-1.3	-2.2	-3.1	-4.0
	Decreased Enplanements	0.0	0.0	0.0	0.0	-3.7	-3.7	-2.8	-1.8	-0.9
	Diverted to Other Modes	0.0	0.0	0.0	0.0	24.6	24.6	18.6	12.4	6.2
	Net	0.0	-4.9	-4.9	-4.9	19.6	19.6	13.6	7.5	1.3
Noninfant	Decreased Enplanements	0.0	-0.1	-0.1	0.0	-18.3	-18.3	-13.8	-9.2	-4.6
	Diverted to Other Modes	0.0	0.3	0.3	0.0	80.9	80.9	61.0	40.8	20.5
	Net	0.0	0.2	0.2	0.0	62.6	62.6	47.2	31.6	15.9

Passengers	Reason for Change	Major Injuries (By Scenario)								
		1	2	3	4	5	6	7A	7B	7C
Infant	CRS used on airplane	0.0	-2.1	-2.1	-2.1	-0.6	-0.6	-1.0	-1.4	-1.8
	Decreased Enplanements	0.0	0.0	0.0	0.0	-1.7	-1.7	-1.2	-0.8	-0.4
	Diverted to Other Modes	0.0	0.0	0.0	0.0	44.8	44.8	33.7	22.5	11.2
	Net	0.0	-2.1	-2.1	-2.1	42.5	42.5	31.5	20.3	9.0
Noninfant	Decreased Enplanements	0.0	-0.1	-0.1	0.0	-29.2	-29.2	-22.0	-14.7	-7.4
	Diverted to Other Modes	0.0	0.5	0.5	0.0	147.1	147.1	110.9	74.1	37.3
	Net	0.0	0.4	0.4	0.0	117.9	117.9	88.9	59.4	29.9

Passengers	Reason for Change	Minor Injuries (By Scenario)								
		1	2	3	4	5	6	7A	7B	7C
Infant	CRS used on airplane	0.0	-3.8	-3.8	-3.7	-1.0	-1.0	-1.7	-2.4	-3.1
	Decreased Enplanements	0.0	0.0	0.0	0.0	-2.9	-2.9	-2.2	-1.4	-0.7
	Diverted to Other Modes	0.0	0.0	0.0	0.0	1,129.3	1,129.3	850.5	567.0	283.5
	Net	0.0	-3.8	-3.8	-3.7	1,125.4	1,125.4	846.6	563.2	279.7
Noninfant	Decreased Enplanements	0.0	-0.1	-0.1	0.0	-47.0	-47.0	-35.5	-23.7	-11.9
	Diverted to Other Modes	0.0	13.1	13.1	0.0	3,706.7	3,706.7	2,794.5	1,867.3	940.2
	Net	0.0	13.0	13.0	0.0	3,659.7	3,659.7	2,759.0	1,843.6	928.3

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The results for air travel under Scenarios 2 through 4 quantify the increased safety resulting from the use of CRSs alone because no FTU diversions occur under these scenarios—Scenarios 2 and 3 display some minor non-FTU diversions because of bumping. Over the 10-year period, it is projected that a CRS mandate will prevent 4.9 infant fatalities on airplanes. However, Scenarios 2 and 3 cause a marginal negative impact on the safety of noninfants traveling by air. Although CRSs do not directly provide safety benefits to noninfants, the mandate causes diversions (because of bumping) under these scenarios and effectively reduces the number of noninfant passengers traveling by air. Thus, Scenario 4 is the most beneficial scenario in terms of reduced fatalities, preventing a total of 4.9 fatalities (infants and noninfants) over 10 years.

By contrast, under Scenarios 5 and 6, the greatest number of passenger diversions occur because the FTUs are required to pay the noninfant ticket price for infants. The high volume of passenger diversions translates to more passengers using ground transportation modes with much higher accident fatality and injury rates than aviation. Under both scenarios, 1.2 infant fatalities in aviation accidents will be prevented because of CRS use and 3.7 prevented because of diversions, but the higher fatality rates of the other modes will cause 24.6 infant fatalities. Therefore, the net impact to infant fatalities is 19.7 infant lives lost. Similarly, 62.6 additional noninfant fatalities will occur over the 10-year forecast period if air carriers charge the noninfant fare for infant tickets. The total of 82.2 additional passenger fatalities projected for 1995 through 2004 under these two scenarios makes them the worst in terms of safety impact. The bottom line is that the net fatalities (and injuries) will increase if air carriers charge for infant tickets to accommodate CRSs.

Scenarios 7A, 7B, and 7C resulted in fatality increases between the minimum value of 4.9 prevented fatalities and the maximum value of 82.2 additional fatalities discussed above. The exact values depend on the fraction of the adult fare that an infant ticket would cost, which results in varying numbers of diversions to other transportation modes. For example, if the results of Scenarios 7A, 7B, and 7C are reviewed in that order, the number of infant fatalities caused by diversions to other transportation modes decreases from 13.6 to 7.5 to 1.3 as the infant ticket price decreases from 75 percent to 50 percent to 25 percent of the noninfant ticket fare.

Exhibit 6-4 shows that the same general trends and explanations are also true for the major and minor injuries sustained over the 10-year period. Scenario 4 results in 2.1 major infant injuries and 3.7 minor infant injuries projected to be avoided through the use of CRSs. On the other hand, under Scenarios 5 and 6, passenger diversions because of increased infant ticket prices result in infants sustaining an additional 42.5 major injuries and 1,125.4 minor injuries.

