A Study of Commercial Aviation Demand and Revenue Responses to Changes in Ticket and Segment Tax

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Abstract

The Strategy Simulator project, funded by the Federal Aviation Administration (FAA), strives to find a tax structure that will support the National Airspace System (NAS) and maintain revenue neutrality, where taxes can be adjusted and the FAA can still attain the same revenue amount if taxes had not changed. Virginia Tech's role in the project is to analyze the effects of different tax structures on passenger demand. Virginia Tech focuses on ticket and segment taxes and runs different tax scenarios through the Transportation Systems Analysis Model (TSAM) and the TSAM Aggregation for the Strategy Simulator (TASS) model. TSAM provides a more microscopic analysis of demand by including spatial representation and mode choice in the model. TASS is a work in progress that aggregates the TSAM analysis in order to reduce computation time so that scenarios can be tested quickly.

Based on data from literature review, TSAM results provides the smallest combined percent error for demand and revenue, followed by TASS, then the Strategy Simulator. TSAM and TASS also provide a detailed analysis of demand behavior in response to tax changes. In general, demand decreases as taxes increase, and demand increases over the years due to a fare scaling factor applied to reduce fares over the years. Revenue increases both over increasing taxes and over the years, indicating that increases in taxes does not harm revenue collection and actually increases revenues for the ticket and segment taxes tested. Revenue increases over the years because demand increases

over the years, and the revenue generated from this increased demand more than makes up for decreased fares.

Executive Summary

The Strategy Simulator project, funded by the Federal Aviation Administration (FAA), focuses on examining alternative tax structures that will support the FAA in managing the National Airspace System (NAS). The project is a collaboration between the FAA, Ventana, and the NEXTOR schools. Ventana is the creator of the software Vensim and the Strategy Simulator program written in Vensim. The NEXTOR schools comprise those graduate schools that are contributing to and validating the Strategy Simulator program.

Virginia Tech's role in the project is to analyze the effects of different tax structures on passenger demand. One goal of the project is to determine tax combinations that will achieve revenue neutrality, which is the revenue amount that is maintained despite changes in tax combinations. The revenue amount to be maintained is the revenue amount earned for the original tax structure. For Year 2005, the original tax rates are a ticket tax of 7.5% and segment tax of $3.10/segment.

Virginia Tech focuses on existing ticket and segment taxes, and examines different tax scenarios through the Transportation Systems Analysis Model (TSAM). TSAM provides a county-level analysis of travel behavior that includes trip type, income brackets, and two modes of transportation - automobile and commercial aviation.

Analysis with TSAM are labor intensive and time consuming. Virginia Tech therefore attempts to develop a stand-alone, aggregated version of TSAM. This model is called the TSAM Aggregation for the Strategy Simulator (TASS). TASS has the capability of running different tax scenarios on the order of minutes instead of hours,

which is the case for TSAM. Calibration and validation of TASS has not been completed at the time of thesis completion.

The taxes that are considered are ticket taxes of 0%, 3%, 7.5%, and 10% and segment taxes of $3.10/segment, $7.00/segment, $11.00/segment, and $15.00/segment. The years 2000, 2005, 2010, 2015, 2020, and 2025 are analyzed. Fare scaling factors are applied to each year to capture the fare reduction trend predicated by FAA forecasts. All combinations of taxes and years are run through TSAM and TASS. TSAM and TASS generate demand in terms of number of round trips. Output variables that are calculated based on TSAM and TASS demand results and fares include revenue passenger miles (RPMs), weighted price per passenger mile (PPM), revenue, and weighted average fare. Weighted average fare and PPM are weighted by the demand for that origin-destination (O-D) pair.

TSAM and TASS produce reasonable results that display logical trends. Demand decreases with increasing taxes and increases over the years because of the fare scaling factor that reduces fares for each year. Revenue increases as taxes increase despite the fact that demand decreases. This behavior indicates that an increase in taxes does not reduce demand significantly enough to reduce revenues and in fact increases revenues for the ticket and segment taxes tested. The revenue amount that TSAM predicts to be the revenue neutral value for Year 2005 is $8.25 billion. TSAM shows that the tax combinations that would achieve revenue neutrality for Year 2005 are a ticket tax of 0% and segment tax of $9.50/segment or a ticket tax of 3% and segment tax of $7.00/segment. TASS reports the revenue neutral amount to be $9.55 billion. The tax combinations that TASS finds to be revenue neutral are a ticket tax of 0% and segment tax of $9.00/segment or a ticket tax of 3% and $6.50/segment.

Sensitivity tests performed on TSAM and TASS show that fare factors of 70% and 85% produce different results in demand. Demand varies from 9% to 21% from the original demand generated with the original scale factor of 54%. This behavior reveals TSAM's and TASS's sensitivity to the fare scaling factor and demonstrates the importance of providing accurate fare scaling factors for these models.

TSAM results contain the smallest combined percent error for demand and revenue based on FAA historical data (25.01%). Strategy Simulator results provide the smallest margin of error for RPM predictions (2.38%); TSAM results provide the smallest percent error for revenue predictions (13.91%). TASS provides results that have a percent error that is between TSAM and TASS for both demand and revenue values.

TASS tends to over-predict demand when compared to TSAM. TASS tends to generate higher demand and lower weighted average fares. This tendency can be due to the aggregation effect and/or the calibration process and should be further investigated.

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Chapter 1 Introduction

The National Airspace System (NAS) contains numerous components that interrelate with each other. The components of the NAS include passengers and cargo, airline entities, and the government. The Federal Aviation Administration wishes to determine to what degree each component affects the other and therefore initiated the Strategy Simulator project. The Strategy Simulator project is a collaboration between the FAA, Ventana, and the NEXTOR (National Center of Excellence for Aviation Operations Research) schools to simulate the behavior of all the components within the NAS, including passenger demand, airline decisions, and FAA strategies and policies. Virginia Tech contributes to this project by analyzing the effects of certain FAA taxes on passenger demand.

Section 1.1 Objective and Background

One objective of the Strategy Simulator project is to examine alternative tax structures that will support the NAS and achieve revenue neutrality. Revenue neutrality is when the total revenue amount stays the same irrespective of specific taxes levied. Revenue neutrality should at least maintain a revenue amount equal to the taxes originally imposed for that particular year. Year 2005 will be used as the model year for this thesis. The 2005 revenue generated is based on a ticket tax of 7.5% and segment tax of $3.10/segment.

The FAA has enlisted Ventana and the NEXTOR schools in order to create a model of the NAS. Ventana created the Systems Dynamic software called Vensim and developed the Strategy Simulator program. The Strategy Simulator program is written in

Vensim and incorporates all the NAS components and NEXTOR schools' inputs into an integrated model. The Virginia Tech Air Transportation Systems Laboratory (ATSL) has been assigned to research how tax changes affect demand and the combination of taxes that will achieve revenue neutrality. This task involves supplying detailed input into the Strategy Simulator program and validating the Strategy Simulator demand module. When this thesis refers to the Strategy Simulator from now on, the report refers to the Strategy Simulator program created in Vensim rather than the project.

Virginia Tech is approaching this task in two ways: a.) running an existing model created by Virginia Tech called the Transportation Systems Analysis Model (TSAM) with different fare tables for each tax and year scenario, and b.) creating an aggregated version of TSAM called the TSAM Aggregation for the Strategy Simulator (TASS). A comparison of the purpose and characteristics of the Strategy Simulator, TSAM, and TASS will reveal the assets of each model and how TSAM and TASS can help in validating the Strategy Simulator.

Section 1.2 The Strategy Simulator

Section 1.2.1 Purpose of the Strategy Simulator

Ventana created the Strategy Simulator under contract to the FAA as a means to forecast the behavior of passengers, airlines, and government policies. The Strategy Simulator also helps the FAA determine the revenue generated in operations in the NAS. The Strategy Simulator includes passenger and cargo considerations, airline and aircraft considerations, and NAS components including government policies and NAS performance. Figure 1 shows the components considered in the Strategy Simulator.

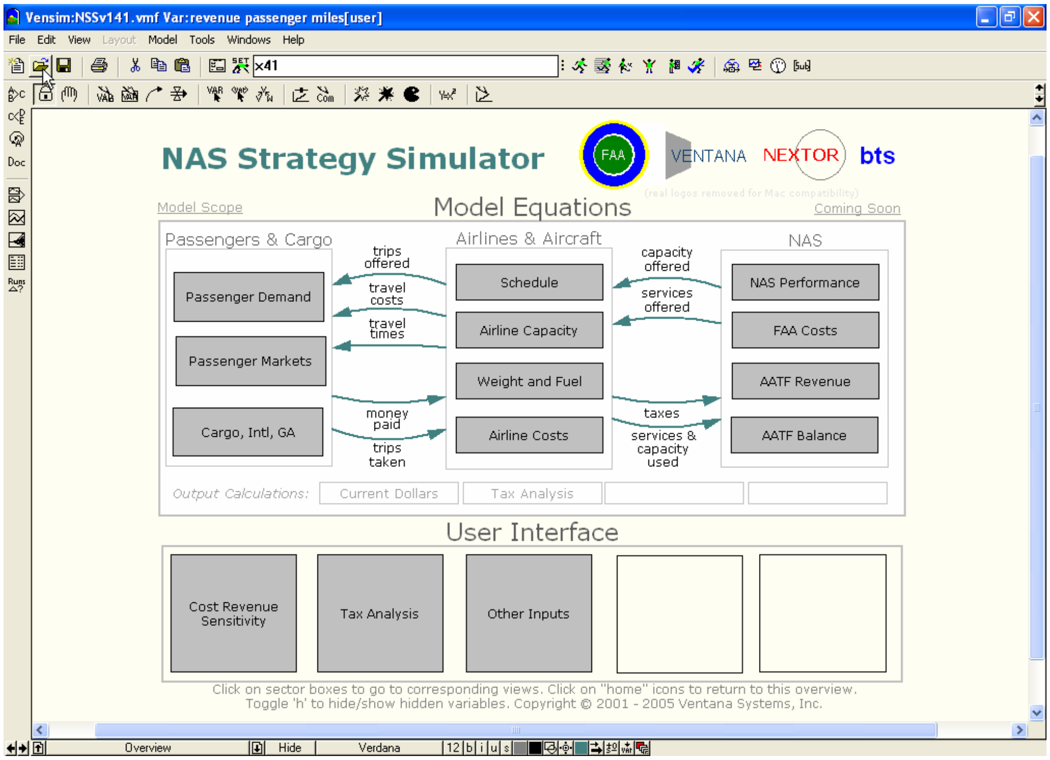

Figure 1. "Overview" Screen of the Strategy Simulator.

Each gray box represents a module that contains variables and equations within it that simulate that particular area. For example, the gray box called "Passenger Demand" contains variables that calculate passenger demand.

Section 1.2.2 Scope of the Strategy Simulator

The Strategy Simulator contains modules that describe various components of the NAS. The version of the Strategy Simulator referred to in this thesis is version 141. This section provides a general description of what variables are considered in each module. Please refer to the Strategy Simulator project website (http://ksn-team.faa.gov/nssg/) for the latest documentation on the Strategy Simulator program.

The Passenger and Cargo modules model passenger and cargo demand. There are three modules within the Passenger and Cargo area. The "Passenger Demand" module generates passenger demand in the form of revenue passenger miles (RPMs). The "Passenger Markets" module reconciles the passenger demand and available supply. The "Cargo, Intl, and GA" module describes cargo, international passenger, and general aviation behavior; at the time this thesis is written, this module is still incomplete.

The Airlines and Aircraft modules pertain to areas that impact airlines. There are four modules within the Airlines and Aircraft area. The "Schedules" module calculates load factor, stage length, and block time variables. The "Airline Capacity" module calculates the sum of total capacity for all airlines in seat-miles. The "Weight and Fuel" module calculates fuel consumption given the Maximum Takeoff Weight (MTOW) of aircrafts. The "Airline Cost" module calculates airline costs given fees, federal taxes, fuel taxes, and employee fees.

The NAS modules pertain to the overall performance of the NAS and government policies. This area contains four modules. The "NAS Performance" module calculates passenger delay. The "FAA Costs" module considers research and development costs, Airport Improvement Plan (AIP) expenses, and Facilities and Equipment (F and E) expenses. The "AATF (Airport and Airway Trust Fund) Revenue" module contains all taxes and policies that would generate revenue for the FAA. Taxes and policies considered in the Strategy Simulator include airspace user fees, airport operation tax, international user fees, ticket tax, segment tax, cargo tax, international tax, domestic passenger taxes, fuel tax, and a field for any other miscellaneous taxes.

Section 1.2.3 Characteristics of the Strategy Simulator

A notable characteristic of the Strategy Simulator is that it can run scenarios in seconds. This capability allows Strategy Simulator users to test many different scenarios quickly. The Strategy Simulator also contains some detailed historical information, such as a variable that adds an additional time penalty for each trip after the terrorist attacks of 9/11. Finally, the Strategy Simulator considers international travel and cargo.

The Strategy Simulator achieves such a short computation time by significantly simplifying NAS behavior. The Strategy Simulator does not include geographical representation, which means it does not discriminate between different regions of the United States. A lack of spatial representation can be a significant omission because it greatly simplifies the behavior of the NAS and applies one nationwide value for capacity and demand. However, if the capacity of a region in the U.S. is met, no further flights can be made into that region, which affects overall capacity and demand. Therefore, spatial analysis is necessary in order to relate how each region's demand and capacity affect other regions.

The Strategy Simulator also does not consider different modes that may compete with commercial aviation, such as automobile or train; it assumes that commercial aviation demand is dependent only on GDP. If competing modes are not considered in the Strategy Simulator, the model will generate artificial travel demands for commercial aviation. This erroneous result can lead policymakers to believe that certain tax structures will generate satisfactory demand when realistically, people will opt for a less expensive mode of transportation.

Section 1.3 TSAM Demand Analysis

Section 1.3.1 Purpose of TSAM Demand Analysis

The Virginia Tech Transportation Systems Analysis Model (TSAM) offers a detailed analysis of demand behavior for commercial airline, automobile, and Small Aircraft Transportation Systems (SATS). TSAM provides detailed analysis to complement the Strategy Simulator by providing spatial representation for demand behavior and mode choice between commercial aviation and automobile. The results generated by TSAM can be used either as input into the Strategy Simulator or as validation for Strategy Simulator demand results. TSAM results can be fed into the Strategy Simulator either as an origin-destination (O-D) matrix or as a look-up table with TSAM results aggregated to suit the format of the Strategy Simulator.

Section 1.3.2 Scope of TSAM Demand Analysis

TSAM incorporates the four-step model and differentiates among several factors when determining demand behavior. TSAM differentiates between business and non-business trip types and analyzes demand based on five income brackets. TSAM has the capability of modeling three mode choices - automobile, commercial aviation, and SATS. TSAM provides a spatial analysis of demand between each O-D pair and considers 3,091 counties within the continental U.S. and 443 airports with commercial aviation services. (Trani et al., 2003)

TSAM outputs consist of demand matrices that display the number of person-trips (round trip) for each O-D pair. The output data are matrices of either a 3,091 x 3,091 counties or 443 x 443 airports.

Section 1.3.3 Characteristics of TSAM

TSAM provides a significantly more detailed analysis of demand behavior than the Strategy Simulator. More specifically, TSAM considers spatial representation and mode choice. These considerations are critical for providing an accurate portrayal of NAS performance and ultimately FAA tax structures. Spatial representation is necessary because each region's demand and capacity is unique from any other region, and some regions' capacities are more constrained than others.

However, a significant attribute of TSAM is its runtime. TSAM takes approximately two to three hours to run one year and one trip type. A scenario with both trip types (business and non-business) run over the life-cycle of TSAM (Year 2000 through 2025 in five year increments) will therefore take approximately twenty-four hours to complete. One of the goals of the Strategy Simulator is to provide a tool that can provide a quick analysis of particular scenarios, which TSAM cannot quickly provide. TSAM also does not consider any states outside of the continental U.S. and does not consider international travel. TSAM only considers passenger demand, not cargo demand.

Section 1.4 TSAM Aggregation for the Strategy Simulator (TASS)

Section 1.4.1 Purpose of TASS

TASS provides a compromise between the Strategy Simulator and TSAM. TASS aggregates TSAM so that it can complete one scenario run in approximately seven minutes. However, TASS still retains a degree of spatial representation and two mode choices.

Section 1.4.2 Scope of TASS

Because TASS is an aggregation of TSAM, TASS does not have the same level of detail found in TSAM. TASS does not distinguish between income levels or trip types. The model considers fewer O-D pairs than TSAM, which allows for fewer computations and therefore a reduction in computation time. Specifically, TASS considers 443 airport-centric clusters of counties instead of 3,091 individual counties, and it treats those clustered counties as one entity. TASS includes only automobile and commercial aviation as viable mode choices. Like TSAM, TASS considers trips only within the continental US, which does not include Alaska, Hawaii, and international trips.

Section 1.4.3 Characteristics of TASS

Since TASS is a compromise between the Strategy Simulator model and TSAM, it assimilates each of these models' characteristics. TASS provides a more detailed analysis of demand behavior by including spatial representation and mode choice. However, because it does not have the level of detail as TSAM does, TASS is able to run one scenario (i.e., one year) in approximately seven minutes. TASS takes approximately 42 minutes to run one life-cycle (Year 2000 through 2025 in five year increments).

The limitations of TASS include limitations mentioned for the Strategy Simulator and TSAM. Because it is an aggregated version of TSAM, TASS cannot provide the same level of detail as TSAM and may contain inaccuracies because of this aggregation. TASS, like TSAM, does not consider international, cargo trips, or trips to Alaska and Hawaii. Finally, TASS's computation time still does not compare to the Strategy Simulator, which can run a scenario for fifty-five years in less than one minute. Finally, TASS is a work in progress and requires further calibration and validation.

Section 1.5 Summary

Virginia Tech is working towards creating a model that will provide accurate demand input into the Strategy Simulator, validate the demand results that the Strategy Simulator obtains, and help determine revenue behavior under different tax scenarios. TSAM and TASS are two models that can accomplish these goals. A review of current literature on aviation forecasting models, a description of the methodology of TSAM and TASS, and an explanation of their results will show how these two models are able to achieve the objectives of the Strategy Simulator project.

Chapter 2 Literature Review

The Strategy Simulator, TSAM, and TASS provide a means to test how changes in certain aviation taxes would affect passenger demand and the overall NAS. All three models include a wide scope of variables - the Strategy Simulator considers passenger demand, airline supply, and governmental policies, and TSAM and TASS include spatial analysis and mode choice.

A review of current literature will provide perspective on the methods that have been tested and in verifying results from TSAM and TASS. First, a review of aviation forecast models is useful to see what methods have been tried and whether these models offer the scope and capabilities required for the Strategy Simulator project. Second, a review of forecast model results and other forecast reports will aid in bounding the tax values to be tested in TSAM and TASS. It would be unreasonable to model air travel demand based on tax values that would never be implemented (i.e., testing a ticket tax of 50%). The FAA has suggested aiming for a "revenue neutral" value, which means that the focus is in finding a combination of taxes that would maintain the revenue amount if taxes had not changed. Finally, a review of clustering methods is required to determine the preferred clustering method for TASS.

Section 2.1 Aviation Forecast Models

The Strategy Simulator, the TSAM runs for the Strategy Simulator, and TASS all use demand forecasting methods to predict future commercial aviation demand based on socioeconomic and governmental influences. A review of existing aviation forecast models will reveal that few models exist that incorporate the scope, details, and capabilities that the Strategy Simulator, TSAM, and TASS contain.

The Terminal Area Forecast (TAF), produced by the Statistics and Forecast Branch of the FAA, forecasts enplanements up to the year 2020. TAF generates this forecast by relating local and national socioeconomic trends to passenger demand. The FAA corrects any forecasts that deviate from the expected trend by applying various statistical methods that include regression analysis and growth rates. The FAA also factors in air traffic growth and airline costs for select major airports. The TAF is a combined effort on the part of FAA headquarters and staff, FAA regional and district offices, and staff economists from the FAA's Aviation Policy and Planning Office (APO). (Long et al., 1999) (Federal Aviation Administration, 2005) Although the TAF considers many factors in its forecasts and includes regional analyses, it does not allow policy makers to examine changes in demand that could result from different policy and demand scenarios. The TAF acts as a guideline rather than a tool with which policymakers can experiment. Therefore, a model that incorporates user inputs is more suited to the Strategy Simulator project.