6.3 SENSITIVITY ANALYSIS

Analyzing the effects of changes in the values of input parameters on fatalities and injuries is important. Improved travel safety is the objective of increasing CRS use and it is important to determine the relative influence of parameters affecting the accuracy of the results. This section discusses the results of the sensitivity analysis pertaining to fatalities. The following input parameters were varied and the resulting impact on the number of fatalities and injuries was evaluated:

- Number of diverted passengers who forego travel
- Percent of FTUs who must buy a CRS
- Automobile fatality rate
- Initial price elasticity of demand.

The effect of reducing the scope of mandatory CRS use to part 121 air carriers is discussed in the next section. These effects are due in large part to the differences in aviation fatality and injury rates between part 121 and part 135 air carrier operations.

In analyzing safety impact results, two scenarios represented the best and worst outcomes. Scenario 4 represented the best case (least change in fatalities and injuries); Scenario 6 represented the worst case. Under Scenario 4, no diversions occur, so only the last parameter (infant enplanements) is pertinent to this analysis. The results from varying the above three parameters under these scenarios are shown in Exhibit 6-5.

The number of fatalities is sensitive to changes in the number of diverted passengers who decide to forego travel. A 10 percent decrease in this parameter increased the number of fatalities by 42.1 percent under Scenario 6 because those travelers who do not forego travel usually choose to travel by automobile and other transportation modes. Traveling by other modes significantly increases the number of fatalities because travelers in those other modes experience high fatality rates; passengers who forego travel are assumed in the analysis to have no fatality rate. When the number of passengers in this group is reduced by 10 percent, almost all of that 10 percent is transferred to automobile travel, which has a much higher fatality rate. The opposite is true for an increase in the number of diverted passengers who decide to forego travel. If more of these passengers decide to cancel their trip, the number of people who risk being involved in a transportation-related accident is significantly reduced.

EXHIBIT 6-5
Sensitivity Analysis for Fatality Impacts

Parameter	Change in Parameter Value	Scenario 4 FTU Reserves Seat at no Cost, FTU Provides CRS	Scenario 6 FTU Pays Full Fare for Infant Ticket, FTU Provides CRS
Number of diverted passengers who forego travel	-10%	0.0 %	+42.1%
	+10%	0.0 %	-42.2%
Percent of FTUs who must buy a CRS	+5%	+46.1%	+2.5%
	+10%	+92.2%	+5.0%
Automobile Fatality Rate	-10%	0.0 %	-12.8%
	+10%	0.0 %	+12.8%

The percent of FTUs that must buy a CRS produced a large change in fatalities under Scenario 4 but not under Scenario 6. In Scenario 6, the change in fatalities results from noninfant passengers who are bumped by infants. Also, the only costs to the FTUs are the noninfant tickets they purchase. Changing assumptions about the need to purchase CRSs greatly impacts the family travel cost in scenario 4; therefore, it causes a significant amount of FTU diversion. Diversion results in increased fatalities related mostly to automobile travel.

The number of fatalities was also sensitive to variations in the automobile fatality rate. As this parameter was changed by 10 percent, the number of fatalities changed by 12.8 percent. This occurs because a 10 percent increase to the automobile fatality rates for infants and noninfants increases the number of automobile fatalities by 10 percent. Bus and rail transportation fatalities are insignificant contributors to the total fatalities and do not need to be considered in this discussion (although they are included in the analysis). However, when automobile fatalities are combined with aviation fatalities prevented by CRS use, the net fatalities are reduced. Because of this reduction of the total fatalities, the 10 percent increase from the automobile contribution increases to a 12.8 percent effect.

Although this outcome seems counterintuitive, it is correct. The prevented aviation fatalities remain constant (and are always a negative number); only the automobile fatality rates are varied. A 10 percent increase in the automobile fatality rate causes the number of automobile fatalities to increase by 10 percent. However, when the prevented aviation fatalities are subtracted from the automobile fatalities, the net increase to fatalities is greater than 10 percent. The following example illustrates this relationship:

	Base Case	10% Increase in Automobile Fatality Rate
Aviation fatalities:	-23	-23.0
Automobile fatalities:	105	115.5
Net fatalities:	82	92.5

The percentage increase in net fatalities resulting from a 10 percent increase in the automobile fatality rate is calculated as follows: (92.5-82)/82 = 12.8 percent.

Changes in infant enplanements as a percentage of total enplanements are not listed in Exhibit 6-5 because they produced the smallest changes in the number of fatalities for both Scenarios 4 and 6. Net fatalities varied in direct proportion to changes in infant enplanements. As the ratio of infants to total passengers increases, more families are affected by the additional cost of infant tickets, and more families divert to automobile travel. Higher fatality rates for automobiles cause a larger number of total fatalities.

Price elasticity was not one of the parameters to which fatalities and injuries were most sensitive. For any price elasticity estimate the same relationship will remain among scenarios—Scenarios 5 and 6 will still result in the greatest number of fatalities and injuries and Scenario 4 will have the fewest. Also, the purchase of the infant ticket will remain the largest cause of diversions. To explore the impacts of changing from an elastic to unitary to inelastic demand, an expanded sensitivity analysis was performed for the price elasticity parameter. Exhibit 6-6 shows the results of the sensitivity analysis.

EXHIBIT 6-6
Price Elasticity of Demand Sensitivity Analysis
Net Fatalities (Totaled over 1995-2004)

Scenario	Baseline * ** Price Elasticities	Initial Point Elasticities Set to -1.0	Initial Point Elasticities Set to -0.8
1. Base Case: No CRS mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	-4.6	-4.6	-4.6
3. Air carrier provides seat at no cost, air carrier provides CRS	-4.6	-4.6	-4.6
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-4.9	-4.9	-4.9
5. FTU pays full fare for infant ticket, air carrier provides CRS	82.3	50.4	39.4
6. FTU pays full fare for infant ticket, FTU provides CRS	82.3	50.4	39.4
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	60.8	36.6	28.4
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	39.0	22.9	17.4
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	17.2	9.1	6.4

* See Exhibit 2-5 for baseline price elasticity estimates.
** These point elasticities characterize the initial point on the linear demand curve. As the cost to FTUs increases, the demand becomes more elastic. Section 2.2.2 and Appendix G provide further discussion of the properties of demand elasticities.

Results of Scenarios 1, 2, 3, and 4 are not affected by changes in the price elasticity because there are no increased costs to FTUs. As the price elasticity estimate is decreased from that used in this analysis (weighted average of -1.6) to unitary elasticity (-1.0) to an inelastic value (-0.8), net fatalities decrease for Scenarios 5, 6, and 7. More families continue to travel by air and the net fatalities are reduced because the FTUs' sensitivity to changes in price decreases.

6.4 EVALUATION OF LIMITING CRS MANDATES TO LARGE COMMERCIAL CARRIERS (PART 121)

This study generally assumed that a CRS mandate would apply to all air carriers—regularly scheduled operations under FAR parts 121 and 135. This is consistent with existing regulations regarding the permitted use of CRSs and the FAA's current effort to assure the level of safety for all commercial air passengers. However, it is possible that CRS use requirements could be limited to only part 121 operations.

To isolate the safety impacts of a CRS mandate on part 121 air carriers, the safety analysis was modified. All part 135 commuter air carrier operations, enplanements, and accident data were removed from the database, so that only part 121 data remained. The fatality and injury results from this analysis are presented in Exhibit 6-7 for infants, Exhibit 6-8 for noninfants, and Exhibit 6-9 for the net effect.

EXHIBIT 6-7
Projected Changes in Part 121 Infant Fatalities and Injuries (Totaled over 1995-2004)

	Infant Fatalities			Infant Major Injuries			Infant Minor Injuries		
Scenario	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case: No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	-1.4	0.0	-1.4	-0.6	0.0	-0.6	-1.6	0.0	-1.6
3. Air carrier provides seat at no cost, air carrier provides CRS	-1.4	0.0	-1.4	-0.6	0.0	-0.6	-1.6	0.0	-1.6
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-1.3	0.0	-1.3	-0.6	0.0	-0.6	-1.6	0.0	-1.6
5. FTU pays full fare for infant ticket, air carrier provides CRS	-1.4	22.5	21.1	-0.6	40.9	40.3	-1.7	1,030.1	1,028.4
6. FTU pays full fare for infant ticket, FTU provides CRS	-1.4	22.5	21.1	-0.6	40.9	40.3	-1.7	1,030.1	1,028.4
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-1.4	16.9	15.5	-0.6	30.8	30.2	-1.7	775.8	774.1
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-1.4	11.3	9.9	-0.6	20.5	19.9	-1.7	517.2	515.5
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-1.4	5.6	4.2	-0.6	10.3	9.7	-1.7	258.6	256.9

The number of infant fatalities presented in Exhibit 6-7 (part 121 data) and those presented in Exhibit 6-1 (part 121 and part 135 data) differ. When part 135 data were removed from the analysis, the maximum prevented infant fatalities decreased from 4.9 (Scenarios 2, 3, and 4) to 1.4 (Scenarios 2 and 3). The universal use of CRSs on part

121 aircraft encompasses a majority of FTUs and air carrier related costs but prevents only about one to two infant fatalities over a ten-year period. Scenarios 5 and 6 resulted in the maximum number of infant fatalities—the number increased from 19.6 (Exhibit 6-1) to 21.1 (Exhibit 6-7).

Two factors caused these results. First, the maximum number of prevented infant fatalities decreased because the infant air fatality rate, with CRS, based on the analysis outlined in Section 2.2.2 decreased from 0.718 to 0.364 fatalities per 10 million enplanements and, for infants not using CRSs, the infant air fatality rate decreased from 1.616 to 0.636 per 10 million enplanements. The reduction in the fatality rates is a result of removing the part 135 data, which decreased the number of preventable infant fatalities from 5 to 3. A lower fatality rate for infants traveling by air results in fewer infant fatalities that could have been prevented in aviation without any accompanying change in fatality rates in other modes of transportation. Second, the maximum number of infant fatalities also decreased because part 135 enplanements were removed from the analysis, resulting in fewer passengers diverting to other modes of transportation. The same general relationship holds for major and minor injuries.

The number of prevented infant fatalities decreases from Scenario 5 to 6 to 7. Exhibit 6-7 shows a constant value of -1.4 (prevented) fatalities for these scenarios because the values are rounded to one decimal place. For example, the actual values are -1.393 for Scenarios 5 and 6, -1.383 for Scenario 7A, -1.373 for Scenario 7B, and -1.362 for Scenario 7C.