Kostiuk et al. of the company LMI have devised an economic model called the Air Carrier Investment Model (ACIM) that can forecast air travel supply and demand. The Functional Cost Module (FCM) within ACIM is the module that reconciles passenger demand with air carrier supply and outputs revenue passenger miles (RPMs) and air carrier supply information such as number of aircraft and profit margins. The air travel demand model in FCM is calculated in terms of RPMs and is modeled based on income, population, an air carrier's average yield, and competing carriers' average yields.

FCM models demand at the city-pair level and bases its calculations on eighty-five U.S. airports and the economic characteristics of the surrounding Standard Metropolitan Statistical Areas. The FCM model also includes ten years of U.S. DOT Origin and Destination data for twenty-six airlines. (Kostiuk et al., 1998) It is possible to model tax changes in ACIM by adjusting the variable called "indirect costs" in the airline cost considerations; however, this provides an indirect method of inducing fare changes to the passenger, while some taxes, such as ticket tax, are taxed directly to the passenger. TSAM and TASS include both ticket and segment taxes in the fare to the passenger, which can be directly tracked to the choice of the passenger and therefore change total demand. TSAM and TASS also consider 196,249 O-D airport pairs rather than 7,225 airport pairs, therefore providing a more realistic scenario.

Ghobrial and Kanafani have also devised a model to estimate daily passenger demand by including many quality-of-service variables within their model. The authors investigate demand sensitivity to airfare, travel time, the population of the origin and destination cities, income per capita for the origin and destination cities, frequency of flights for peak and non-peak periods, aircraft size during peak and non-peak periods, whether a city is considered a tourist market, and whether an airport is capacity-constrained. Ghobrial and Kanafani test their model using different combinations of variables and find that the model is significantly sensitive to travel time, airfare and aircraft size. (Ghobrial and Kanafani, 1995) TSAM and TASS both base their mode choice model on travel time and cost and therefore include variables deemed to be significant in affecting air travel demand.

Based on the evaluation of several aviation forecast models, the approach taken for the TSAM runs and for TASS prove to be best suited to answering the FAA's questions while including variables that significantly affect air travel demand, such as travel time and travel cost.

Section 2.2 Review of Forecasts and Current Revenue Data

Several forecast models and databases provide present and future revenue and demand data. Section 2.1 reviews the efficacy of those models as a means to model FAA policies in relation to air traffic demand. This section reviews the values that the forecast models produced as well as data from FAA and other governmental reports. This data serves to both find a means to constrain the bounds of taxes that should be analyzed and to serve as verification of outputs from TSAM and TASS. The data can also be used to determine what might be the revenue neutral amount that the FAA wishes to achieve for Year 2005.

The TAF forecast summary provides historic and forecasted enplanements for Fiscal Years 2004 through 2020. Figure 2 shows the trend for enplanements for those years (Office of Aviation Policy and Plans, 2005 [2]).

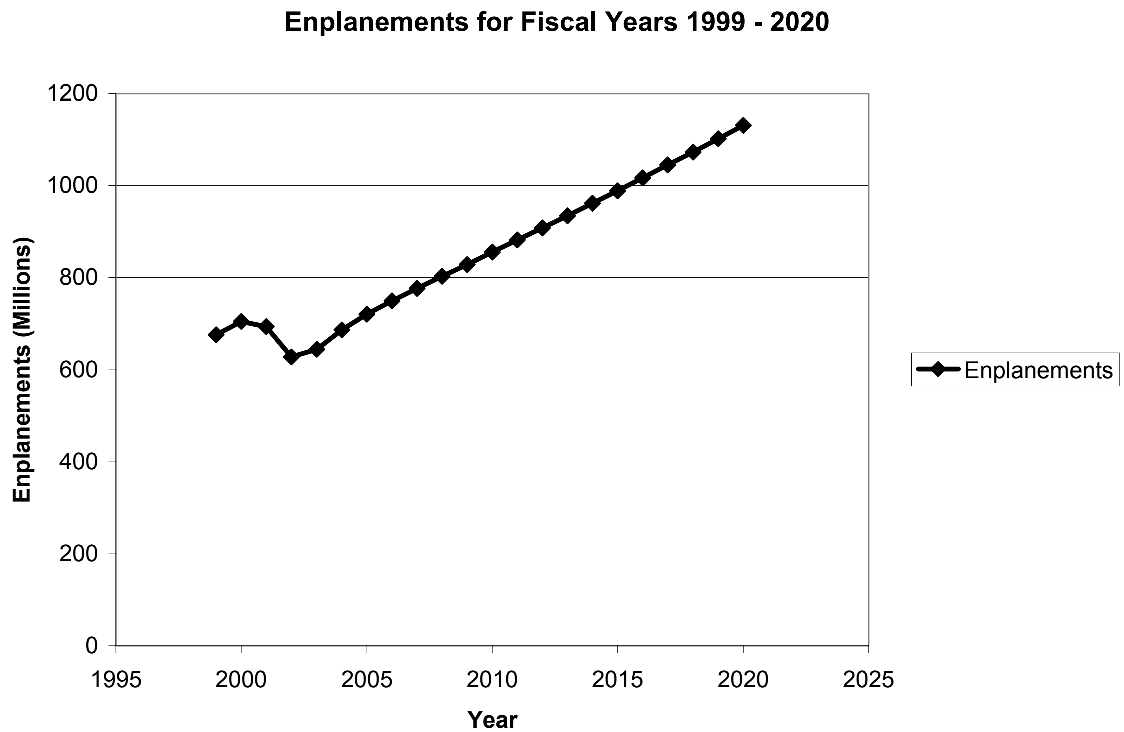

Figure 2. TAF Historical and Forecasted Enplanements for Fiscal Years 1999 through 2020.

The values reported by TAF will be higher than the values that are generated from TSAM and TASS because TAF reports forecasted demand in terms of enplanements. An enplanement is considered as any time a passenger is issued a ticket, which would include all legs of a trip. TSAM and TASS generate demand in number of round trips, and a round trip can contain several legs. The values reported by TAF will be higher because TAF also considers enplanements from Alaska and Hawaii, and TSAM and TASS only consider trips within the continental U.S. The numbers provided by TAF will be helpful in providing a maximum value that TSAM and TASS should not exceed.

The American Travel Survey (ATS) reports that the number of commercial aviation round trips that occurred in 1995 is approximately 161 million, and the number of person miles traveled round trip (also known as RPMs) is approximately 348 billion (Bureau of Transportation Statistics, 1997). The number of round trips made for Year 2000 (the initial analysis year for TSAM and TASS) should be greater than those reported in 1995 since populations continue to grow and air travelers therefore continue to increase. The values that the ATS reports can provide the minimum number of trips and RPMs that TSAM and TASS should generate.

The 2005 FAA Aerospace Forecasts indicate that total domestic RPMs in Year 2000 is 512.8 billion; forecasted RPMs for Years 2005, 2010, and 2015 are 559.7 billion, 687.9 billion, and 826.2 billion respectively (Office of Aviation Policy and Plans, 2005[1]). ACIM, the econometric model developed by LMI, forecasts RPMs for Year 2005 and Year 2015 as 850.3 billion and 1,304.8 billion (Kostiuk et al., 1998). These numbers provide more points that can be used to validate TSAM and TASS.

The United States General Accounting Office reports that the commercial aviation taxes collected for Year 2002 amounts to $8.6 billion dollars. These taxes include passenger ticket tax, passenger segment tax, waybill (cargo) tax, international departure/arrival tax, fuel tax, and rural airport tax. (United States General Accounting Office, 2004) The Strategy Simulator considers all of these taxes; Virginia Tech is focusing only on ticket and segment tax changes since these taxes directly affect passenger fares and therefore demand.

An audit report from the United States Department of Treasury indicates that the total revenue generated from taxes in Year 1999 amounted to approximately $10.4 billion with $7.5 billion generated excises taxes on "transportation of persons by air", which includes ticket and segment taxes (Office of Inspector General, 2000). These revenue amounts can act as further verification of revenue amounts that should be generated from TSAM and TASS.

The Subcommittee on Aviation under the U.S. House of Representative's Committee on Transportation and Infrastructure reports that, of the $8.7 billion in taxes collected in Fiscal Year 2003, $4.2 billion comes from the passenger ticket tax and $1.8 billion from the passenger segment fee (Subcommittee on Aviation, 2004). The TSAM runs and TASS should therefore generate ticket and segment tax revenues that amount to at least $6 billion if not more since this revenue value pertains to Fiscal Year 2003 and segment taxes have increased since then. The Subcommittee also adds that the President's budget predicts that the revenue collected will rise to $11.1 billion in 2005; however, this includes interest earned on the Aviation Trust Fund (Subcommittee on Aviation, 2004).

The National Civil Aviation Review Commission (NCARC) reports aviation tax revenues for years 1994 through 1997 with an estimate for 1997 and 1998. Figure 3 shows the passenger ticket tax revenues for these years. (National Civil Aviation Review Commission, 1997)

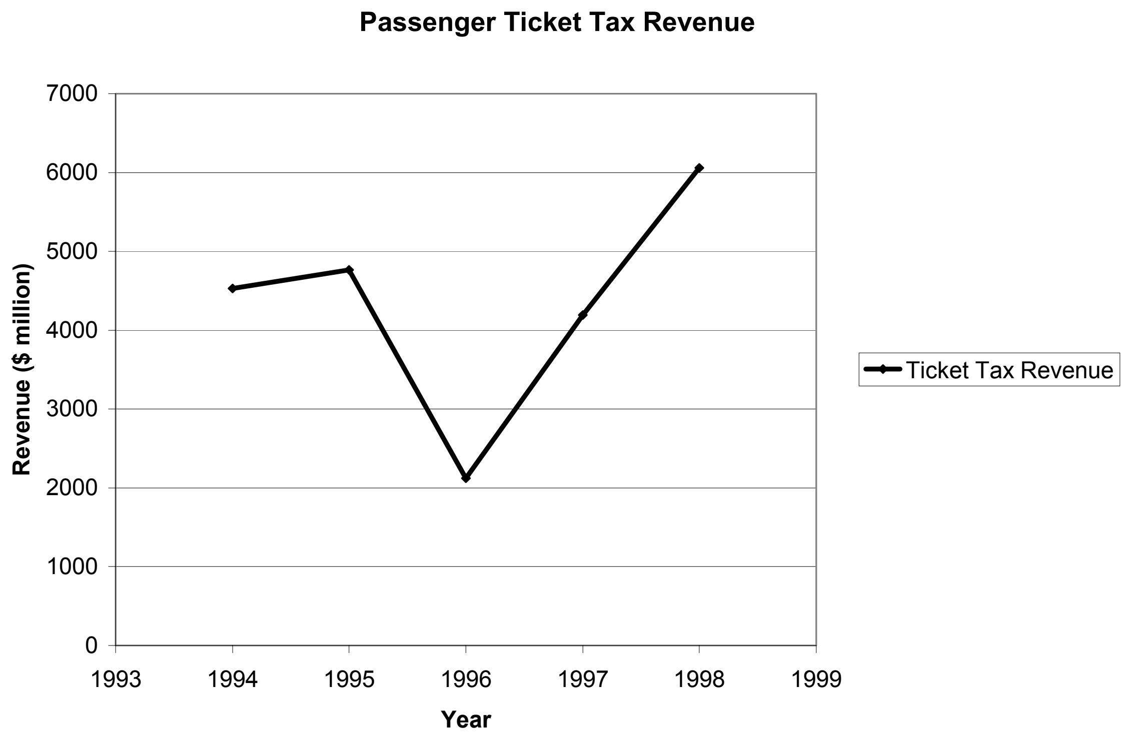

Figure 3. Passenger Ticket Tax Revenue for Years 1994 through 1998 (Years 1997 and 1998 are Estimates).

The dip in Revenue in Year 1996 indicates the year when the ticket tax lapsed and was not reinstated until later that year. The estimated passenger ticket tax in 1998 is 6,057.1 million, which is more than the amount reported by the Subcommittee on Aviation. Two explanations are plausible: a.) ticket tax revenue is lower in FY2003 than FY 1998 because of the effects of 9/11, and/or b.) the NCARC estimated the 1998 revenues based on a ticket tax of 10%, which is greater than the ticket tax during FY2003 (7.5% ticket tax). The Commission adds that "historically, about 87 percent of the excise tax revenues come from the tax on domestic airline tickets" (National Civil Aviation Review Commission, 1997), which provides an approximate means of calculating how much revenue comes from the ticket tax for any prediction of total revenue for later years.

The Federal Aviation Administration also reports the Airport and Airway Trust Fund revenues and provides historical data for revenues for Year 1996 through 2004. These revenues include ticket and segment tax revenue, as well as waybill tax revenue, fuel tax revenue, international arrival/departure tax revenue, rural airport tax revenue, and frequent flyer tax revenue. Figure 4 shows the behavior of the combined total of ticket and segment tax revenues. (Federal Aviation Administration, 2005)

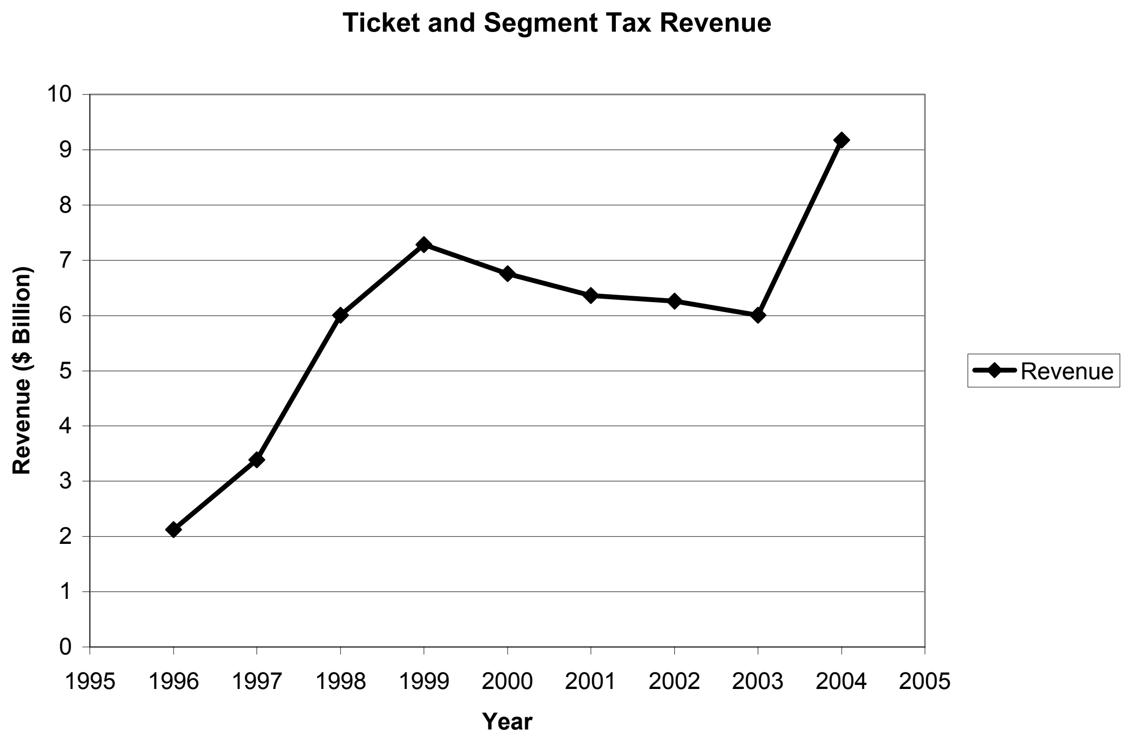

Figure 4. Ticket and Segment Tax Revenue for Years 1996 through 2004.

Revenue steadily increases until Year 1999, and then it decreases past this year. Although it is unclear why revenues decrease in Year 2000, the fact that revenues continue to decrease after Year 2000 can be attributed to the terrorist attacks of 9/11. This graph is important because it provides historical data for Year 2000, which is the only common year of analysis between the literature and TSAM and TASS that is not a forecast.

Section 2.3 Clustering Methods

One of Virginia Tech's objectives for the Strategy Simulator project is to provide a computationally fast demand model for the project. One solution to make TSAM run more quickly is to aggregate the level of detail in TSAM. TASS accomplishes this aggregation by formulating airport-centric clusters of counties so that the O-D matrix is now 443 x 443 instead of 3,091 x 3,091. A review of clustering methods is necessary in order to determine the reasonableness of the clustering method used in TASS and to determine whether clustering methods still provide accurate results.

Guo and Bhat suggest a multi-scale logit (MSL) model to more accurately define "neighborhoods". Guo and Bhat's interest lies in accurately representing an area's characteristics since the way a study area is divided or aggregated can affect the results of the study. This problem is known as the modifiable areal unit problem (MAUP), and it exists whenever aggregation occurs and information for individual areas is therefore lost. Guo and Bhat propose the MSL, which is a residential location choice model that assigns a utility to a "neighborhood" based on multiple criteria. The utility value assigns an attractiveness factor to a particular area. This model combines the spatial attributes of census blocks, block groups, and tracts in order to more accurately calculate the utility value. By considering all of these land categories, Guo and Bhat avoid the MAUP. (Guo and Bhat, 2004) Although the MAUP can be encountered in the analysis that TASS provides, the considerations that Guo and Bhat include are very microscopic in detail. TASS does not look at county-level details, much less tract details, and therefore social and economic behavior at this level would not be considered when aggregating counties. Clustering by demographics or MSAs was considered as possible options for aggregating counties; however, these choices result in too large areas (i.e., areas considered non-MSAs can be extremely large). Assigning utility values to each area would also require further analysis on each area's socioeconomic characteristics, which is beyond the scope of this project.

Ng and Han evaluate several different clustering methods for the purposes of spatial data mining, which is the process of discovering patterns in spatial databases. They introduce one clustering method called PAM (Partitioning Around Medoids). PAM finds a representative object, called a "medoid", for each cluster, which is "the most centrally located object within the cluster" (Ng and Han, 1994). Any object that is not selected as a medoid is clustered to a medoid to which it has the closest relationship. (Ng and Han, 1994) The clustering method that TASS uses applies logic similar to PAM when clustering counties to airports - TASS already has pre-defined medoids (443 airports) that non-selected objects (counties) should cluster around. Ng and Han mention two more clustering methods - CLARA (Clustering LARge Applications) and CLARAN (Clustering Large Applications based on RANdomized Search) - but these methods involve more complex algorithms to sort large datasets. A more simplified approach to clustering counties is used initially to observe whether clustering counties significantly affects demand behavior; CLARA and CLARANS can be tested later to determine whether they provide more accurate demand forecasts.

Goulias et al also devised a clustering method to categorize individuals according to travel behavior. The technique used is called latent class cluster analysis, and it provides probabilistic clustering in which the object is assigned a probability of belonging in a particular cluster. This technique also finds correlations between criteria variables, which can help reveal the strength of the correlations in a cluster. (Goulias et al., 2003) TASS does not require this level of complexity at the moment. First, TASS does not require probabilistic clustering since this technique would require detailed analysis on the county level, and the objective of TASS is to generalize travel demand analysis. Adding more computations to the TASS procedure would also increase computation time, which defeats the purpose of creating TASS.

Shortle et al. have tackled the exact same problem that TASS is solving - to simplify the NAS in order to reduce simulation time for models. The network that Shortle et al. work with consists of approximately 6,200 nodes, where a node represents a point of entry or exit for a single airport; therefore, a medium to large hub airport can have multiple nodes, each node representing a possible arrival or departure entry way into the airport. Shortle et al. apply an electrical engineering theory known as Norton's Theorem to the NAS, which assumes that the NAS is a Jackson network. Norton's Theorem states that a circuit containing a complex network of voltages and resistors can be reduced to one current in parallel with one resistor (Wikipedia, 2005). This theorem essentially provides a means of clustering nodes in an airport and simplifying the network. Shortle et al. apply this theory to the Total Airspace and Airport Modeler (TAAM), which is a model that simulates the motion of individual aircrafts throughout the NAS. The authors conclude that the simplified network is almost as accurate as simulating the complete network and that computation time is reduced by 80%. (Shortle et al., 2003) However, the authors reduce the network by reducing the number of nodes within an airport into one node, which is still very microscopic in detail. TASS is attempting to aggregate 3,091 nodes (counties) into 443 nodes (airports). Therefore, it is unclear from this report whether the large-scale aggregation that TASS is performing will produce accurate results.

The clustering method that TASS uses is most similar to the TwoStep Cluster Analysis method from the analysis software SPSS. SPSS's TwoStep cluster method groups data into the specified number of clusters in two steps. The first step involves merging data into initial sub-clusters based on a specific criterion. This step reduces large datasets into more manageable sub-clusters. The second step involves using the agglomerative hierarchical clustering method to further group and categorize the sub-clusters into the specified number of clusters. TASS's clustering method uses the same basic steps as SPSS's TwoStep cluster method - TASS first finds all airports that are within a two hundred mile radius of a county (some airports may be repeated). TASS then assigns to the county the closest airport within the sub-cluster created in the first step and generates a list of counties that are clustered to each airport. This last step effectively converts 3,091 clusters (airports clustered to a county) into 443 clusters (counties clustered to an airport).

Chapter 3 Methodology

The process for running TSAM demand scenarios and aggregating TSAM into the model TASS are detailed in the following sections. The process of creating TSAM will not be described in detail; for more information on how TSAM was created, please refer to the paper "Integrated Model for Studying Small Aircraft Transportation System" by Trani et al. (Trani et al., 2003).

Section 3.1 Methodology for TSAM Runs

Section 3.1.1 Overview and Scope of TSAM

Section 1.3.2 provides a brief outline of the scope of TSAM. This section provides more details regarding the level of detail considered in TSAM.

TSAM is a demand forecast model that includes the four-step process for urban transportation planning. The four steps are trip generation, trip distribution, mode choice, and trip assignment. The analysis performed in TSAM for the Strategy Simulator project requires trip distribution results from TSAM and requires the mode choice module of TSAM to be run for each tax scenario and year. The mode choice module uses a nested logit model in order to determine the probabilities that a given mode is chosen. The nested logit model is calibrated based on ATS data, and probabilities are calculated based on travel time and travel cost.

TSAM includes many variables that affect demand behavior. TSAM models demand behavior for the 3,091 counties that exist in the continental U.S. The model includes two trip types: business and non-business. The model considers five income groups broken down into the following income brackets for Year 2000 dollar values: below $30,000; $30,000 to $60,000; $60,000 to $100,000; $100,000 to $150,000; and above $150,000. TSAM can compare three possible modes in its mode choice module - automobile, commercial aviation, and Small Air Transportation System (SATS). The SATS mode will not be considered in the analysis for the Strategy Simulator since it is beyond the project's scope. TSAM considers three candidate origin airports and three candidate destination airports as possible alternatives to the traveler. TSAM also includes access and egress times to and from these airports as part of its analysis. The variables used to compute automobile travel costs and times include hotel costs, fuel costs, and maximum number of hours of driving per day.

TSAM does confine its scope of analysis. TSAM currently considers only captive travelers, which are travelers that are limited to the modes of automobile and commercial aviation. TSAM also only considers passenger trips within the continental US; Alaska, Hawaii, international, and cargo trips have not been modeled yet. Finally, TSAM includes only those trips that are more than one hundred miles because the American Travel Survey (ATS) data that is used to calibrate TSAM only contains data for trips greater than one hundred miles. Air travel for distances less than one hundred miles is also unlikely in that costs would be higher, and the time spent for the entire air trip would generally be greater than those for automobile travel.

Section 3.1.2 Input Modifications for TSAM

The Strategy Simulator project focuses on altering tax structure and policies in order to observe the effects of such changes on NAS behavior. In order to reflect policy changes in TSAM, the fare tables must be modified to include any changes in the tax structure. Ticket and segment taxes in particular are modified within the TSAM input fare tables.

Four ticket taxes and four segments taxes are chosen for analysis. The ticket taxes considered are 0%, 3%, 7.5%, and 10%. The reason for these values is that the FAA would ideally like to decrease ticket taxes; therefore, 0% and 3% are tested. The ticket tax of 10% is selected to determine how demand would behave if ticket taxes increased above the current ticket tax of 7.5%. The segment taxes considered are $3.10/segment, $7.00/segment, $11.00/segment, and $15.00/segment. Because the FAA wishes to decrease ticket taxes, other taxes must be increased in order to gain back the revenue lost from the ticket tax decrease; therefore, segment taxes above the current amount of $3.10/segment are tested. This range of taxes should provide tax combinations that output a revenue neutral amount to an amount that is slightly higher than revenue neutral. A total of sixteen runs are performed in TSAM for every combination of ticket and segment tax. Therefore, a total of thirty-two fare tables are generated: sixteen possible combinations of ticket and segment tax and two possible trip types - business and non-business.

The fare tables supplied to TSAM are two 5 x 443 x 443 matrices that represent the two trip types, five income brackets, and 443 O-D airport pairs. The fare tables already contain ticket and segment taxes and these taxes must be removed before applying new tax scenarios.

The first step of the procedure is to apply a yearly fare scaling factor to the TSAM fare table.. According to the 2005 FAA forecasts, it is postulated that fares will decrease over the years; therefore, the fare scaling factor reduces the original fare table by a certain amount. Table 1 specifies the fare scaling factor applied for each year that is being analyzed (Office of Aviation Policy and Plans, 2005[1]). The fare scaling factor is applied to the base year, which is Year 2000.

Table 1. Fare Scaling Factor per Year

Fare Scaling Factors per Year	
2000	1.0000
2005	0.8300
2010	0.6751
2015	0.6150
2020	0.5798
2025	0.5445

The ticket and segment taxes are then removed from the TSAM fare tables, and new ticket and segment taxes are applied to the "base" fare table, or the table that contains fares to which no ticket or segment taxes are applied. Since the fare table was created based on fare data from Year 2000, the ticket and segment tax values included in the fare tables are 7.5% and $2.25/segment respectively. Segment tax is removed from the original fare table first, and the amount removed is determined by multiplying the base segment tax ($2.25/segment) with a 443 x 443 matrix containing the average number of segments for each O-D pair. The average segments table is a 443 x 443 matrix that is computed by first finding the average number of segments over all possible routes for an O-D pair (one-way) from TSAM's network table. The number of segments for round trips is then found by adding the average number of segments from origin to destination and the average number of segments from destination to origin (the average number of segments from origin to destination and from destination to origin can be different). The original ticket tax is then removed from the fare table.

The entire ticket and segment tax amounts are assumed to be billed directly to the air traveler, which means that the entire amount of the new ticket and segment taxes are added to the fare. The new ticket tax is applied before the segment tax; applying the ticket tax after the segment tax would be taxing a tax, which would add unreasonable charges to the fare. The segment tax is applied by multiplying the segment tax rate by the average segment tax table. The new fare tables for one year consist of two 5 x 433 x 443 matrices that include fares for two trip purposes, the five income groups, and 443 O-D airports.

One observation that should be made is that, even though ticket and segment taxes are removed from the fare before adding in new ticket and segment taxes, other taxes such as fuel tax and security taxes are not removed. These taxes are not removed because it requires an analysis of factors beyond the scope of TSAM and TASS, such as aircraft type and routes used. Therefore, the resulting fares may be greater than they would realistically be. Demand values that TSAM and TASS generate may be lower than actual demand because of these inflated fares, or revenue values may be higher than the actual revenue. Further investigation is necessary to determine whether these inflated fares have any significant effect on demand and revenue.

Six sets of fare tables are created for the six years of analysis. A total of 192 tables are therefore generated - one table is required for each of the sixteen tax scenarios, for each of the two trip types, and for each of the six years. These input tables are placed in the mode choice input folder of the TSAM program.

Section 3.1.3 Procedure for Running TSAM Demand Analysis

TSAM incorporates the four-step model in its analysis of demand behavior; however, only the mode choice module is used to generate results for the Strategy Simulator. Trip generation and trip distribution data have already been generated for the version of TSAM that is used for this analysis (version 3.42). No alterations to the TSAM code itself are made; only changes to mode choice model input data are made. TSAM is run for both business and non-business trip types and is run every five years from Year 2000 to Year 2025, which is a total of six years. A different fare table is used for each tax scenario, year, and trip type.

TSAM can be run as a stand-alone program and has its own Graphical User Interface. However, the user must change the fare tables within the mode choice input folder in order to reflect changes in tax scenarios and fare scaling. The user then runs TSAM from its Graphical User Interface. Please see Appendix F for a complete, step-by-step procedure on how to run TSAM. Figure 5 provides the basic schematic of how TSAM results are generated.

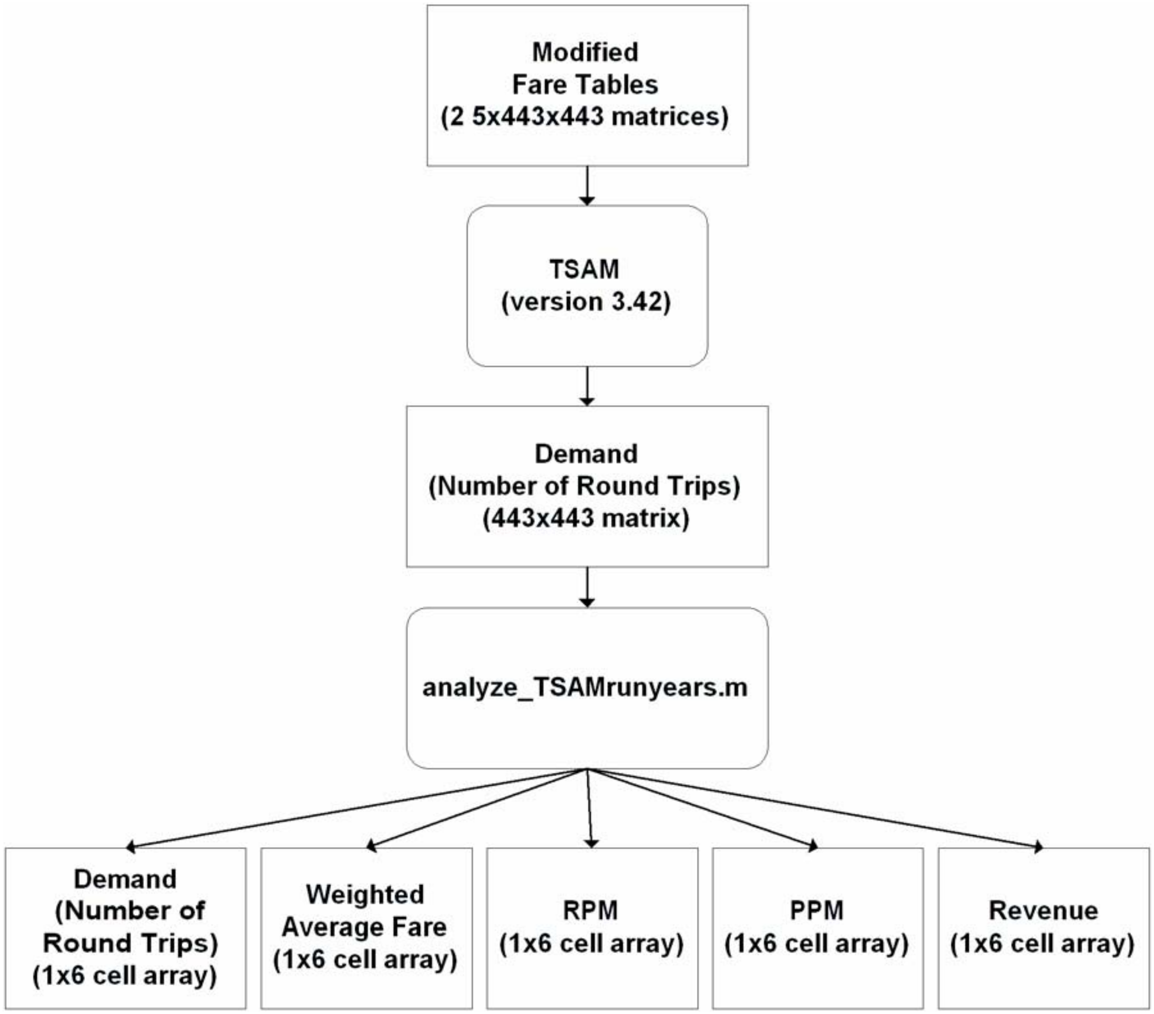

Figure 5. Flowchart of TSAM Run Process.

Section 3.1.4 TSAM Output for the Strategy Simulator

TSAM generates trip demand tables that display the number of round trips made for each O-D pair and for each income bracket. The units of the demand table are number of round trips. Because the Strategy Simulator does not require such a high level of detail, the TSAM demand tables are manipulated to achieve the values required for the Strategy Simulator.

The Strategy Simulator in particular requires revenue passenger miles (RPMs) and Price per Passenger Mile (PPM) to be supplied to the program. RPM is defined as the total number of miles each passenger travels. RPM is calculated by taking the number of trips generated by TSAM and multiplying this table by the average route distance by air from origin to destination. The average route distance (one-way) for each O-D pair is calculated by first taking the existing network table in TSAM and then averaging the distance between all the possible routes from the origin airport to the destination airport. To get the round trip average route distance, the distance from origin airport to destination airport is added to the distance from the destination airport to the origin airport (it is possible that the route traveled from destination to origin is different from the route traveled from origin to destination). PPM is the cost of the fare to the passenger per mile and includes all taxes and fees. PPM is found by taking the respective fare table for each tax scenario, trip type, and year, and dividing the table by the average route distance table.

In addition to calculating RPMs and PPMs, weighted average fares and revenue are calculated for each tax scenario and year. The weighted average fare (WAF) is calculated using Equation 1:

$$\text{WAF} = (\Sigma \text{ business fare} * \text{business demand} + \Sigma \text{ non-business fare} * \text{non-business demand}) / (\text{business demand} + \text{non-business demand}) \qquad \text{(Eq. 1)}$$

Revenue is calculated by adding the total segment and ticket tax revenues together. The segment tax revenue can be found by multiplying the segment tax with the average segments table. The ticket tax revenue is found by taking the percentage equal to the ticket tax out of a fare table after segment taxes have been taken out.

Section 3.2 Methodology for Creating TASS

Section 3.2.1 Overview and Scope of TASS

TASS is an aggregated version of TSAM's mode choice model that outputs demand as number of trips for each O-D pair. The purpose of TASS is to provide a tool that can generate results much more quickly than TSAM yet maintain a sufficient level of detail; specifically, TASS should retain spatial representation and mode choice in order to achieve more accurate results. TASS accomplishes this goal by reading in a smaller matrix of O-D pairs than TSAM. TASS currently considers county clusters grouped around an airport that has commercial services. TASS is a work in progress, and calibration and validation have not been completed on this model.

TASS still maintains some of the same characteristics as TSAM. TASS also uses a nested logit model based on ATS data to find the probabilities of taking a certain mode of transportation, and the nested logit model uses travel time and cost as its basis for decision. TASS also includes three candidate origin and destination airports in its analysis. TASS considers only captive travelers. TASS only considers the continental US, which means Alaska, Hawaii, and international travel are not included in TASS's analysis. TASS also does not include cargo demand. Finally, like TSAM, TASS only include trips of more than one hundred miles route distance.

TASS's scope is further limited than TSAM because of the need to reduce computation time. Because the main purpose of TASS is to provide a spatial representation of demand while achieving fast computation times, TASS's level of detail is limited compared to TSAM's level of detail. TASS considers 443 airport-centric county clusters instead of 3,091 individual counties. TASS does not specifically consider trip type; instead, some input variables are weighted based on trip type (see Section 3.2.2 for affected input variables). TASS does not differentiate between income groups. Finally, TASS considers only automobile and commercial aviation as the only viable mode choices; it does not have the capability of including SATS as a mode of transportation.

Section 3.2.2 TASS Inputs

TASS includes most variables from TSAM. This section outlines the scope of inputs considered in TASS; for a full list of input variables, please see Appendix H.

In general, TASS does not consider income brackets, trip type, and SATS-related variables. However, trip type is considered when calculating commercial aviation fare tables, maximum daily drive times, and average cost for hotel stays and for the automobile mode. TASS weights these variables according to the percentage of business to non-business travelers as reported in ATS, which are 43% and 57% respectively (Bureau of Transportation Statistics, 1997).

Inputs that TASS considers that are also included in TSAM are variables such as maximum daily drive time, hotel lodging costs, waiting times at the origin airport according to airport hub type (2 hours, 1.5 hours, 1.25 hours, and 1 hour), waiting times at the destination airport according to airport hub type (1 hour, 0.75 hours, 0.5 hours, and 0.5 hours), and average automobile occupancy. Finally, TASS also considers reductions in airline fares for each year.

Some input variables must be modified from the original TSAM structure in order to fit into TASS. TASS requires a trip distribution table as an input for each year that is to be analyzed. The trip distribution table must be aggregated from a 3,091 x 3,091 trip distribution table into a 443 x 443 matrix; a separate Matlab program written for the purpose of aggregating data tables is used to aggregate the trip distribution table and all other tables that require aggregation. TASS determines auto travel times and costs based on driving distances and times from the origin airport to the destination airport. These driving times and costs differ from TSAM since TSAM considers driving times and costs from origin *county* to destination *county*. This logic should be investigated further to determine whether this simplification significantly affects the resulting demand. Finally, TASS also considers three origin airports and three destination airport as possible airport options. The candidate airport list is aggregated from 3,091 counties assigned to three airports per county into 443 airport-centric clusters assigned to three airports per cluster.

In addition to the variables retained from TSAM, TASS requires additional variables to be defined. TASS requires a list of counties clustered to each airport. TASS also incorporates ticket and segment taxes. The base ticket tax, base segment tax, new ticket tax, and new segment tax are variables that can be changed in TASS. Unlike TSAM, TASS does not require the user to modify the fare table; TASS only requires the user to specify the new ticket tax, new segment tax, and the fare scaling factor for each analysis year. The base ticket tax is set at 7.5%, and the base segment tax is set at $2.25/segment. A table that contains the number of average segments for each O-D pair is also required input for TASS in order to calculate the segment tax included in the fare.

Section 3.2.3 TASS Clustering Method

One of the goals that TASS achieves is to produce results more quickly than TSAM. TASS achieves this goal by reducing the level of detail that TSAM has; in this case, TASS considers 443 county clusters rather than the 3,091 individual counties that

TSAM considers. An algorithm was created in order to perform this aggregation and is contained in the Matlab function called "SSdatamanipulation.m". The algorithm first collects all airports within two hundred miles Great Circle Distance (GCD) of each county in the 3,091 county list. The value of two hundred miles is chosen because this value is approximately the minimum value at which all counties can be assigned at least one airport. The algorithm then chooses the closest airport to the county out of the list of airports within the two hundred mile radius of the county.

One assumption is that all travelers within a county cluster will choose automobile as their mode of transportation. The county clusters are formed with the criterion that all county centroids are at most two hundred miles away from the airport that the counties are clustered around. This assumption leads to the conclusion that the distance between county centroids can be around four hundred miles. Although commercial aviation trips are possible for trips of this distance, it is still assumed that travelers within a county cluster will drive. The reason for this assumption is as follows: a.) the value of two hundred miles was chosen so that all counties would be included in a cluster, and b.) performing a mode choice analysis within county clusters will be too time consuming, and fast computation time is a high priority.

Section 3.2.4 TASS Calibration Method

TASS is calibrated based on similar methods to TSAM. A separate calibration program is called, and the resulting output from this calibration program are the travel time and travel cost coefficients needed in the nested logit function of TSAM or TASS. The main difference between the TSAM calibration method and the TASS calibration method is that the TASS calibration method considers aggregated data rather than distinguishing between trip types and income groups.

The goal of the calibration process is to find a utility function that is a function of travel time and cost that properly fits ATS data. The calibration program uses sample data generated from TASS, fits this data to ATS data, and derives coefficients for travel time and travel cost based on the fit to ATS data. The sample data generated from TASS is a collection of travel times and costs that are found by taking all the possible candidate airports for an O-D pair, calculating the travel times and costs for each of the possible candidate origin and destination pairs, and saving the fastest route and the cheapest route. This data is then input into the calibration program as sample data that represents the range of travel times and costs that are possible in TASS.

The calibration program calls the statistical analysis software SAS, which runs the sample data through its nested logit model procedure in order to acquire the travel time and cost coefficients. The coefficients are saved in a data file and are called in TASS. The coefficient for travel time is -0.1619, and the coefficient for travel cost is -0.0382. The negative sign in front of both coefficients indicate that the probability of choosing air travel decreases as travel time and cost increase. Travel time has a greater influence on travel decisions than travel cost since the magnitude of the travel time coefficient is greater than the coefficient for travel cost. These coefficients must be further calibrated and verified.