EXHIBIT 6-8
Projected Changes in Part 121 Noninfant Fatalities and Injuries (Totaled over 1995-2004)

	Noninfant Fatalities			Noninfant Major Injuries			Noninfant Minor Injuries		
Scenario	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case: No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	0.0	0.3	0.2	-0.0	0.5	0.5	-0.0	11.9	11.9
3. Air carrier provides seat at no cost, air carrier provides CRS	0.0	0.3	0.2	-0.0	0.5	0.5	-0.0	11.9	11.9
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. FTU pays full fare for infant ticket, air carrier provides CRS	-7.1	73.8	66.7	-5.4	134.2	128.8	-17.2	3,381.1	3,363.9
6. FTU pays full fare for infant ticket, FTU provides CRS	-7.1	73.8	66.7	-5.4	134.2	128.8	-17.2	3,381.1	3,363.9
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-5.3	55.6	50.3	-4.1	101.2	97.1	-13.0	2,549.0	2,536.0
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-3.6	37.2	33.6	-2.7	67.6	64.9	-8.7	1,703.3	1,694.6
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-1.8	18.7	16.9	-1.4	34.0	32.6	-4.4	857.6	853.2

Exhibit 6-8 shows the impact to noninfant fatalities and injuries when part 135 data were removed. The pattern is similar to that of infant fatalities. The minimum number of projected noninfant fatalities in Scenario 4 is zero because this scenario has no diversions—the same result given in Exhibit 6-2. The maximum number of noninfant air fatalities decreased from -18.3 (Exhibit 6-2, Scenarios 5 and 6) to -7.1 (Exhibit 6-8, Scenarios 5 and 6). This decrease is caused by the noninfant air fatality rate decrease from 1.480 to 0.628 per 10 million enplanements when part 135 data were removed.

EXHIBIT 6-9
Projected Changes in Part 121 All Fatalities and Injuries (Totaled over 1995-2004)

	Total Fatalities			Total Major Injuries			Total Minor Injuries		
Scenario	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change	Air	Diversion to Other Modes	Net Change
1. Base Case: No CRS mandate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Air carrier provides seat at no cost, FTU provides CRS	-1.4	0.3	-1.1	-0.6	0.5	-0.1	-1.7	11.9	10.2
3. Air carrier provides seat at no cost, air carrier provides CRS	-1.4	0.3	-1.1	-0.6	0.5	-1.1	-1.7	11.9	10.2
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-1.3	0.0	-1.3	-0.6	0.0	-0.6	-1.6	0.0	-1.6
5. FTU pays full fare for infant ticket, air carrier provides CRS	-8.5	96.3	87.8	-6.0	175.0	169.0	-18.9	4,411.3	4,392.4
6. FTU pays full fare for infant ticket, FTU provides CRS	-8.5	96.3	87.8	-6.0	175.0	169.0	-18.9	4,411.3	4,392.4
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-6.7	72.6	65.9	-4.7	131.9	127.2	-14.6	3,324.7	3,310.1
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-4.9	48.5	43.6	-3.3	88.1	84.8	-10.3	2,220.5	2,210.2
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-3.2	24.4	21.2	-2.0	44.3	42.3	-6.0	1,116.2	1,110.2

Exhibit 6-9 summarizes the net impact to infant and noninfant fatalities and injuries when part 135 data were removed from the analysis. Scenario 4 remains the most beneficial scenario—the greatest number of fatalities and injuries are prevented. In Scenario 4, the number of prevented fatalities decreases by approximately 75 percent from 4.9 to 1.3 as a result of the decreased fatality rates and the decreased number of enplanements and air carrier operations.

The number of fatalities and injuries is greatest in scenarios 5 and 6. When part 135 data were removed, the number of fatalities and injuries under these scenarios increases. This is because the number of enplanements only decreases by approximately 10 percent, so there are still significant diversions, and the fatalities resulting from other modes of transportation remain relatively high. Additionally, the air transportation fatality rates decrease by more than 50 percent; therefore, there are fewer prevented infant fatalities in air transportation.

7. FINDINGS—ECONOMIC IMPACT ON AIR CARRIERS

7. FINDINGS—ECONOMIC IMPACT ON AIR CARRIERS

This chapter documents the economic impact of a potential CRS mandate on air carriers. Although the primary intent of such a mandate is to increase the safety of infants traveling by air, compliance with such a regulation will inevitably affect air carriers economically.

Air carriers may experience changes in their costs and revenues resulting from the mandatory use of CRSs. Potential cost increases are the result of:

- Purchase and maintenance of CRSs, projected to cost up to $10.1 million over 10 years; this cost was derived from recurring and nonrecurring CRS costs described in Section 2.2.2

- Initial modification and continuous maintenance of reservation systems, projected to cost up to $60.0 million over 10 years. (A detailed discussion of this cost is in Section 2.2.2.)

If air carriers elect to charge the adult fare for those seats used with a CRS, potential air carrier revenue changes include:

- Revenue gains from charging for infant tickets, projected to be an additional $201.46 per round trip. This projection totals a maximum of $1.1 billion over 10 years.

- Revenue losses from diversions of families with children. This projection totals a maximum of $6.3 billion over 10 years, with minor revenue losses from displaced non-FTU passengers.

- Net revenue losses could be $5.2 billion over 10 years (or $3.6 billion present value). However, air carriers are expected to charge for infants only with the possibility of minimal passenger diversions and no net loss of revenues. Those charges would occur during peak travel seasons and peak periods of the day. FTUs may be offered significant infant fare discounts or free infant passage during off-peak periods.

The above economic impacts cannot be directly aggregated because the cited values occur under different scenarios. The analysis determined that the economic impacts on air carriers were likely to be adverse under all scenarios evaluated. The most beneficial outcome for the air carriers occurred when air carriers guaranteed aircraft seats for infant use at no cost and FTUs provided their own CRSs. Under this scenario, the NPV of incurred loss by air carriers was $28.4 million.