Section 3.2.5 TASS Procedures

The TASS program is written in Matlab and contains logic that is almost identical to TSAM. The main difference between the TASS code and TSAM is the aggregation factor. The TASS code also includes a segment of code that subtracts the base taxes from the fare and inserts the new taxes.

TASS does not have a Graphical User Interface. All inputs can be changed in the main function of TASS. Please see Appendix H for a list of TASS inputs. TASS is run from the Matlab command window by typing in "TASS_modechoice" into the command line. Figure 6 provides a schematic of how TASS results are generated.

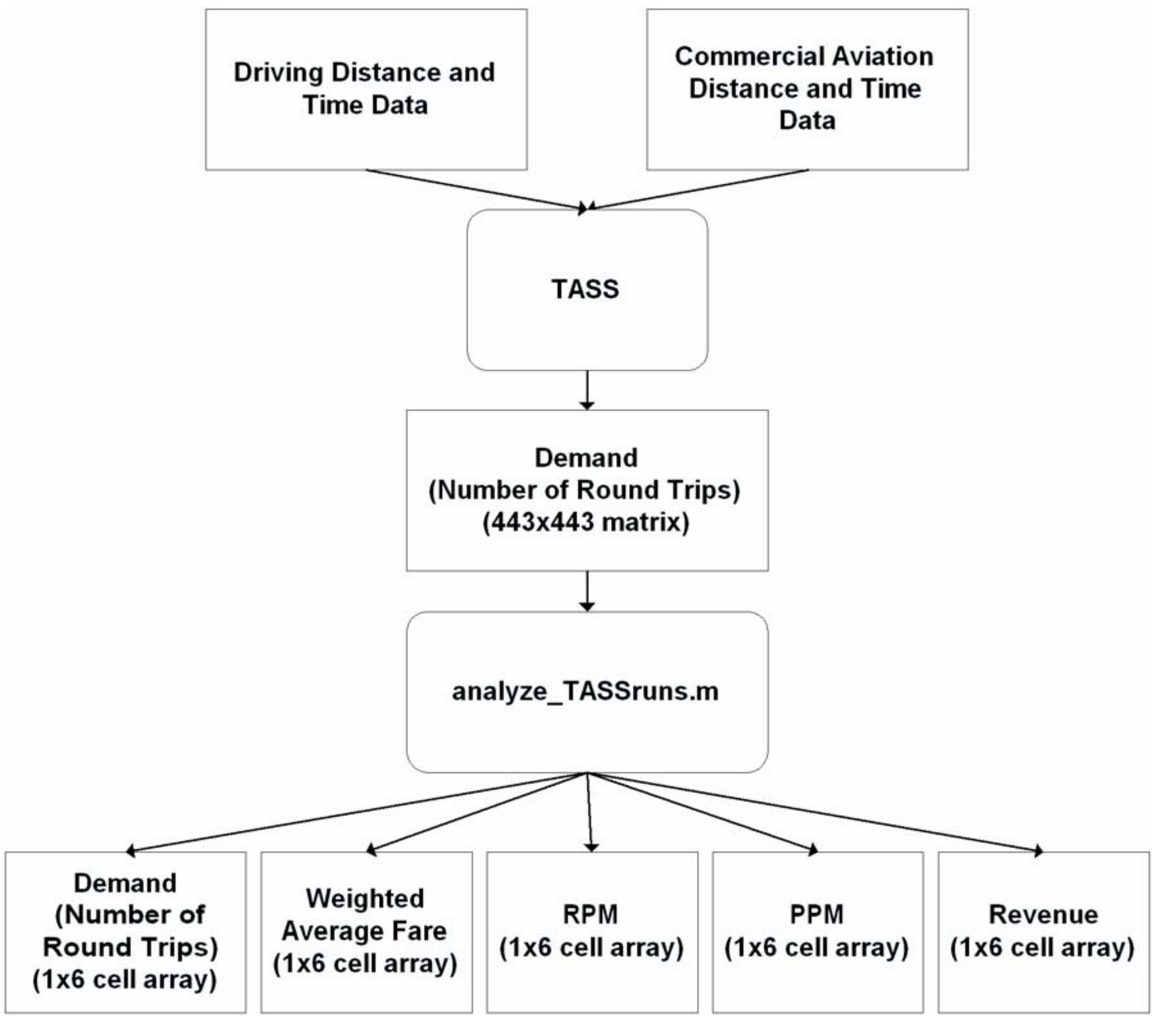

Figure 6. Flowchart of TASS Run Process.

Section 3.2.6 TASS Output for the Strategy Simulator

TASS output must be manipulated in the same way as TSAM output in order for the data to be useful to the Strategy Simulator program. TASS generates demand in number of round trips. Using the demand output and fare tables from TASS, weighted average fare, RPM, PPM, and revenue can be generated using the same methods described in Section 3.1.4.

Chapter 4 Results and Verification

The results of the TSAM and TASS runs show that passenger demand decreases as taxes increase, but demand increases over the years. Revenue Passenger Miles (RPMs) likewise decrease as taxes increase and increase over the years. Revenue increases both as taxes increase and years increase. Weighted average fares increase as taxes increase, and fares decrease over the years.

TSAM and TASS results are compared with sources reviewed in Chapter 2 to verify the reasonableness of their output. TSAM generates results that have the least margin of error overall; the Strategy Simulator has the smallest percent error for RPM results, whereas TSAM has the smallest percent error for revenue results. TASS results typically have higher values than TSAM and generate results with margins of error between TSAM and the Strategy Simulator.

Because Virginia Tech is focusing on providing demand and revenue analysis for the Strategy Simulator project, the focus of this section is on displaying and verifying the effects tax changes have on demand and revenue for TSAM and TASS. Virginia Tech ultimately will deliver a PPM versus RPM table to Ventana. The PPM versus RPM table is included in Appendix E. Graphs of demand, weighted average fare, RPM, and revenue are provided for each tax scenario and each year in Appendix C. This section provides several representative graphs to portray the general trends found over tax scenarios and years.

Section 4.1 Demand Trends over Tax Scenarios

Figure 7 describes how demand behaves when ticket and segment taxes change while the year remains constant. The year that is analyzed for these graphs is Year 2000 since data from the literature is available to verify the values that TSAM and TASS generate.

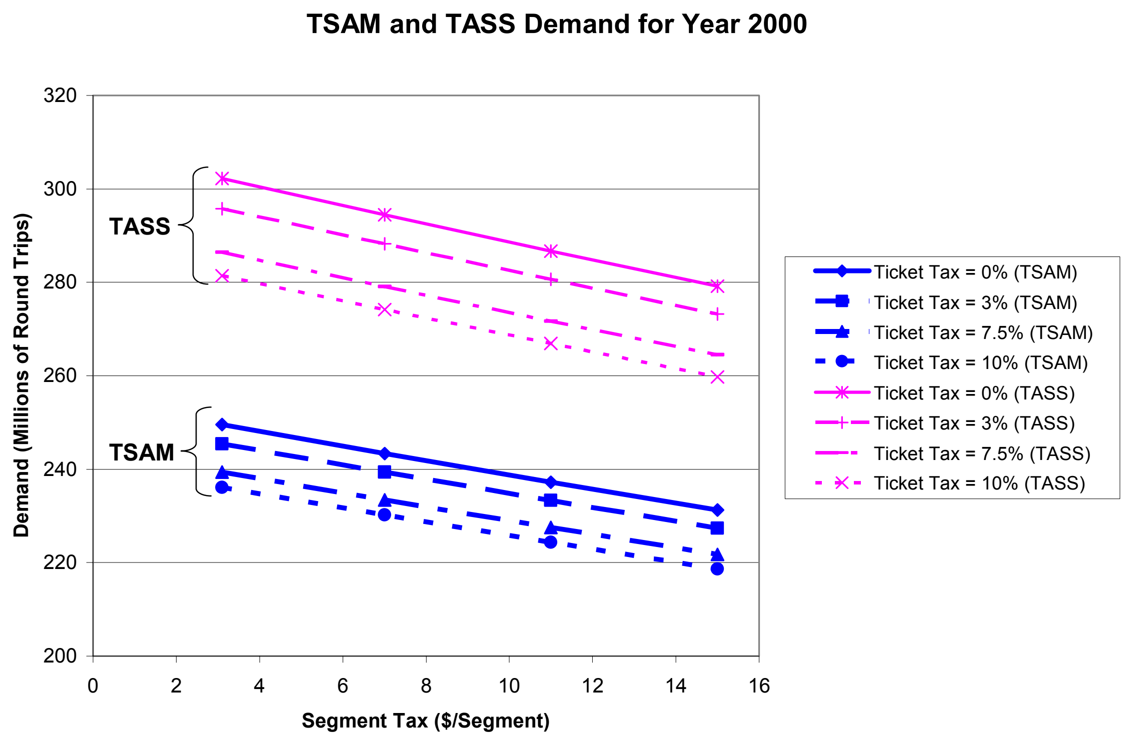

Figure 7. TSAM and TASS Demand for Year 2000.

The demand graphs for both TSAM and TASS show that demand decreases with increasing ticket and segment tax. This trend is logical since increasing taxes means increasing fares, which would induce individuals to choose a less expensive mode of transportation.

TASS tends to generate higher demand values than TSAM. One explanation for this behavior is that the weighted average fares from TASS are lower than the weighted average fares for TSAM, indicating that TASS fares for each O-D pair is generally lower than TSAM fares. Because fares are generally lower for the TASS model, more travelers would tend to choose commercial aviation over automobile. See Appendix C for the values and trends for weighted average fare. Several reasons exist that can explain why TASS fares are lower than TSAM fares. First, TASS does not distinguish between business and non-business trips; therefore, the fare table TASS uses is a weighted average of TSAM's fare table and would therefore provide fares that are lower than those fares found in the business fare table in TSAM. TASS also does not make any distinction between income brackets and is calibrated differently from TSAM. All of these factors can cause TASS to generate higher demand than TSAM. Further investigations should be made as to what aspect of TASS's aggregation causes TASS to generate higher demand than TSAM.

Figure 8 and Figure 9 show demand trends for TSAM and TASS over the six analysis years. These figures also show how sensitive TSAM and TASS are to the fare scaling factor that is applied to each year by applying different fare factors to Year 2025. The fare scale factor was tested for sensitivity because it applies a factor to each entry in the fare table, and the fare table is a critical input that determines the choice of the traveler. A fare scale factor of 70% and 85% are applied to Year 2025.

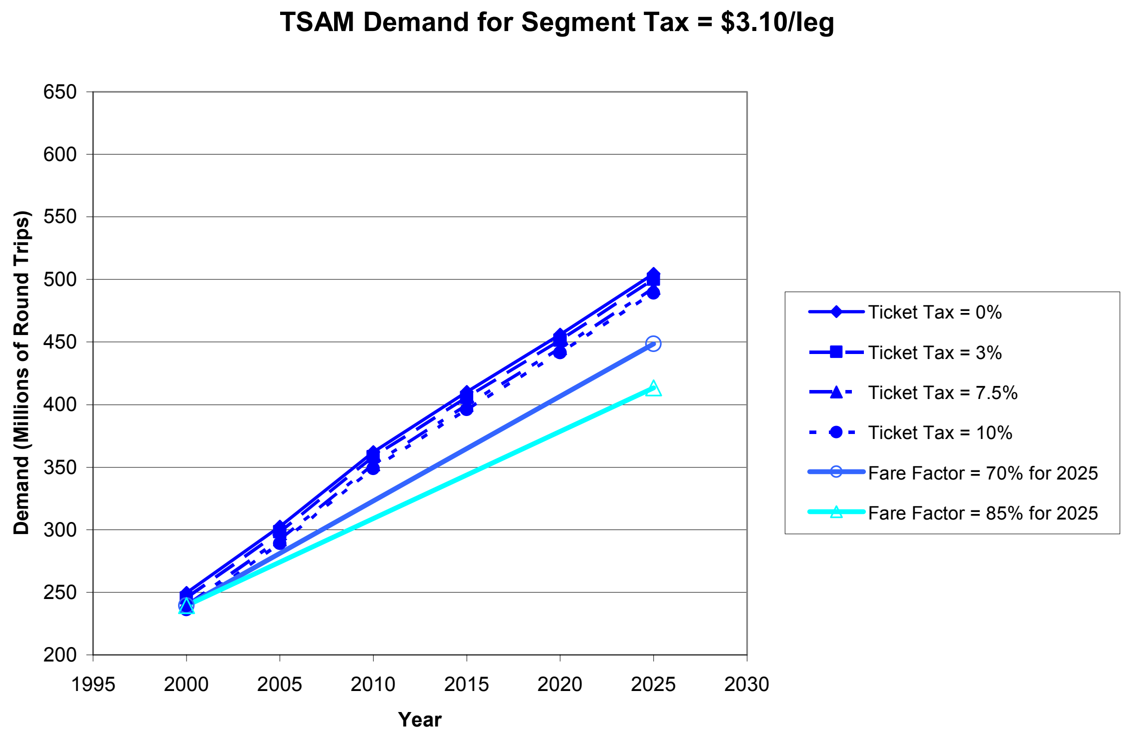

Figure 8. TSAM Demand for Segment Tax = $3.10/segment.

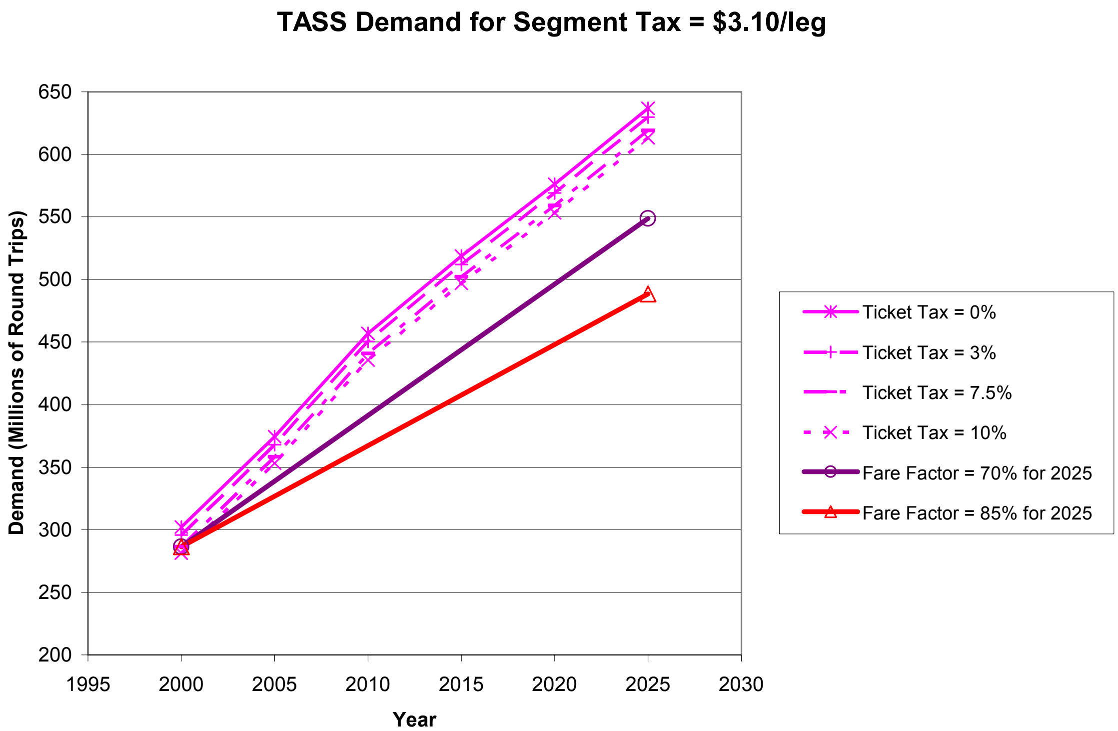

Figure 9. TASS Demand for Segment Tax = $3.10/segment.

Demand for both TSAM and TASS increase over the years; this trend is logical since fare prices are reduced over the years due to the fare scaling factor applied to each year. See Appendix C for weighted average fare values over the years. Demand decreases as the fare scaling factor increases when comparing the new fare factors to the original fare factor for Year 2025, which was 54%. TSAM demand decreases by 9.02% from the original demand value for a scale factor of 70%, and demand decreases by 16.14% for a scale factor of 85%. TASS demand decreases 11.34% for a scale factor or 70%, and demand decreases by 21.05% for a scale factor of 85%. A larger scaling factor should result in lower demand because fares are not reduced as much from the original fare.

These results indicate that TASS is more sensitive to changes in the fare scaling factor than TSAM. TASS can be more sensitive than TSAM because of its aggregation and how it is calibrated. TSAM is calibrated with the consideration that different income groups would be more or less sensitive to particular fares. TASS does not include such detailed consideration and uses a set of utility coefficients that assumes only one traveler type. TASS's coefficients may also be too sensitive to changes in fares, which is why further calibration is necessary.

A look at the elasticities of demand for both TSAM and TASS can reveal how sensitive TSAM and TASS are to fare changes. Table 2 and

Table 3 provide representative demand elasticities for TSAM and TASS for the Year 2000. Demand elasticity is calculated using Equation 2:

demand elasticity = % change in quantity demanded / % change in price (Eq. 2)

In Equation 2, the percent change in price is calculated using weighted average fares for each tax and year scenario.

Table 2. TSAM Demand Elasticities for Year 2000.

TSAM Demand Elasticities								
Elasticities Across Segment Taxes				Elasticities Across Ticket Taxes				
Year 2000				*Year 2000*				
	Segment Tax				Segment Tax			
Ticket Tax	\$3.10 -> \$7	\$7 -> \$11	\$11 -> \$15	Ticket Tax	\$3.10/leg	\$7/leg	\$11/leg	\$15/leg
0%	-0.579	-0.606	-0.635	0% -> 3%	-0.564	-0.586	-0.607	-0.629
3%	-0.594	-0.622	-0.650	3% -> 7.5%	-0.574	-0.596	-0.618	-0.639
7.50%	-0.617	-0.645	-0.673	7.5% -> 10%	-0.599	-0.621	-0.643	-0.663
10%	-0.630	-0.658	-0.685					

Table 3. TASS Demand Elasticities for Year 2000.

TASS Demand Elasticities								
Elasticities Across Segment Taxes				Elasticities Across Ticket Taxes				
Year 2000				*Year 2000*				
	Segment Tax				Segment Tax			
Ticket Tax	\$3.10 -> \$7	\$7 -> \$11	\$11 -> \$15	Ticket Tax	\$3.10/leg	\$7/leg	\$11/leg	\$15/leg
0%	-0.596	-0.620	-0.644	0% -> 3%	-0.772	-0.802	-0.831	-0.861
3%	-0.611	-0.634	-0.658	3% -> 7.5%	-0.786	-0.815	-0.844	-0.873
7.50%	-0.633	-0.656	-0.680	7.5% -> 10%	-0.821	-0.849	-0.878	-0.907
10%	-0.645	-0.668	-0.692					

Both TSAM and TASS results produce demand elasticities that are negative and fairly inelastic. Negative elasticities are logical because a rise in fare typically results in a decrease in demand. It is reasonable that the elasticity values for TSAM and TASS are fairly inelastic; this behavior indicates that, although changes in fares still have an affect on the demand for air travel, commercial aviation still retains enough attractiveness that price does not drastically affect demand. Reasons why travelers are attracted to commercial air include savings on time and cost for long distance trips (i.e., traveling in a car over a long distance can incur hotel and gas costs).

TASS tends to have greater negative elasticities than TSAM, which indicates that TASS's demand is more sensitive to fare changes than TSAM. The difference in elasticities between changes in segment taxes for TSAM and TASS are not very different, and this trend can be seen in Figure 7 - the slopes of TSAM and TASS are very similar. However, the difference between changes in ticket taxes for TSAM and TASS are noticeably different - the separation between lines for TASS are much wider than the separation between lines for TSAM.

This behavior indicates that TASS is more sensitive to changes in ticket tax than TSAM. This behavior can again be attributed to the aggregation factor - TASS uses only one fare table, whereas TSAM has a fare table for each income group and trip type. Applying a ticket tax to a fare table that is tailored for lower income travelers would mean adding a lower tax on top of the ticket price (i.e., $100 fare * 7.5% ticket tax = $7.50 additional tax on ticket). Applying a ticket tax to a fare table that is tailored for higher income travelers would result in a higher tax on top of the ticket price (i.e., $1000 fare * 7.5% ticket tax = $75). However, since the higher income groups are typically able to pay such fares, they still tend to choose commercial air as a mode of transportation. TSAM's mode choice reflects these differences between income groups and trip types; TASS, however, does not make such fine distinctions, and this lack of detail may be reflected in the above results.

One observation to note is that trends in RPMs for both TSAM and TASS are the same as their respective demand trends. RPMs reflect the total number of miles flown for a single year. These results are unsurprising since the route distance for each O-D pair remains the same regardless of the ticket tax, segment tax, or year; only the number of trips demanded between each O-D pair changes. Because the trends for RPM are identical to behavior, the results are included in Appendix C and not displayed in this section. However, this observation is worth mentioning because most literature report historical and forecasted demand in terms of RPMs; therefore, RPM values from TSAM and TASS will be displayed in Section 4.3, which is the verification section.

Section 4.2 Revenue

Revenue is of primary interest in the Strategy Simulator project and is calculated based on demand results from TSAM and TASS. The revenues displayed in Figure 10 and Figure 11 are the total of the ticket and segment tax revenues. Year 2005 is displayed because this is the year on which the FAA wishes to start testing different tax scenarios.

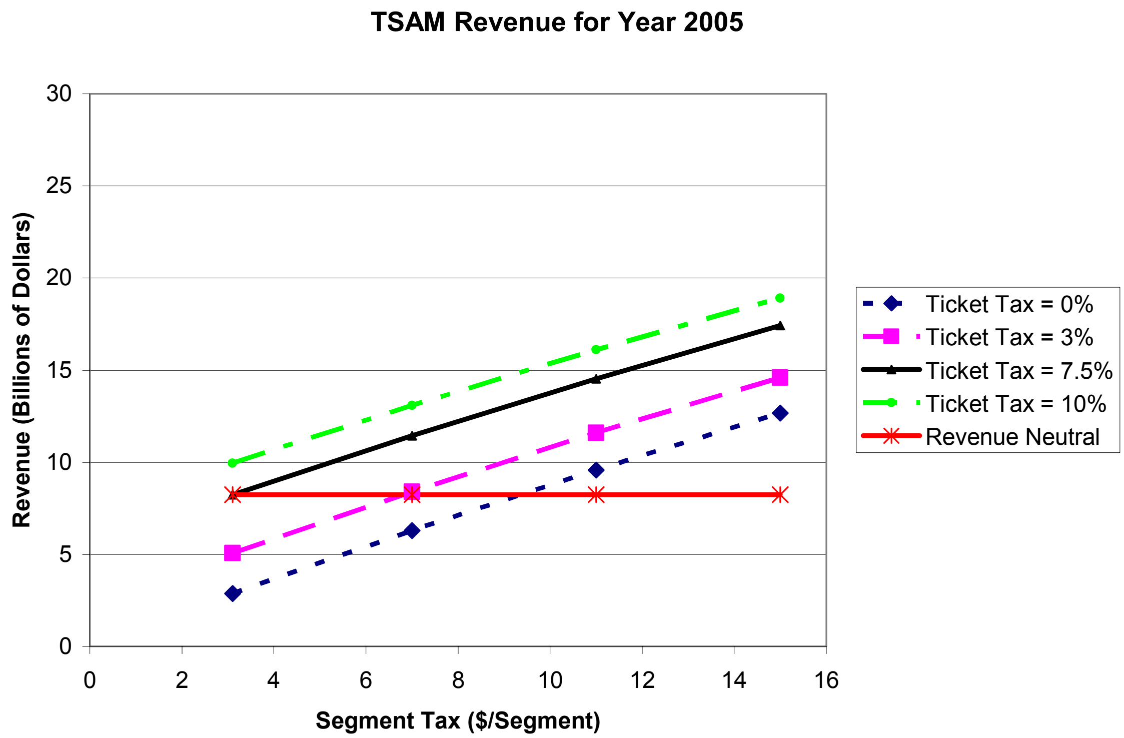

Figure 10. TSAM Revenue for Year 2005.

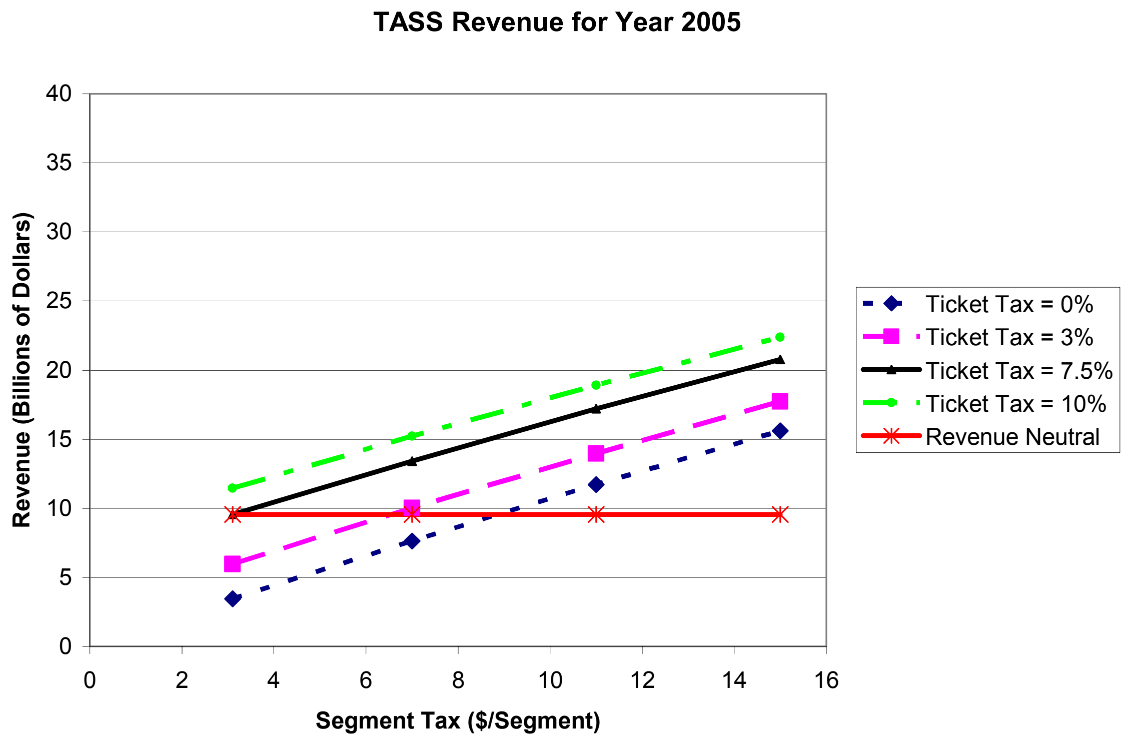

Figure 11. TASS Revenue for Year 2005.

Revenue increases as ticket and segment taxes increase, and revenue increases over the years (revenue graphs for each year are shown in Appendix C). This trend indicates that, despite the fact that demand decreases with increasing taxes, tax rates are high enough that they can more than make up for the loss of demand. It is logical that revenue increases over the years - fares decrease over the years, which leads to an increase in demand that is significant enough that demand more than makes up for the revenue that is lost due to decreased fares.

The revenues obtained from TASS are greater than the revenues obtained from TSAM. This behavior is unsurprising since the demand for TASS is greater than the demand for TSAM; therefore, the revenue collected would be greater.

The revenue graph for Year 2005 shows the revenue neutral boundary. The revenue neutral amount (ticket tax of 7.5% and segment tax of $3.10/segment) for TSAM occurs at $8.25 billion and at $9.55 billion for TASS. Where the revenue neutral line crosses other tax lines is where those ticket and segment tax combinations would generate a revenue value that achieves the revenue neutral amount. For TSAM, the revenue neutral ticket tax combinations are a ticket tax of 0% and a segment tax of $9.50/segment or a ticket tax of 3% and a segment tax of $7.00/segment. A ticket tax of 10% appears to always achieve a higher revenue amount than revenue neutrality given the segment taxes tested. TASS indicates that revenue neutral tax combinations are at a ticket tax of 0% and segment tax of $9.00/segment or a ticket tax of 3% and segment tax of about $6.50/segment. The ticket tax of 10% again does not cross the revenue neutral line, which indicates that a ticket tax of 10% always achieves a higher revenue amount than revenue neutrality.

Section 4.3 Verification

Data collected from the literature review in Chapter 2 will help in verifying the results generated from TSAM and TASS. All literature is compared to the revenue for ticket tax of 7.5% and segment tax of $3.10/segment for TSAM and TASS since these taxes are the current ticket and segment taxes, all other tax combinations being theoretical scenarios.

Providing a direct comparison of historical data from literature in Chapter 2 reveals how accurate TSAM, TASS, and the Strategy Simulator predictions are with historical data. Only Year 2000 can be compared because the version of TSAM and

TASS that are used can only generate demand data for the year starting Year 2000 in increments of five years; historical data does not currently exist for Year 2005 and on.

Table 4. Comparison of TSAM, TASS, and SS to Historical Data.

	RPM	Revenue
TSAM (2000)	455.9 billion	$7.70 billion
TASS (2000)	487.3 billion	$8.67 billion
SS (2000)	525.0 billion	$9.44 billion
2005 FAA Aerospace Forecast	512.8 billion	--
FAA AATF	--	$6.76 billion

Table 5 shows the percent error that exists between TSAM, TASS, and SS with historical data.

Table 5. Percent Error of TSAM, TASS, and SS to Historical Data.

	RPM	Revenue	|RPM|+|Revenue|
TSAM (2000)	-11.10%	13.91%	25.01
TASS (2000)	-4.97%	28.25%	33.22
SS (2000)	2.38%	39.64%	42.02
FAA Aerospace Forecast 2005	--	--	--
FAA AATF	--	--	--

The Strategy Simulator program provides the most accurate calculation for RPM based on the FAA forecasts, followed by TASS, then TSAM. The Strategy Simulator over-predicts demand, while TSAM and TASS under-predict the FAA forecast. TSAM has the greatest margin of error of -11.10%. However, TSAM is the most accurate in predicting ticket and segment tax revenue based on FAA AATF data, followed by TASS and then the Strategy Simulator. The Strategy Simulator has the greatest margin of error for predicting revenue, over-predicting the actual revenue by 39.64%. Based on the total percent error from historical data, TSAM provides the most accurate results, followed by TASS, then the Strategy Simulator.

It is not surprising that TSAM and TASS are under-predicting RPMs and over-predicting revenue. The FAA forecast for RPM includes Alaska and Hawaii, and TSAM and TASS do not, which means that TSAM and TASS would predict lower RPMs than the FAA forecast. TSAM and TASS can generate higher revenues than the FAA predictions. As mentioned earlier, other taxes such as fuel and security taxes are not removed from TSAM and TASS fare tables. Therefore, new fares are calculated with those taxes included in the base fare, resulting in fares that are higher than what the fare should be. Revenue extracted from these fares would also be higher, which would lead to higher revenue predictions. It is possible that the over-inflated fares could cause a reduction in demand, therefore reducing the total revenue collected. This subject should be further investigated to see whether the inflated fares cause an increase or decrease in revenues.

Other literature from Chapter 2 either provide historical data that do not coincide with the analysis years of TSAM and TASS, or the literature provides forecasts, which do not provide solid grounds for comparison. Therefore, only several pieces of literature are briefly compared with TSAM and TASS as part of the verification of TSAM and TASS. For more details on the literature, please see Chapter 2.

The TAF and the ATS provide minimum and maximum bounds for number of round trips and RPMs; both TSAM and TASS results are well within the boundaries of TAF and the ATS. Both TSAM and TASS Year 2005 results exceed the $6.0 billion mark in the revenues the Subcommittee on Aviation reports for Year 2003, which is reasonable since demand has increased for Year 2005, and therefore revenues should have increased as well.

TSAM revenue amounts are lower than the revenues the U.S. General Accounting Office reports, which is correct since TSAM considers only ticket and segment tax and the Accounting Office reports a total revenue amount. TASS generates revenue amounts that are higher than the U.S. Accounting Office's numbers, which indicates that TASS may be over-predicting demand and therefore generating higher revenues than it is supposed to. However, one thing to note is that the U.S. Accounting Office is reporting the revenue for Year 2002, which is the year right after the 9/11 terrorist attacks. Therefore, revenues may be lower than they would typically be because of decreased demand for the years following 9/11. TSAM and TASS are modeled based on Woods and Poole data and do not consider historical events such as 9/11.

Data from other literature sources suggests that unpredictable events have affected the general trend of revenue growth. The 1999 revenue figures from the United States Department of Treasury reveal that total revenues being collected was greater than the revenue collected in Year 2003, which may indicate that events such as the 9/11 terrorist attacks have disrupted the typical increase of revenues over the years. The National Civil Aviation Review Commission (NCARC) reports that revenues dropped for Years 1996 and 1997 because aviation taxes had expired and had not been immediately restored. Therefore, TSAM and TASS results may not be unreasonable, but further investigation is required.

The Strategy Simulator provides RPM and revenue values for Year 1970 through 2025. The Strategy Simulator obtains RPM values that are higher than TSAM and TASS and are also higher than the FAA aerospace forecast predictions. The ticket and segment tax revenues that the Strategy Simulator generates are lower than the ones generated by TSAM and TASS. The Strategy Simulator does model events such as 9/11, which explains the dip in revenue between Year 2000 and the following years and would explain why Strategy Simulator revenues are lower than TSAM and TASS. Further investigations should be made to determine whether modeling unpredictable events is necessary and how to model these events.

Chapter 5 Conclusion

Section 5.1 Summary of Objectives

The Strategy Simulator project strives to provide a tool for the FAA to test tax combinations that would support the NAS and achieve revenue neutrality. Virginia Tech has devised two ways of answering the FAA question of how tax policies affect demand: using TSAM to generate demand based on different tax scenarios and creating an aggregated version of TSAM known as TASS. TASS is still a work in progress and all results must still be validated for this model.

Virginia Tech captures demand behavior in response to different tax scenarios using these two models. Virginia Tech provides input into the Strategy Simulator program using results from the TSAM model and verifies the results that the Strategy Simulator program is generating using TSAM and TASS results.

Section 5.2 Summary of Results

The work presented in this thesis achieves logical results based on reviews of current literature. TSAM and TASS results both indicate that demand and RPMs decrease as taxes increase, and increase over the years. The decline in demand as taxes increase does not affect revenue, however, and increases in taxes actually increase revenue. The revenue neutral amount for Year 2005 for TSAM is $8.25 billion. The tax combinations at which revenue neutrality is achieved for Year 2005 in TSAM are a ticket tax of 0% and a segment tax of $9.50/segment or a ticket tax of 3% and a segment tax of $7.00/segment. The revenue neutral amount for TASS is $9.55 billion. The tax combinations at which revenue neutrality is achieved in TASS are a ticket tax of 0% and segment tax of $9.00/segment or a ticket tax of 3% and segment tax of about $6.50/segment.

Sensitivity tests are performed on TSAM and TASS by changing the fare scaling factors. Scaling factors of 70% and 85% are applied to Year 2025 to determine the difference in demand between the original fare scaling factor (54%) and the new scaling factors. TSAM and TASS demand varies from 9% to 21% for different fare scaling factors, which indicates TSAM's and TASS's sensitivity to this input. The effects the fare scaling factor has on TSAM and TASS demonstrate the importance of entering accurate fare scaling factors into these models.

TSAM, TASS, and Strategy Simulator results are compared to historical data collected by the FAA, and percent errors are calculated from these results. TSAM provides the smallest combined percent error when compared to the FAA data. The Strategy Simulator has the lowest percent error for demand prediction, and TSAM has the lowest percent error for revenue prediction. TASS produces results that results in error margins that are between TSAM and TASS for both demand and revenue. Further verification is required since only one data point, Year 2000, is common to all literature and models.

Section 5.3 Recommendations and Future Research

TSAM and TASS provide means of exploring demand behavior that is detailed and that provides a level of accuracy that is comparable to the Strategy Simulator. Further research is recommended to continue improving these two models. TSAM is an on-going project and is still being modified at the present time. TASS has not been fully calibrated and validated yet, and its aggregation scheme should be analyzed further to determine how significant is the effect that aggregation has on the output. Other improvements that can be made to both models include adding capacity constraints to the demand model and including other NEXTOR schools' work in these two models.

Future work can include integrating these models, especially TASS, into the Strategy Simulator to provide a more comprehensive analysis of demand.

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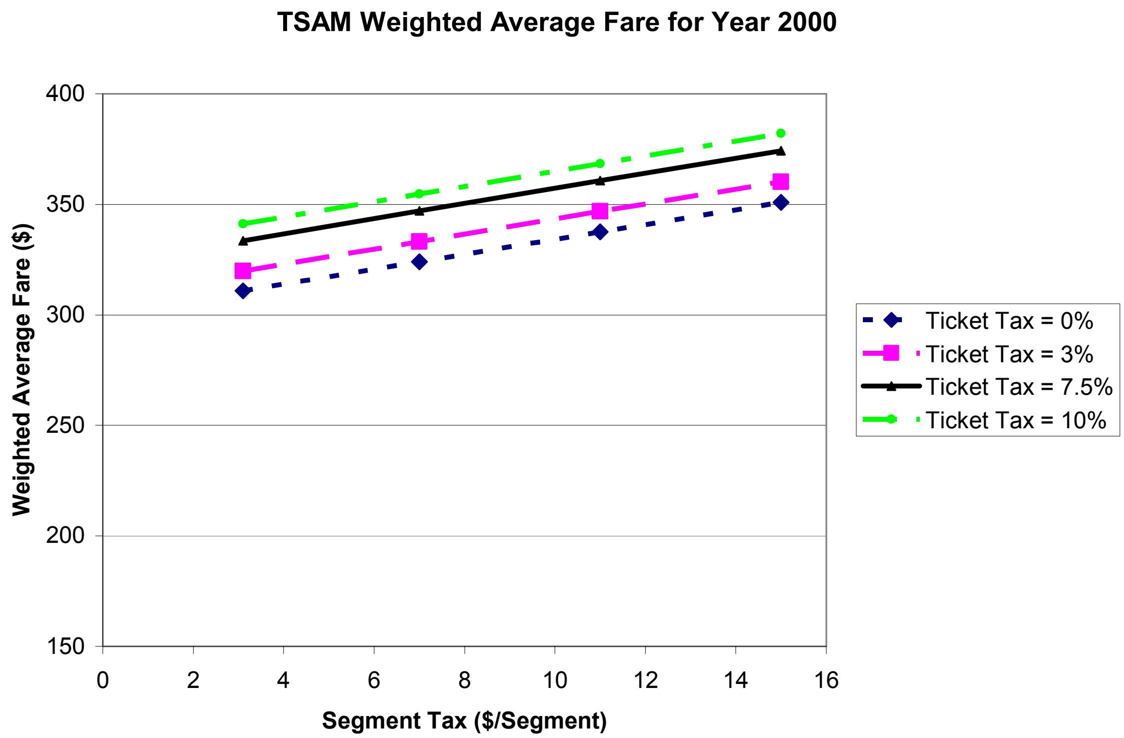
Appendix B Acronyms

ACIM	Air Carrier Investment Model
AIP	Airport Improvement Plan
AATF	Airport and Airway Trust Fund
APO	Aviation Policy and Plans Office
ATS	American Travel Survey
ATSL	Air Transportation Systems Laboratory
CLARA	Clustering Large Applications
CLARAN	Clustering Large Applications based on Randomized Search
DOT	Department of Transportation
F and E	Facilities and Equipment
FAA	Federal Aviation Administration
FCM	Functional Cost Module
MAUP	Modifiable Areal Unit Problem
MSL	Multi-Scale Logit model
O-D	Origin-Destination
NAS	National Airspace System
NEXTOR	National Center of Excellence for Aviation Operations Research
NCARC	National Civil Aviation Review Commission
PPM	Price per Passenger Mile
RPM	Revenue Passenger Mile
SS	Strategy Simulator

TAAM	Total Airspace and Airport Modeler
TAF	Terminal Area Forecast
TASS	TSAM Aggregation for the Strategy Simulator
TSAM	Transportation Systems Analysis Model
WAF	Weighted Average Fare