7.1 RESULTS

Exhibit 7-1 summarizes the revenue and cost impacts for each of seven scenarios (as defined in Section 2.2.1); these results present average annual impacts. The NPVs were also computed so that the effects of the CRS mandate over the 10-year time period (1995 through 2004) could be examined.

EXHIBIT 7-1
Projected Changes in Air Carrier Economic Impact—1995 Dollars
(Averaged over 1995-2004; Millions of Dollars)

Scenario	Annual Economic Impact: Cost Impact (1995 Dollars)	Annual Economic Impact: Revenue Impact (1995 Dollars)	Annual Net Impact (1995 Dollars)	Life Cycle Cost (NPV)
1. Base Case -- No CRS mandate	$0	$0	$0	$0
2. Air carrier provides seat at no cost, FTU provides CRS	$0	-$4.1	-$4.1	-$28.4
3. Air carrier provides seat at no cost, air carrier provides CRS	$1.0	-$4.1	-$5.1	-$35.4
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	$6.0	$0	-$6.0	-$42.3
5. FTU pays full fare for infant ticket, air carrier provides CRS	$1.0	-$520.5	-$521.5	-$3,603.1
6. FTU pays full fare for infant ticket, FTU provides CRS	$0	-$520.5	-$520.5	-$3,596.2
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	$0	-$337.9	-$337.9	-$2,334.9
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	$0	-$189.7	-$189.7	-$1,311.0
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	$0	-$78.5	-$78.5	-$542.2

11.013.94-08

Generally, the economic impact of a CRS mandate on air carriers varies widely across the scenarios considered and is primarily driven by the extent to which costs of complying with such a mandate are absorbed by the air carrier industry. The findings indicate that Scenario 5 results in the greatest economic impact on air carriers—an average annual loss of $522 million or an NPV loss of $3.6 billion. The impact under Scenario 6 is almost identical to Scenario 5, except for the added cost of air carriers providing the CRS under Scenario 5.

By contrast, the financial burden to air carriers associated with Scenarios 2, 3, and 4 is much less, with average annual costs ranging from $4 million to $6 million and NPVs from $28 million to $42 million. The annual impacts of Scenarios 7A, 7B, and 7C change from $338 million to $79 million (with the NPV decreasing from $2.3 billion to $542 million) as the amount that a family must pay for an infant decreases from 75 percent to 25 percent of the full fare.

This overall economic effect comprises both cost and revenue impacts. Air carriers incur about $1 million in annual expenses under Scenarios 3 and 5; these costs increase to $6 million under Scenario 4. The annual revenue losses experienced in each scenario, ranging from $0 under Scenario 4 to $521 million under Scenarios 5 and 6, when added to the costs cause significant negative economic impacts to air carriers. The next section explains the variations in these results.

7.2 ANALYSIS OF RESULTS

Interpreting the results of the economic impact analyses requires an understanding of the underlying reasons for these results. Therefore, it is necessary to examine the projected revenue and cost impacts to air carriers. Exhibits 7-2 and 7-3 summarize these total impacts and their fundamental causes for all scenarios. All the results are presented relative to the base case (Scenario 1).

Exhibit 7-2 indicates that revenue losses may be significant if air carriers charge infant air fares. In Scenarios 5 and 6, which result in the greatest economic impact, the loss of revenues from passengers diverting to other modes of transport amounts to $6.3 billion over the 10-year period. On the other hand, total revenues received as a result of charging the FTUs for the infant seats are only $1.1 billion.

Although the most adverse economic impact to the air carriers occurs under Scenario 5, Scenario 6 can potentially become the worst-case scenario. Currently, this scenario assumes that all the FTUs will provide their own CRSs. If this assumption is relaxed—that is, all FTUs may not necessarily own CRSs, then requiring the FTUs to bring their own CRSs will cause additional diversions because some FTUs who do not own CRSs will forego air travel rather than purchase them. This variable may cause the loss in revenues to increase significantly and make Scenario 6 the worst case.

Scenario 4 has no associated revenue impacts. Under this scenario, the air carriers provide traveling infants a seat only if one is available (that is, if the flight is not completely booked); FTUs provide their own CRSs. Because no passengers will divert to other modes of transport and no opportunity cost results from bumping adult passengers, air carriers do not lose any revenues under this scenario.

For Scenarios 2 and 3, air carriers do not lose any revenues from FTU diversions because they provide each traveling infant a seat at no cost to the FTUs. However, in providing these seats, air carriers will actually lose some revenues because infants will occasionally displace other noninfant paying passengers.

EXHIBIT 7-2
Reasons for Projected Changes in Air Carrier Revenue Impacts—1995 Dollars
(Totaled Over 1995-2004; Millions of Dollars)

Scenario	Reason for Change			Net Change	Net Present Value
	Decrease in FTU Enplanements	Displaced non-FTU Enplanements	Charge for Infant Ticket		
1. Base Case – No mandate	$0	$0	$0	$0	$0
2. Air carrier provides seat at no cost, FTU provides CRS	$0	-$41.1	$0	-$41.1	-$28.4
3. Air carrier provides seat at no cost, air carrier provides CRS	$0	-$41.1	$0	-$41.1	-$28.4
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	$0	$0	$0	$0	$0
5. FTU pays full fare for infant ticket, air carrier provides CRS	-$6,296.3	$0	$1,091.8	-$5,204.6	-$3,596.2
6. FTU pays full fare for infant ticket, FTU provides CRS	-$6,296.3	$0	$1,091.8	-$5,204.6	-$3,596.2
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-$4,735.3	-$4.7	$1,360.7	-$3,379.2	-$2,334.9
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-$3,156.9	-$13.0	$1,272.5	-$1,897.4	-$1,311.0
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-$1,578.4	-$25.2	$819.0	-$784.7	-$542.2

Under Scenarios 7A, 7B, and 7C, air carriers lose revenues because of both passenger diversions and the displacement of paying passengers. The magnitude of these losses depends on the proportion of the adult fare that an FTU must pay for an infant—as this proportion increases, the losses from diversions continue to increase. In each of these scenarios, this loss of revenue is partially compensated by the revenues gained from the amount charged for the infants' tickets. However, from the air carriers' standpoint, each of these scenarios causes substantial adverse economic impact.