Appendix C TSAM and TASS Results

Weighted Average Fare



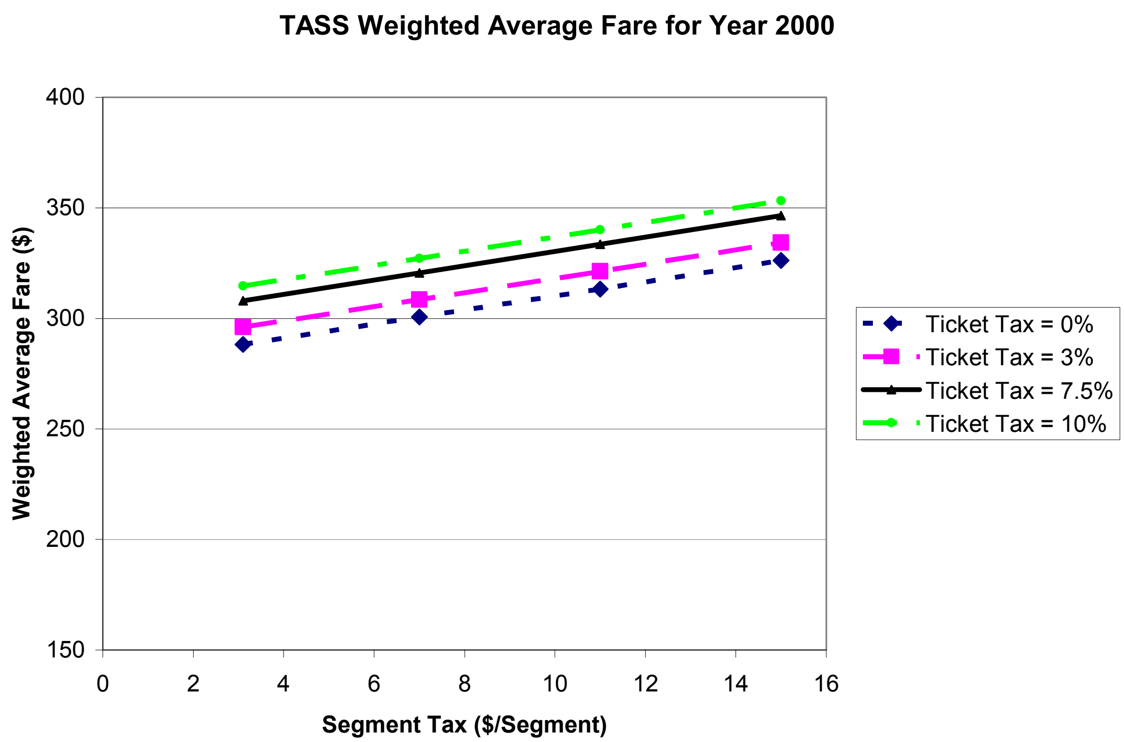
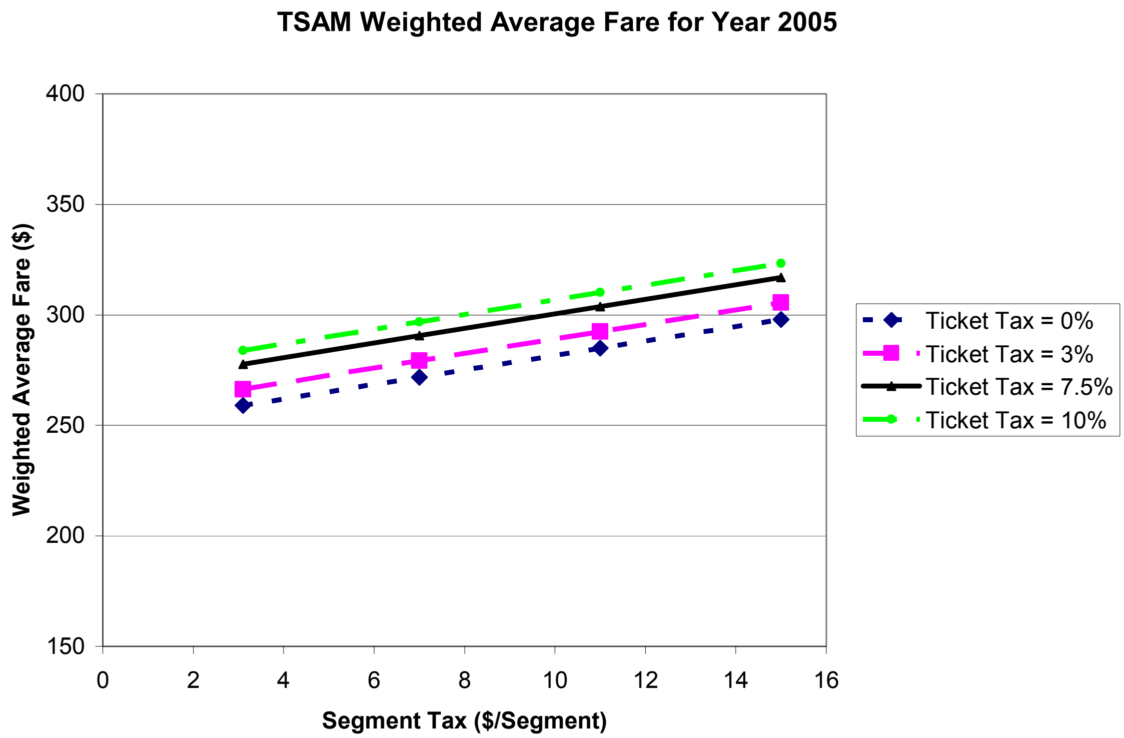


Figure 12. Weighted Average Fares for Year 2000 for (a) TSAM, and (b) TASS.



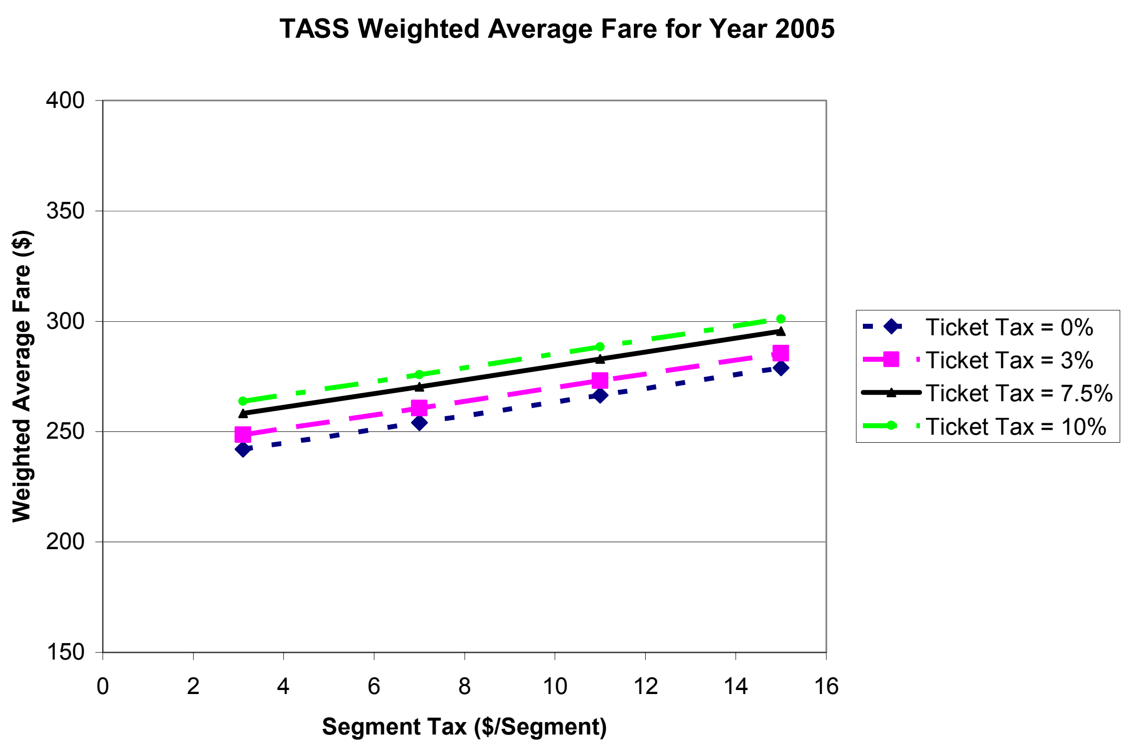
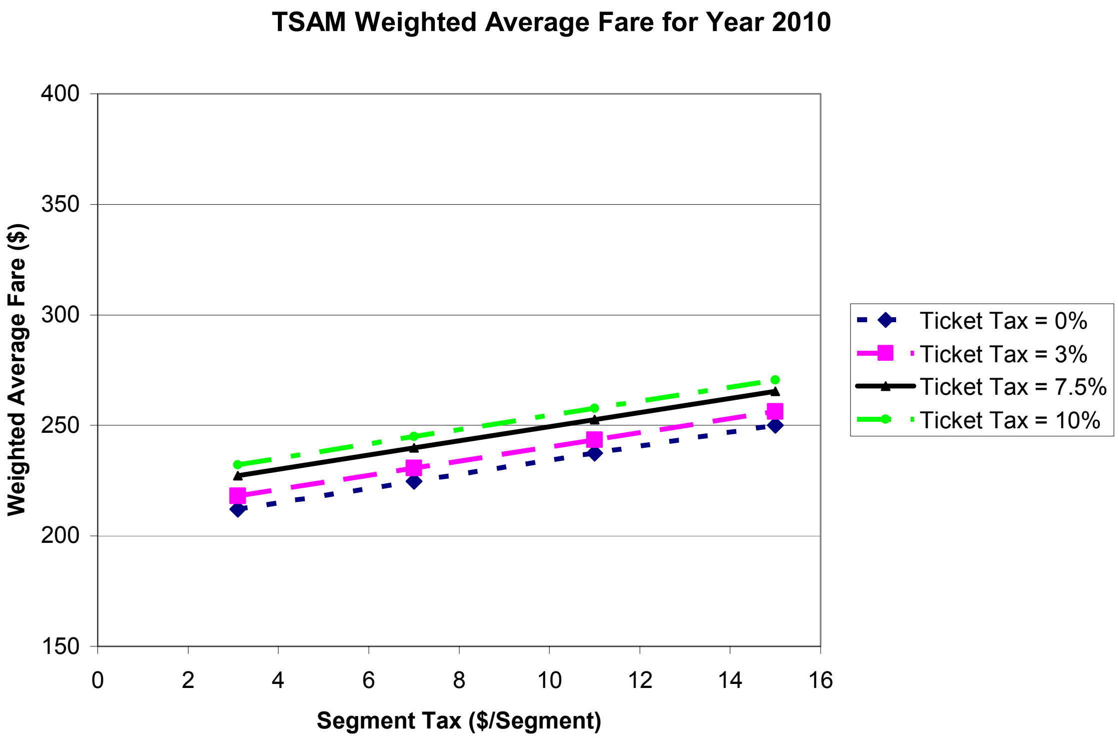


Figure 13. Weighted Average Fares for Year 2005 for (a) TSAM, and (b) TASS.



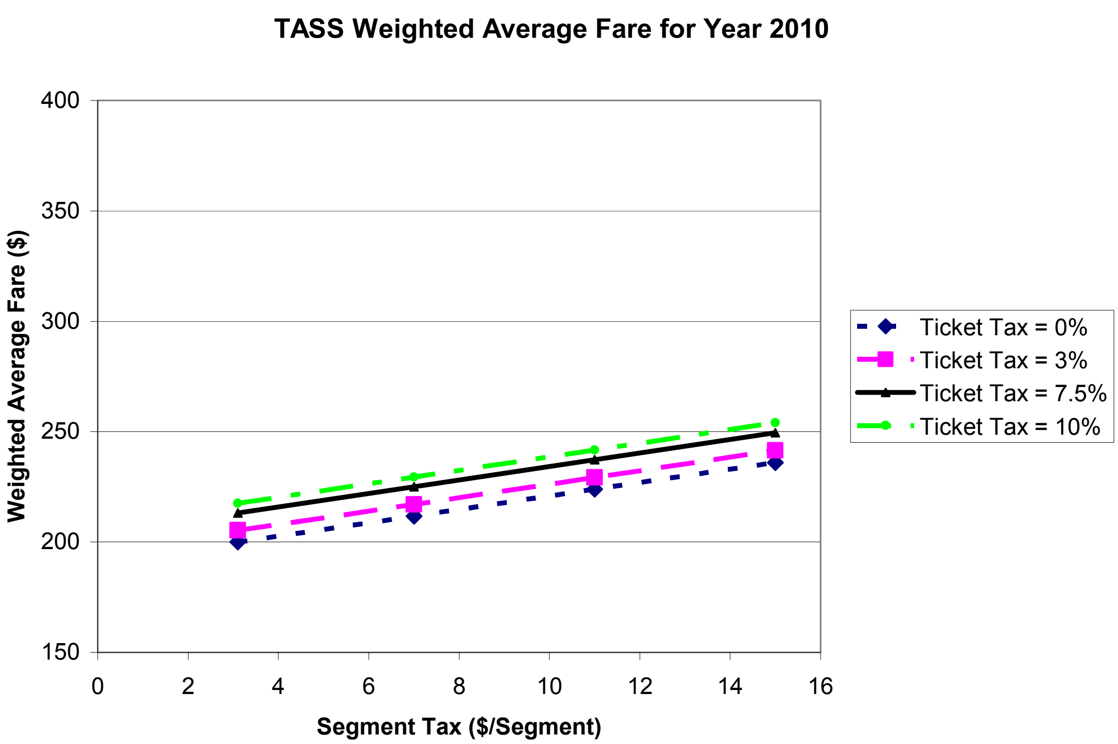
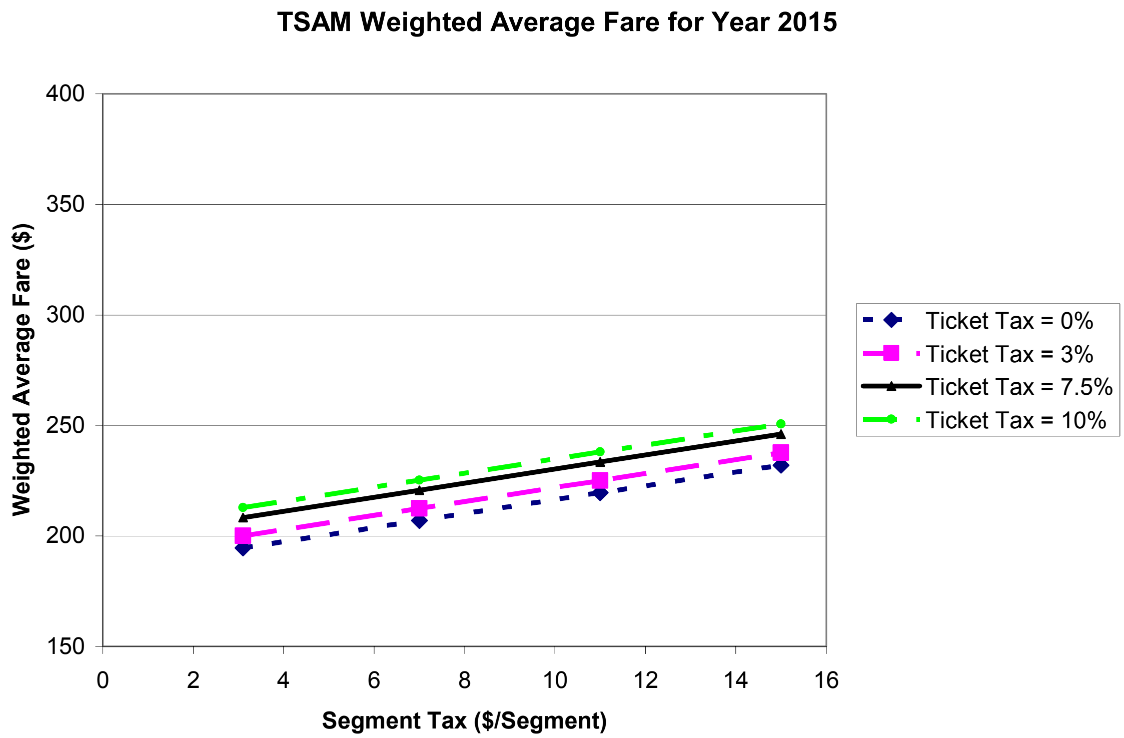


Figure 14. Weighted Average Fares for Year 2010 for (a) TSAM, and (b) TASS.



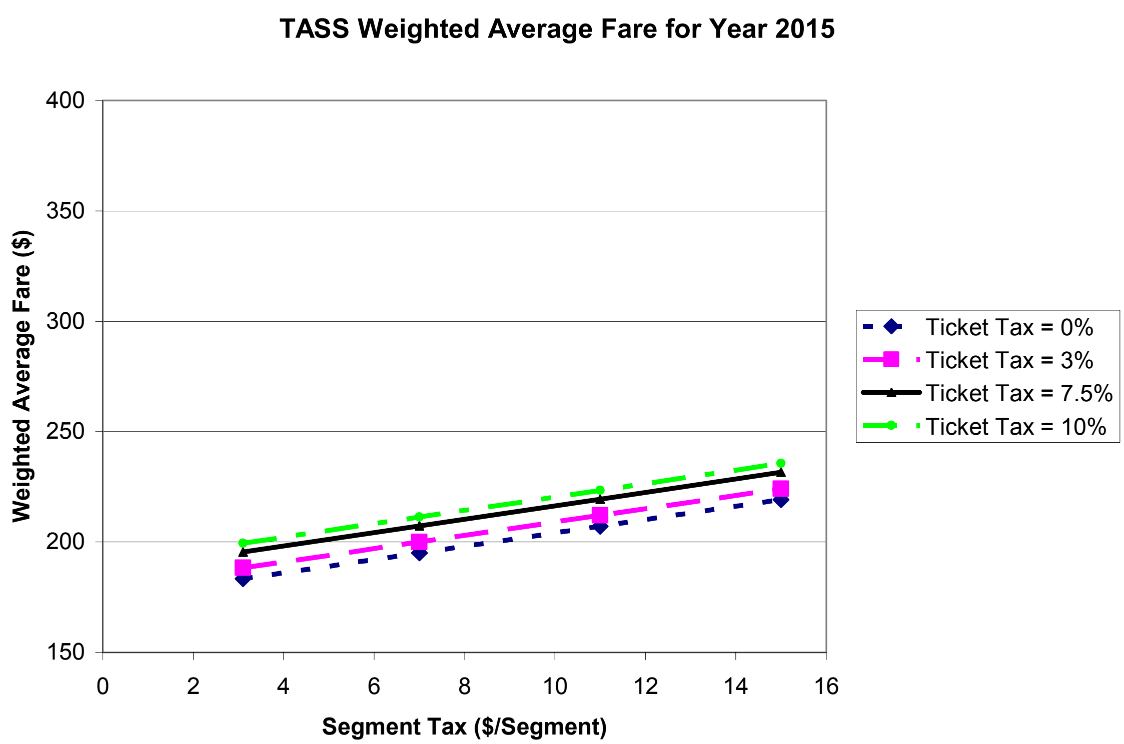
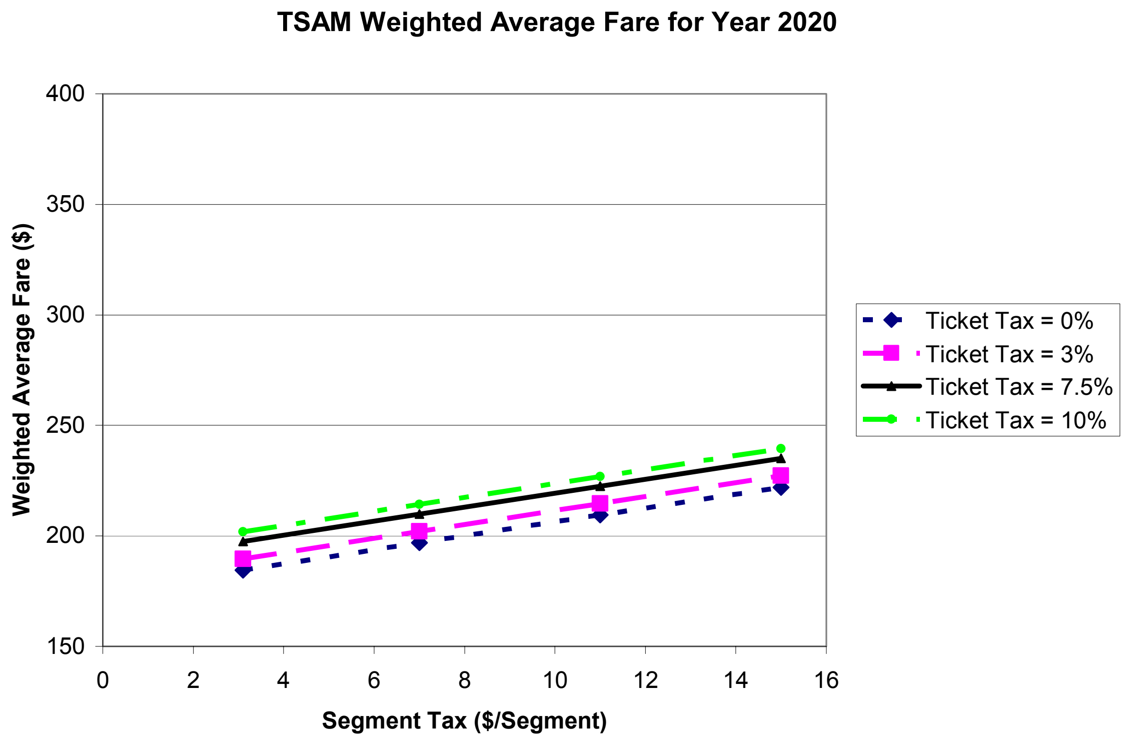


Figure 15. Weighted Average Fares for Year 2015 for (a) TSAM, and (b) TASS.



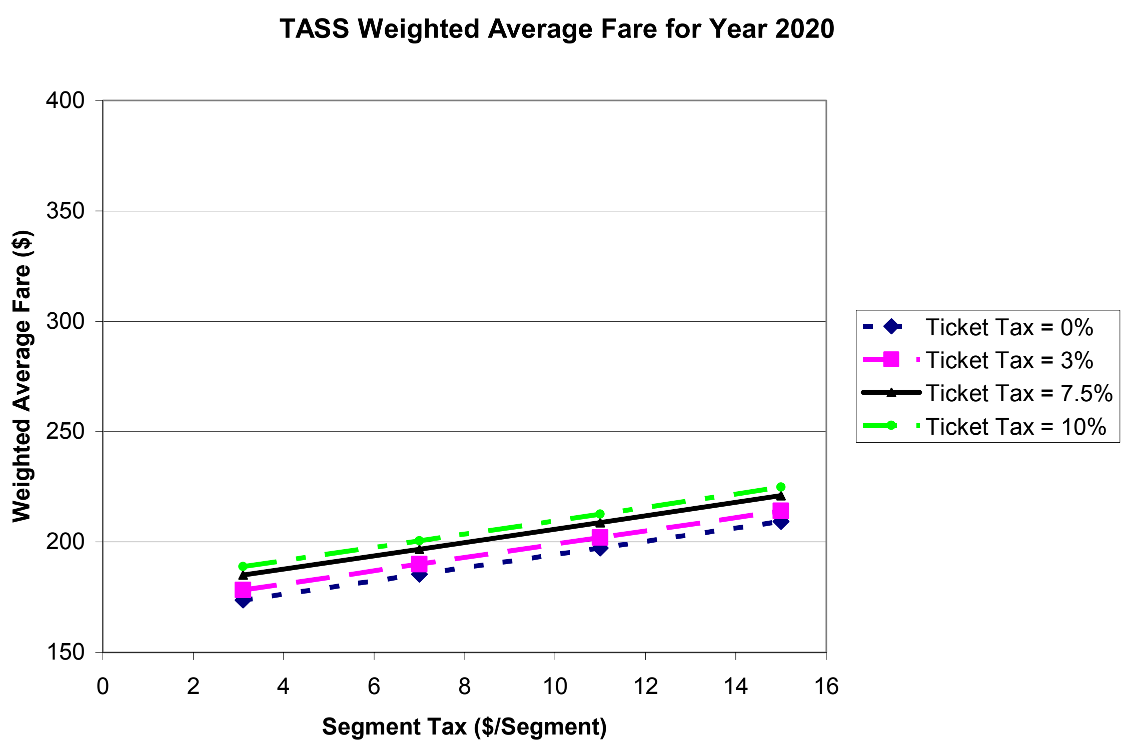
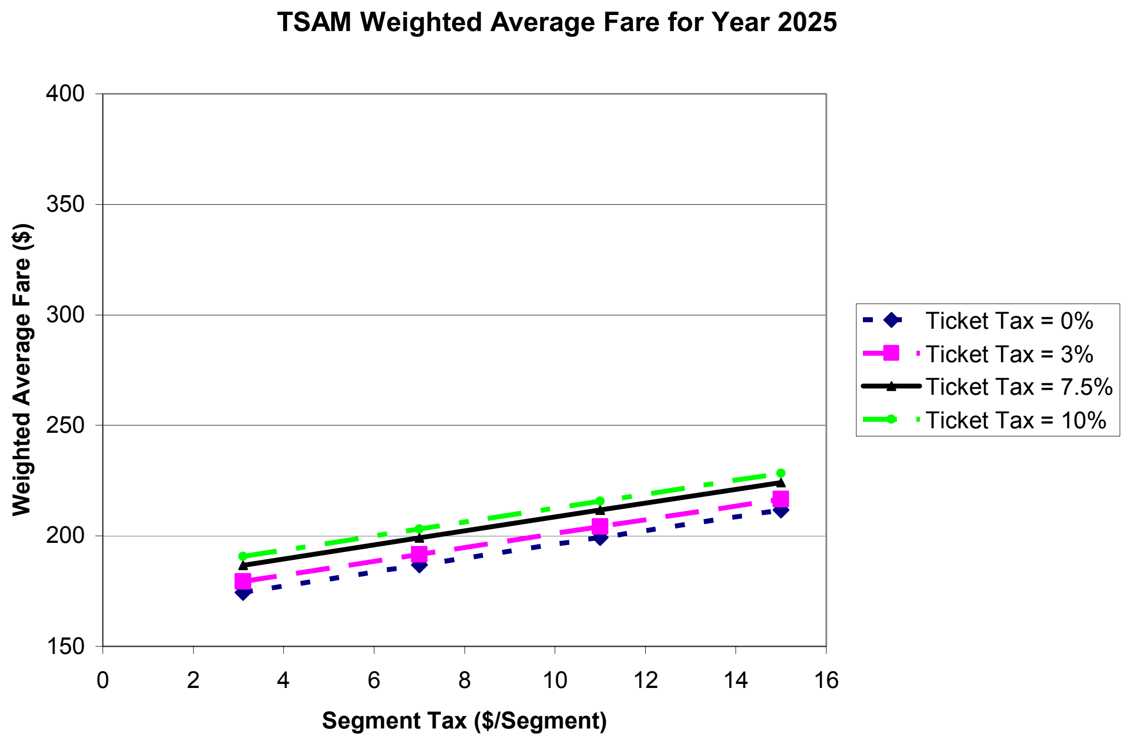


Figure 16. Weighted Average Fares for Year 2020 for (a) TSAM, and (b) TASS.



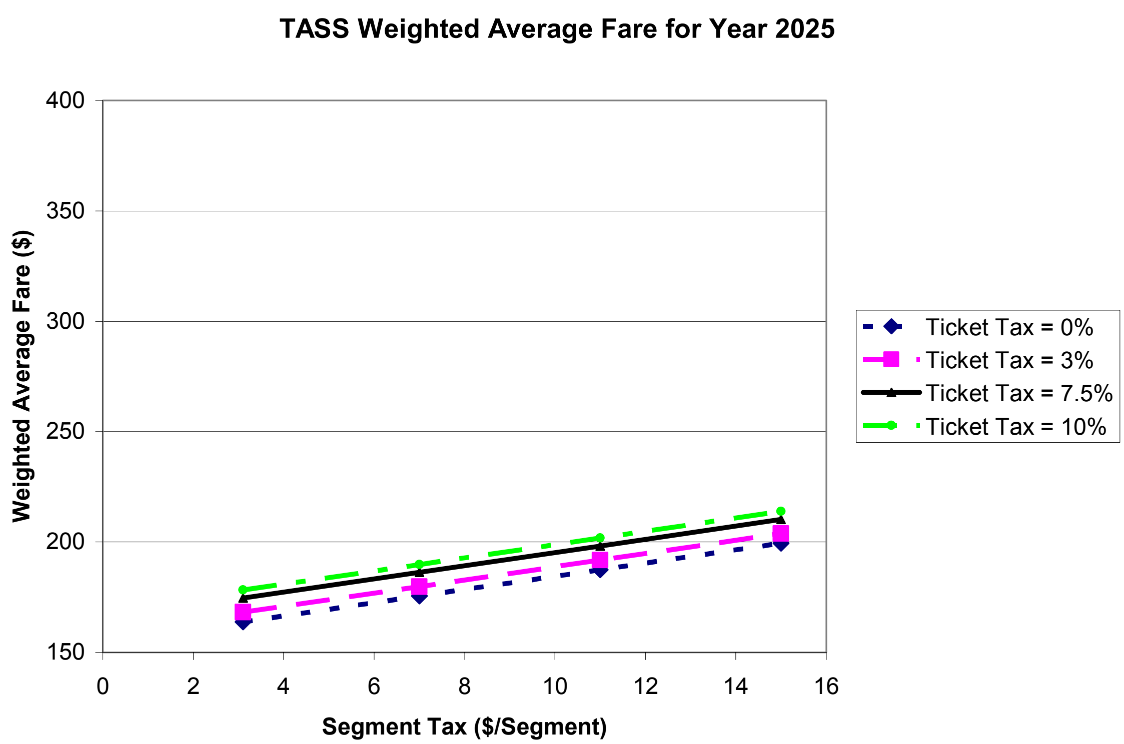
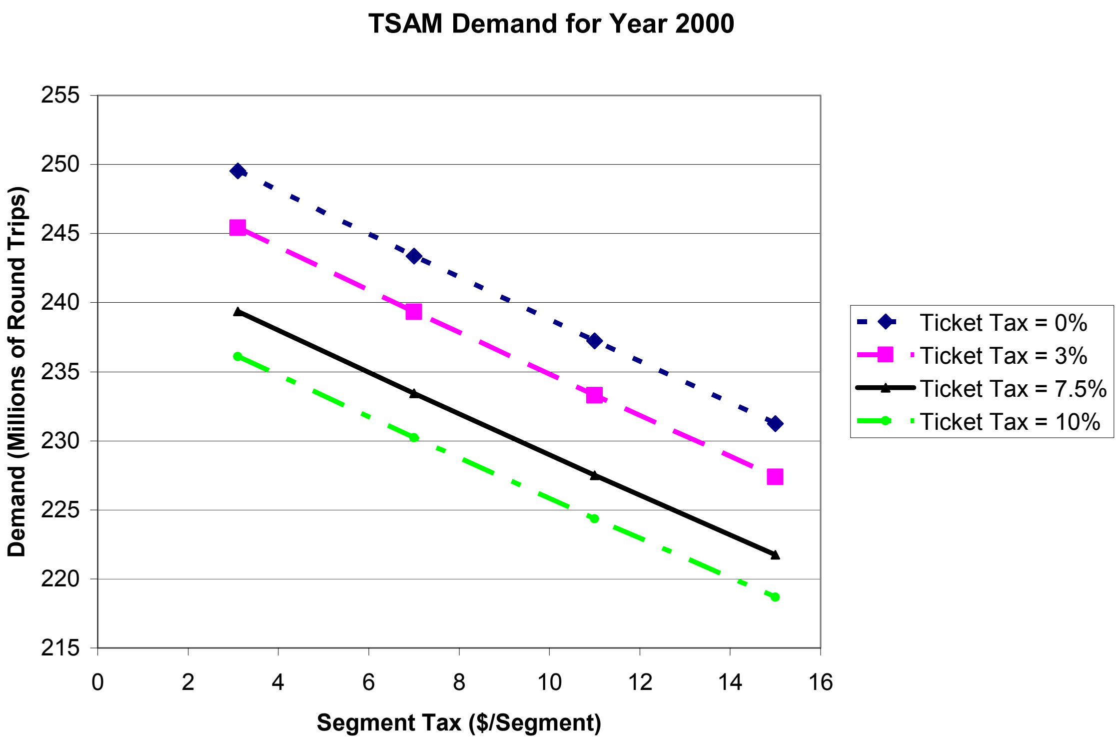


Figure 17. Weighted Average Fares for Year 2025 for (a) TSAM, and (b) TASS.

Passenger Demand



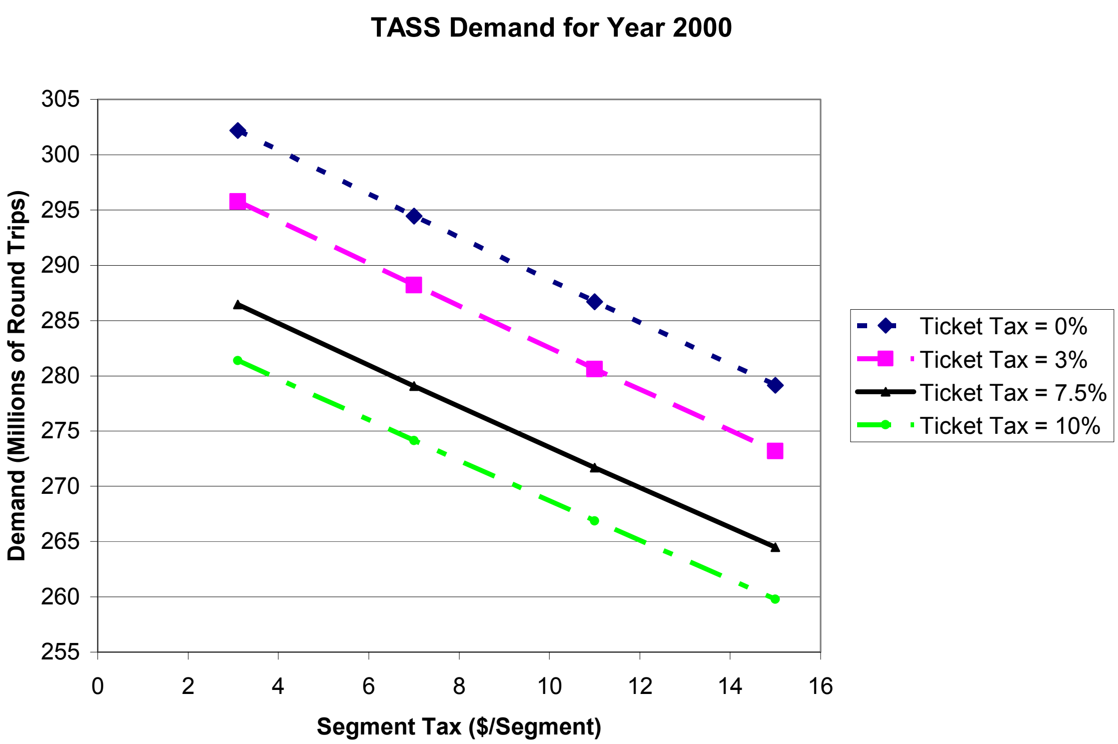


Figure 18. Demand in Millions of Round Trips for Year 2000 for (a) TSAM, and (b) TASS.

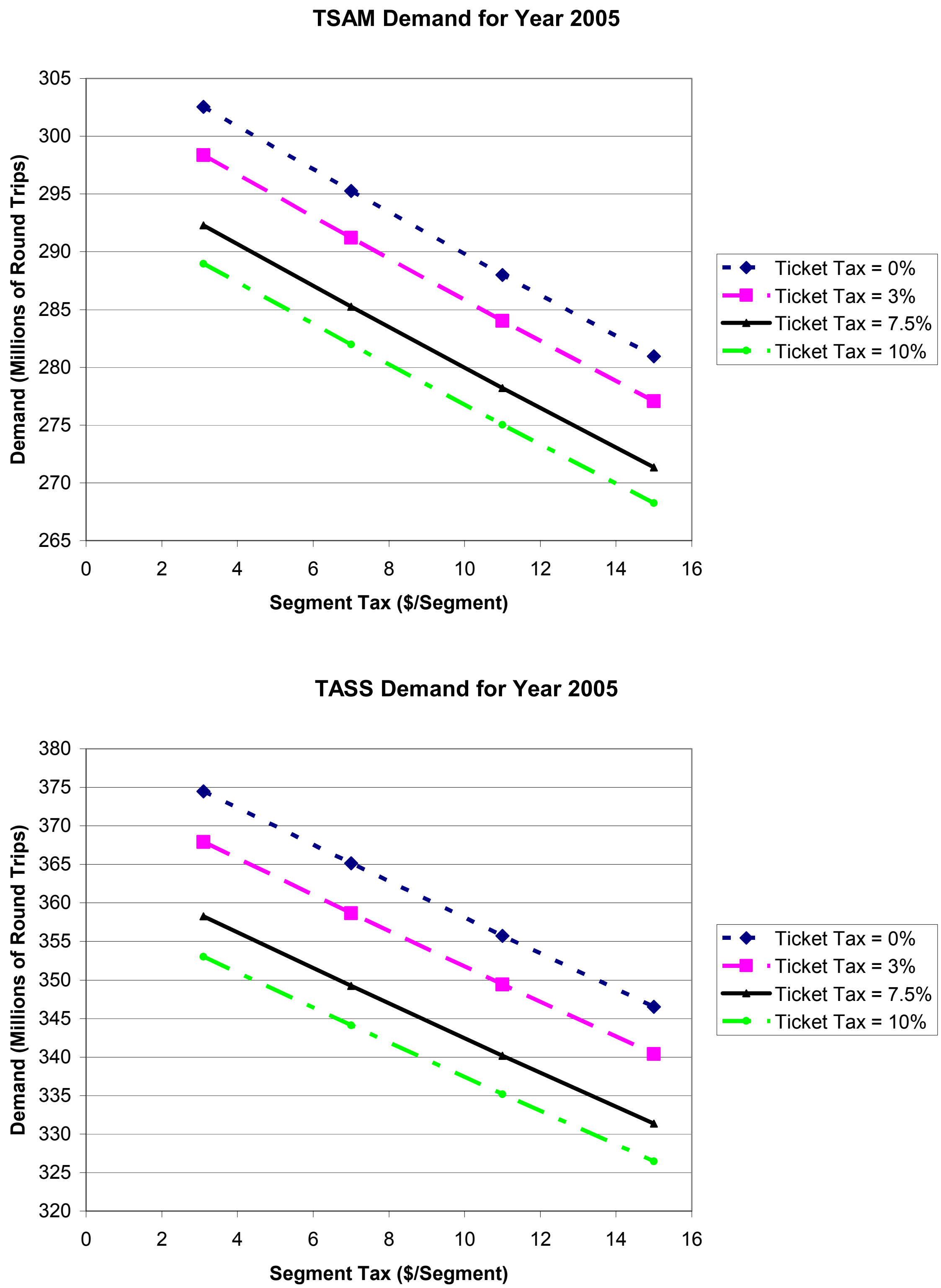
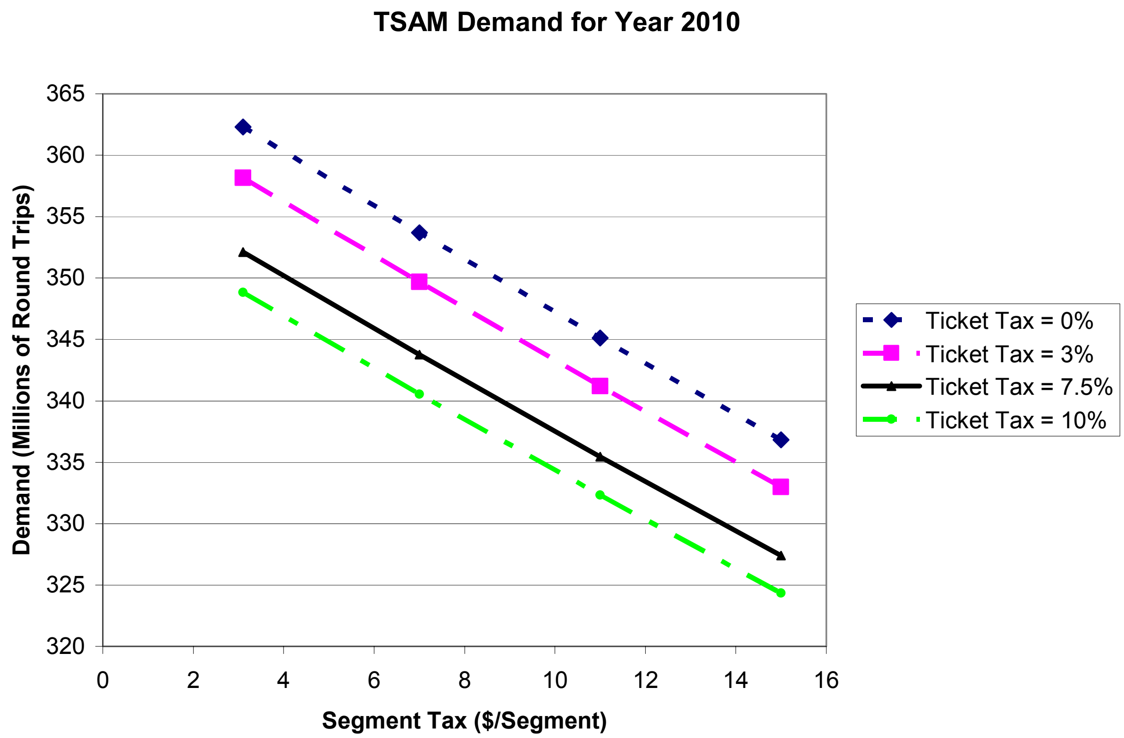


Figure 19. Demand in Millions of Round Trips for Year 2005 for (a) TSAM, and (b) TASS.