There could be times, such as blackout periods or the holiday season, when air carriers could charge for infants without causing significant passenger diversion. Demand for air travel increases considerably during the holidays. Given the short time frame and limited transportation options, travelers may be less sensitive to price increases. That is, their price elasticity of demand may become more inelastic during this time period.

Exhibit 7-3 shows that, under Scenarios 3 and 5, air carriers would spend about $10 million to acquire and maintain CRSs from 1995 through 2004 to provide CRSs for traveling infants at no cost to the FTUs. Furthermore, during this time period under Scenario 4, air carriers will spend almost $60 million to modify, upgrade, and maintain their computerized reservation systems to keep up-to-date records of all enplaned infants—a feature that these systems do not currently provide because they are not required to do so.

The potential revenue losses from charging infant air fares far outweigh the cost of providing CRSs or modifying the reservation system. From the air carrier point of view, Scenario 2 is most beneficial because it results in the least adverse economic impact. The economic impact of mandatory CRS use on air carriers depends more on whether air carriers decide to charge for seats occupied by infants and less on the direct cost incurred by air carriers for purchasing and maintaining CRSs and modifying reservations systems.

EXHIBIT 7-3
Reasons for Projected Changes In Air Carrier Cost Impacts—1995 Dollars
(Totaled Over 1995-2004; Millions of Dollars)

Scenario	Reason for Change		Net Change	Net Present Value
	Provide CRS	Provide Infant Reservation		
1. Base Case -- No mandate	$0	$0	$0	$0
2. Air carrier provides seat at no cost, FTU provides CRS	$0	$0	$0	$0
3. Air carrier provides seat at no cost, air carrier provides CRS	$10.1	$0	$10.1	$7.0
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	$0	$60.0	$60.0	$42.3
5. FTU pays full fare for infant ticket, air carrier provides CRS	$10.1	$0	$10.1	$7.0
6. FTU pays full fare for infant ticket, FTU provides CRS	$0	$0	$0	$0
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	$0	$0	$0	$0
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	$0	$0	$0	$0
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	$0	$0	$0	$0

7.3 SENSITIVITY ANALYSIS

Fluctuations in the cost and revenue impacts associated with variations in each of the input parameters were examined and analyzed. The following input parameters were varied and the resulting changes to air carrier economic impacts were evaluated:

- Infant enplanements as a percentage of total enplanements
- Percent of FTUs who must buy a CRS
- Initial price elasticity of demand.

In examining the changes in air carrier passenger volume and air carrier economic impacts, two scenarios were considered. Scenario 2 represented the best case (least adverse economic impact); Scenario 5 represented the worst case. Exhibit 7-4 shows results from varying the above latter two parameters for these two scenarios.

EXHIBIT 7-4
Sensitivity Analysis for Air Carrier Economic Impact

Parameter	Change in Parameter Value	Change in NPV	
		Scenario 2 Air Carrier Provides Seat at no Cost, FTU Provides CRS	Scenario 5 FTU Pays Full Fare for Infant Ticket, Air Carrier Provides CRS
Infant enplanements as a percentage of total enplanements	-10%	-19.2%	-10.0%
	+10%	+21.3%	+10.0%
Percent of FTUs who must buy a CRS	+5%	-383.0%	0.0%
	+10%	-765.9%	0.0%

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The change in NPV is sensitive to the change in infant enplanements as a proportion of total enplanements, with a ±10 percent variation causing the net economic impact to vary ±10 percent for Scenario 5. Because it is assumed that each FTU has exactly one infant, as the ratio of infants to total air passengers increases, the number of FTUs will increase by that same percentage and so will the diversions for this scenario. By contrast, this variation in infant enplanements causes the net economic impact under Scenario 2 to fluctuate by a much larger amount—about 20 percent. Scenario 2 results in a relatively small number of diversions—all a consequence of bumping. As the percentage of infants increases, these diversions increase significantly. This large increase to a small base number of diversions causes a relatively higher change in the NPV.

Varying the percentage of FTUs who must buy a CRS produced diverse results. A significant impact to air carrier NPV occurs under Scenario 2 because the CRS is the only additional cost to the FTUs; therefore, it causes a large number of diversions and results in a decrease in air carrier NPV. The additional CRS cost to FTUs is minor relative to the infant ticket costs. As a result, there was no change in NPV under Scenario 5 because the additional passenger diversions were minimal.

The change in NPV resulting from changes in the price elasticity of demand is shown in Exhibit 7-5. When the FTU price elasticities are assumed to be in the elastic range (less than -1.0), Scenarios 5 and 6 will still result in the greatest economic impact to air carriers; the least impact will be under Scenario 2. Also, the infant ticket cost will remain the largest cause of passenger diversions.

EXHIBIT 7-5
Price Elasticity of Demand Sensitivity Analysis
NPV of Air Carrier Economic Impact—1995 Dollars
(Totaled Over 1995-2004; Millions of Dollars)

Scenario	Baseline * ** Price Elasticities	Initial Point Elasticities Set to -1.0	Initial Point Elasticities Set to -0.8
1. Base Case - No CRS mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	-$28.4	-$28.4	-$28.4
3. Air carrier provides seat at no cost, air carrier provides CRS	-$35.4	-$35.4	-$35.4
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-$42.3	-$42.3	-$42.3
5. FTU pays full fare for infant ticket, air carrier provides CRS	-$3,603.1	-$1,283.9	-$474.8
6. FTU pays full fare for infant ticket, FTU provides CRS	-$3,596.2	-$1,277.0	-$467.9
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-$2,334.9	-$722.9	-$164.5
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-$1,311.0	-$330.2	$9.9
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-$542.2	-$98.7	$55.2

* See Exhibit 2-5 for baseline price elasticity estimates.

** These point elasticities characterize the initial point on the linear demand curve. As the cost to FTUs increases, the demand becomes more elastic. Section 2.2.2 and Appendix G provide further discussion of the properties of demand elasticities.

As the initial point price elasticity estimates are reduced from the baseline values (with a weighted average of -1.6), to unitary elasticity (-1.0) to an inelastic value (-0.8), the NPV of air carrier economic impact is unchanged for Scenarios 1, 2, 3, and 4. There are no FTU costs under these four scenarios; therefore, varying the price elasticity does not cause diversion or have an impact on air carrier revenues. There is a minor impact to revenues caused by infants bumping noninfants in Scenarios 2 and 3, but it is too small to be shown at the level of accuracy in Exhibit 7-5.

Scenarios 5 and 6 result in decreasing air carrier economic impacts as the initial point elasticity estimates are reduced. The lower elasticities mean fewer diversions, which reduces revenue losses to air carriers. Although the revenue losses decrease under Scenarios 5 and 6, the impact to air carrier NPV remains significant. For example, an elasticity of -0.8 results in economic impacts ranging from $468 million to $475 million. As previously discussed, the primary reason that reduced initial point elasticities of -1.0 or -0.8 show economic losses is that on a linear demand curve the elasticity varies significantly over the curve. The results show that even though this initial point elasticity is unitary (-1.0) or inelastic (-0.8), the curve becomes elastic (more negative than -1.0) with increased FTU fares.

Air carrier costs estimated in this study are based on the assumption that virtually no families today are paying fares to assure the availability of passenger seats in which to install CRSs. To the extent that some FTUs may be paying for such seats, air carrier revenue losses due to diversion and bumping are overestimated. No adequate data exist concerning this issue. Anecdotal evidence supports the view that relatively few families purchase seats for their infants. The impact of this factor on airline revenue estimates would be linear. For example, if 10 percent of FTUs currently purchaser passenger seats, then FTU travel cost increases and air carrier revenue losses due to diversion and bumping would be reduced by 10 percent from values shown in the tables.

8. SUMMARY OF FINDINGS

8. SUMMARY OF FINDINGS

This chapter summarizes the overall findings of the CRS benefit/cost analysis. The safety and economic impacts for the seven scenarios are presented in Exhibit 8-1.

EXHIBIT 8-1
Summary of Findings

Scenario	Change in FTU Air Passenger Volume (Annual Average)	Change In Total Fatalities*	Change in Total Injuries*	NPV of Air Carrier Economic Impacts (In Millions of Dollars)*	NPV of FTU Air Travel Cost (In Millions of Dollars)*
1. Base Case -- No CRS mandate	0.0%	0.0	0.0	$0	$0
2. Air carrier provides seat at no cost, FTU provides CRS	0.0%	-4.6	7.5	-$28.4	$0
3. Air carrier provides seat at no cost, air carrier provides CRS	0.0%	-4.6	7.5	-$35.4	$0
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	0.0%	-4.9	-5.8	-$42.3	$0
5. FTU pays full fare for infant ticket, air carrier provides CRS	-73.4%	82.2	4,945.6	-$3,603.1	$754.4
6. FTU pays full fare for infant ticket, FTU provides CRS	-73.4%	82.2	4,945.6	-$3,596.2	$754.4
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-55.4%	60.8	3,725.9	-$2,334.9	$940.2
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-36.9%	38.9	2,486.5	-$1,311.0	$879.3
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-18.5%	17.2	1,247.0	-$542.2	$565.9

11.013.94-41

* Totaled over 1995 to 2004; NPV in 1995 dollars

FTU passenger volume is the main factor for determining economic impacts to air carriers and the number of fatalities and injuries. The most significant factor affecting FTU passenger volume is the number of diversions from air travel. These diversions are a result of increased costs experienced by FTUs. Scenarios 5 and 6 result in the most diversions because infant ticket prices in these scenarios equal ticket prices for noninfants. Scenarios 7A, 7B, and 7C display varying numbers of diversions based on the relative increases in infant ticket costs. There are no FTU diversions under Scenarios 2, 3, and 4 because there are no costs to FTUs. Some diversion of non-FTUs occurs in Scenarios 2 and 3 because of bumping, but the effect on passenger volume is minimal.

The changes in fatalities and injuries are driven by the number of air passengers who divert to automobile travel, which has significantly higher casualty rates. Scenarios 5 and 6 result in the greatest number of casualties because they have the largest number of passenger diversions. Scenarios 2 and 3 result in some prevented fatalities, but still have a net increase in total injuries because of the diversion of bumped passengers. Scenario 4 is the only scenario resulting in both prevented fatalities and prevented injuries; therefore, it is the most beneficial scenario regarding increased safety.

Revenue lost to diversion may be the most significant economic factor affecting air carriers if passengers divert and cause a reduction in the air carrier revenue stream. Scenarios 5 and 6 result in the most diversions, which cause the largest economic impacts to air carriers. Scenarios 7A, 7B, and 7C result in reduced, yet significant, economic impacts that vary according to the number of passenger diversions. The economic impact under Scenarios 2, 3, and 4 is orders of magnitude lower than the other scenarios because of minimal passenger diversions. The least adverse air carrier economic impact occurs in Scenario 2, when air carriers provide the aircraft seat for infant use at no cost and the FTU provides the CRS.

Infant ticket prices reflect the largest impact on family air travel costs. The greatest impact on total FTU air travel costs occurs in Scenario 7B, followed by 7A, then 7C. This phenomenon, described in detail in Chapter 6, is caused by a combination of the number of FTUs continuing to travel by air and the corresponding air travel cost. Scenarios 2, 3, and 4 result in no impact on FTU air travel costs. In these scenarios, infants continue to fly at no cost and all FTUs are assumed to already own CRSs. Families would experience some inconvenience under Scenario 4 because infant seating is provided on a space-available basis only. In addition, if some portion of FTUs had to procure CRSs to travel by air, only Scenario 3 would minimize the FTU cost impacts.

From the FAA's perspective, prevented fatalities and injuries remain the most important criterion for determining the most beneficial scenario. Increased safety is the primary reason for requiring CRSs on airplanes. The most fatalities and injuries are prevented, with minimal economic impact to air carriers, under Scenario 4. In addition, passengers are not burdened by additional costs.

Although assessing the impact of a CRS mandate on aviation safety is the primary reason for conducting this study, the benefit/cost analysis was designed to capture impacts to the entire transportation system in accordance with Public Law 103-305. This law required an investigation of the impact to other transportation modes because it is unrealistic to assume that passengers will not divert from air travel if their air travel costs increase. Precedents for this approach had been set by four other studies [Apogee 1990; Apogee 1993; Windle and Dresner; and McKenzie and Lee}. If the scope of this study were limited to the aviation system only, then the safety impact would be as summarized in Exhibit 8-2.

EXHIBIT 8-2
Summary of Aviation-only Safety Impact
(Totaled over 1995 to 2004)

Scenario	Infant Fatalities	Infant Major Injuries	Infant Minor Injuries
1. Base Case -- No CRS mandate	0	0	0
2. Air carrier provides seat at no cost, FTU provides CRS	-4.9	-2.1	-3.8
3. Air carrier provides seat at no cost, air carrier provides CRS	-4.9	-2.1	-3.8
4. FTU reserves seat at no cost on space available basis, FTU provides CRS	-4.9	-2.1	-3.7
5. FTU pays full fare for infant ticket, air carrier provides CRS	-1.3	-0.6	-1.0
6. FTU pays full fare for infant ticket, FTU provides CRS	-1.3	-0.6	-1.0
7A. FTU pays 75% of full fare for infant ticket, FTU provides CRS	-2.2	-1.0	-1.7
7B. FTU pays 50% of full fare for infant ticket, FTU provides CRS	-3.1	-1.4	-2.4
7C. FTU pays 25% of full fare for infant ticket, FTU provides CRS	-4.0	-1.8	-3.1

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Safety impacts listed in Exhibit 8-2 result from the use of CRSs only; no comparison is made to fatalities or injuries sustained from other modes of transportation. The key factor affecting the casualty impacts above is the number of infants continuing to travel by air. Scenarios 5 and 6 show the fewest number of prevented fatalities because the large number of diversions significantly reduces the population of infants traveling by air. Therefore, this reduction produces fewer preventable fatalities. Scenarios 2, 3, and 4 result in the most prevented fatalities because there are no diversions in these scenarios; therefore, a larger population of infants is saved by CRS use. The number of major and minor injuries conforms to this relationship—Scenarios 2, 3, and 4 prevent the most fatalities; Scenarios 5 and 6 prevent the fewest fatalities.

Air carrier policies could significantly alter the overall results summarized in Exhibits 8-1 or 8-2. Specifically, the air carrier pricing policy in response to the CRS mandate would impact these outcomes. For example, if air carriers passed costs to all passengers, then diversions from air travel would increase, causing increased fatalities and injuries. How air carriers will respond to such a mandate is not clear, but it is considered likely that they will elect to pass on added costs and charge for infant seats to the extent the market will permit.

Variations in the values of several input parameters could significantly alter the results of this analysis. The five most significant parameters identified by the sensitivity analysis are:

- The price elasticity of demand estimates
- The percentage of FTUs who must buy a CRS
- Infant enplanements as a percentage of total enplanements
- The number of diverted passengers who forego travel
- Automobile fatality rates.

The values used for these parameters were derived from the most current data available. In some cases, the parameter values were derived from historical data, expert opinions, survey results, or a combination of these sources. Further basic research conducted in these areas could refine the parameter values and improve the accuracy of the analysis.

For purposes of the economic analysis part of this study, it was assumed that the CRSs used for air travel were effective. However, tests show that not all CRSs currently on the market perform satisfactorily in the aviation environment.

In summary, the analysis demonstrated that a CRS mandate could prevent as many as 4.9 infant fatalities in aircraft accidents over the next 10 years. However, passenger diversion to other, less-safe modes could cause a net increase in fatalities. Revenues lost to diversions produce the greatest potential economic impact on air carriers. These impacts range from moderate to significant, depending on the scenario. Cost impacts to FTUs are minimal if the air carriers absorb all of the costs associated with a CRS mandate.