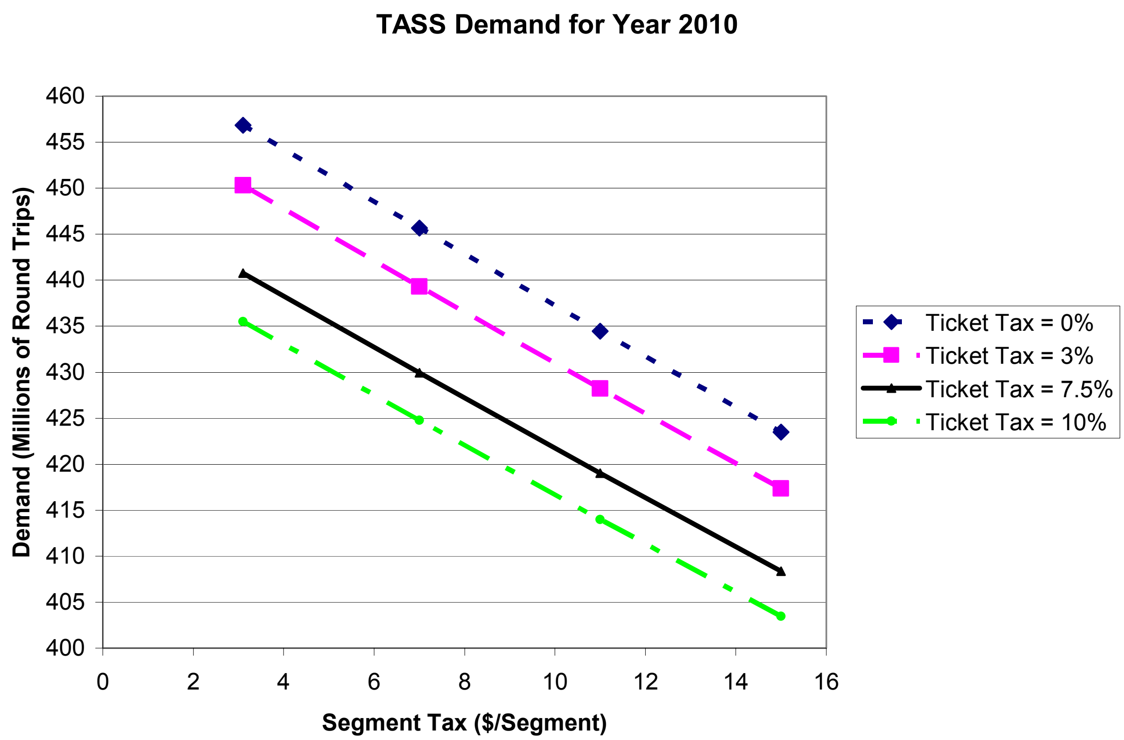


Figure 20. Demand in Millions of Round Trips for Year 2010 for (a) TSAM, and (b) TASS.

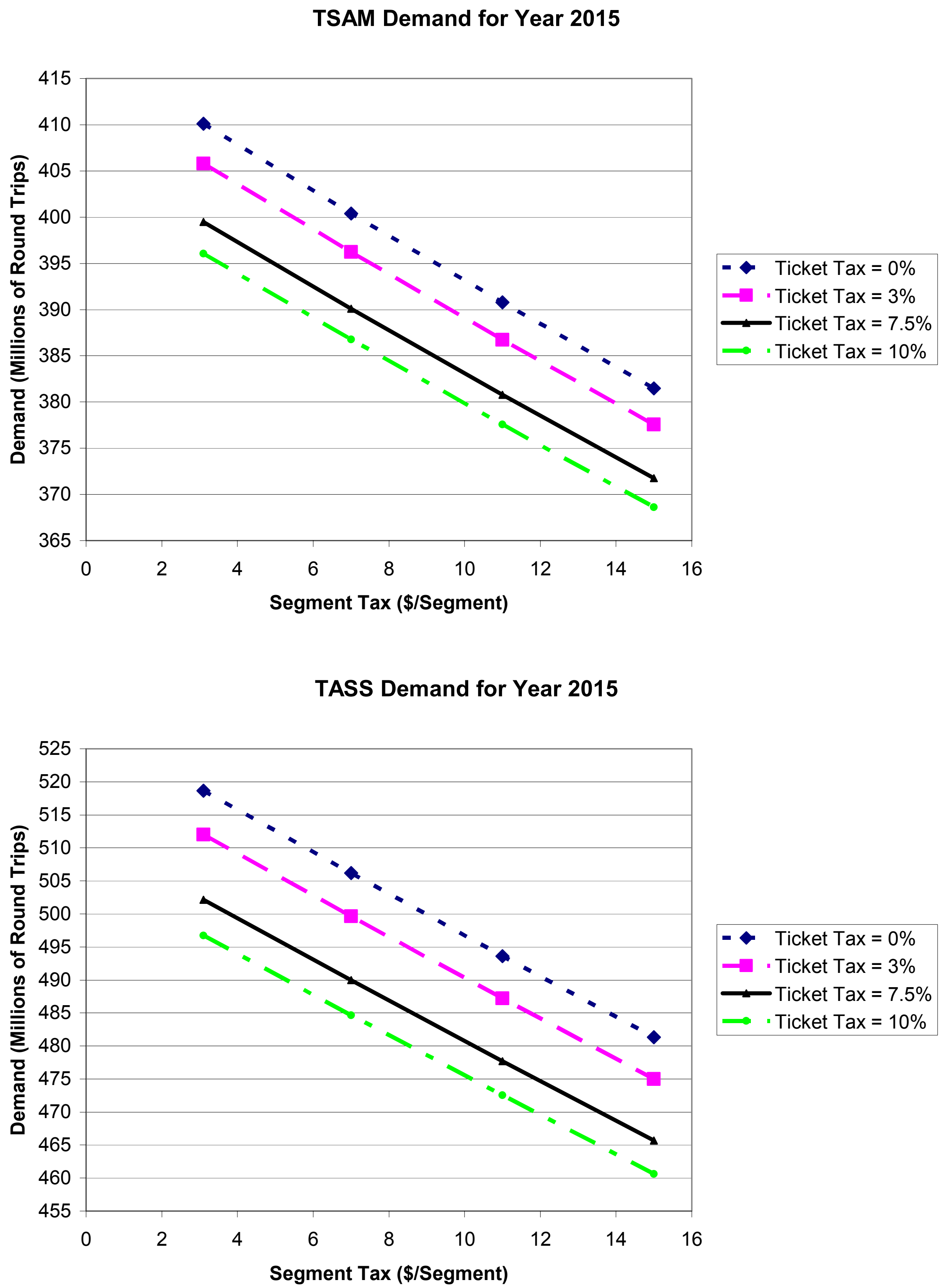


Figure 21. Demand in Millions of Round Trips for Year 2015 for (a) TSAM, and (b) TASS.

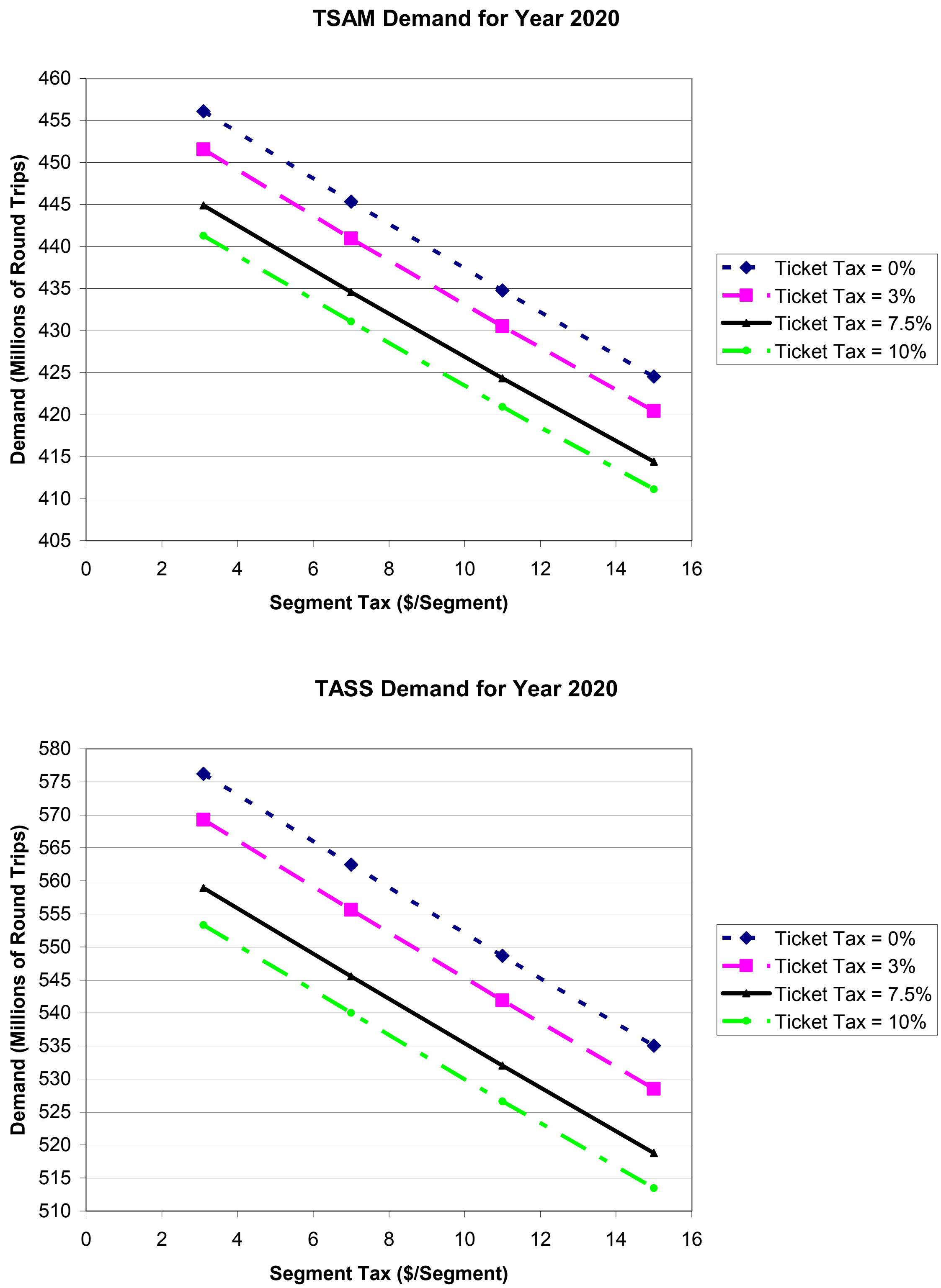
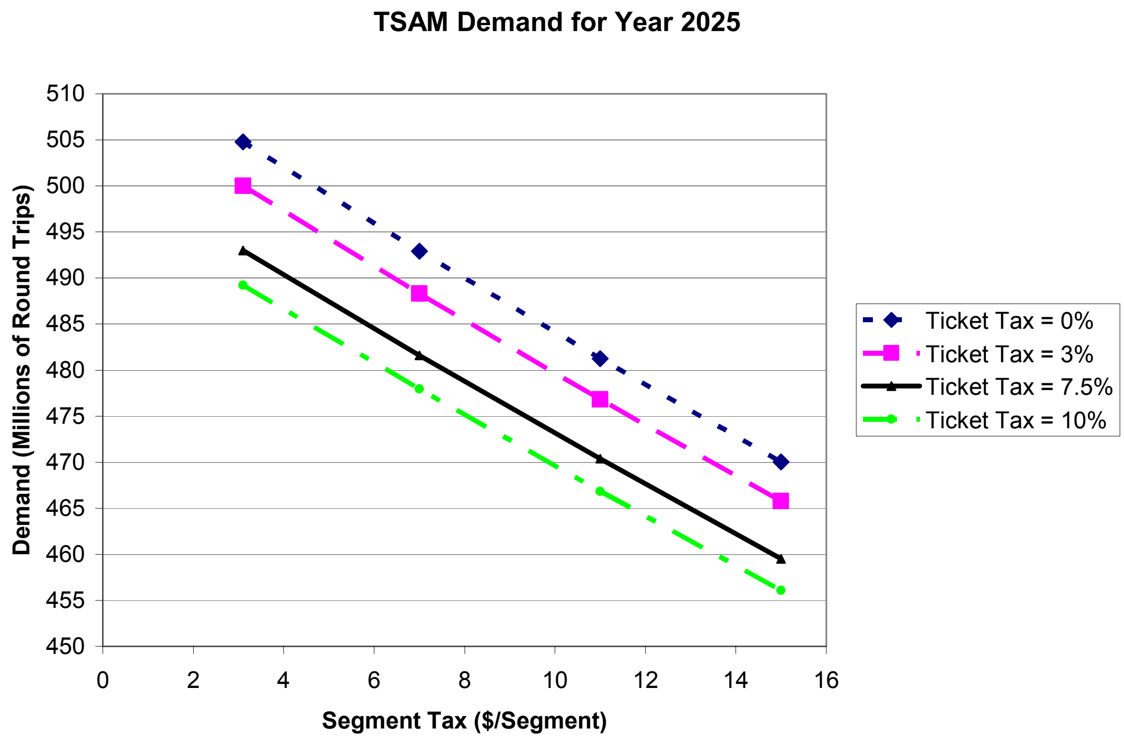


Figure 22. Demand in Millions of Round Trips for Year 2020 for (a) TSAM, and (b) TASS.



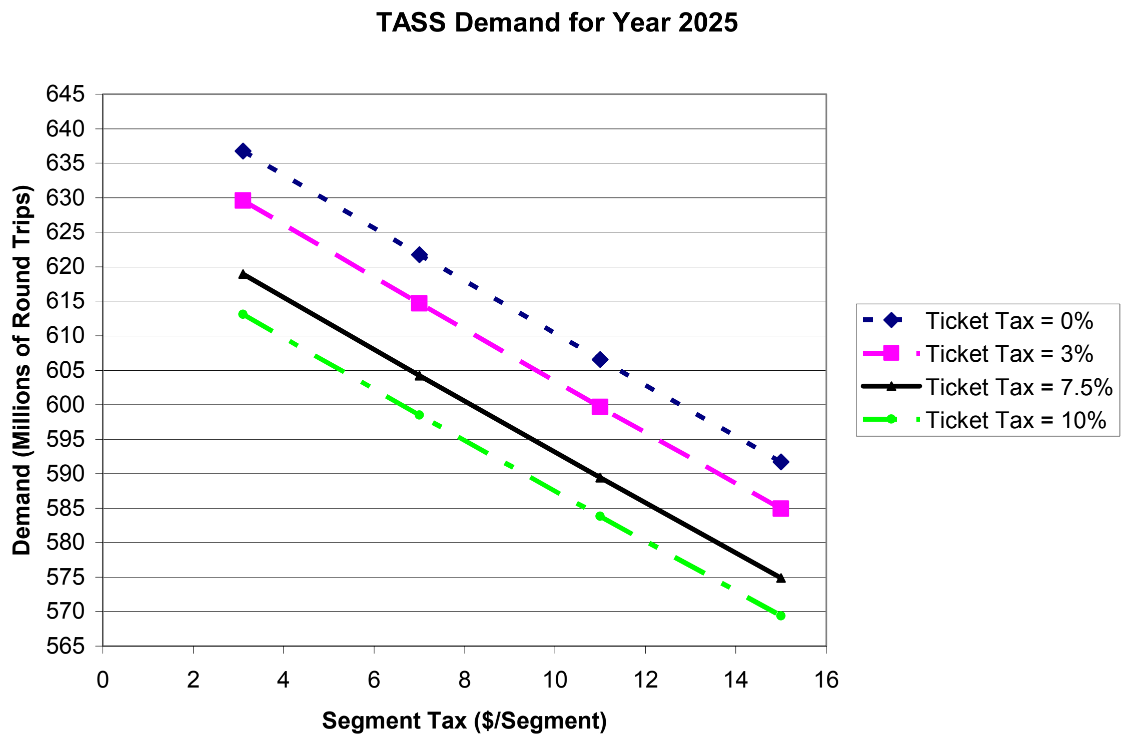
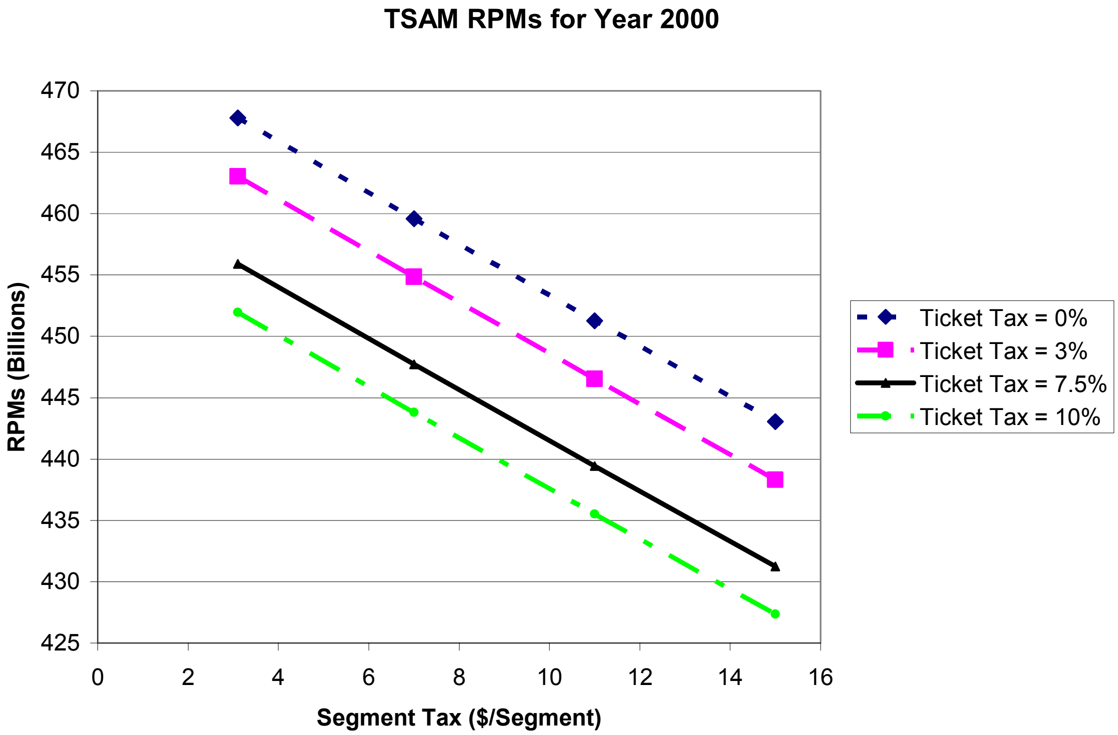


Figure 23. Demand in Millions of Round Trips for Year 2025 for (a) TSAM, and (b) TASS.

Revenue Passenger Miles (RPMs)



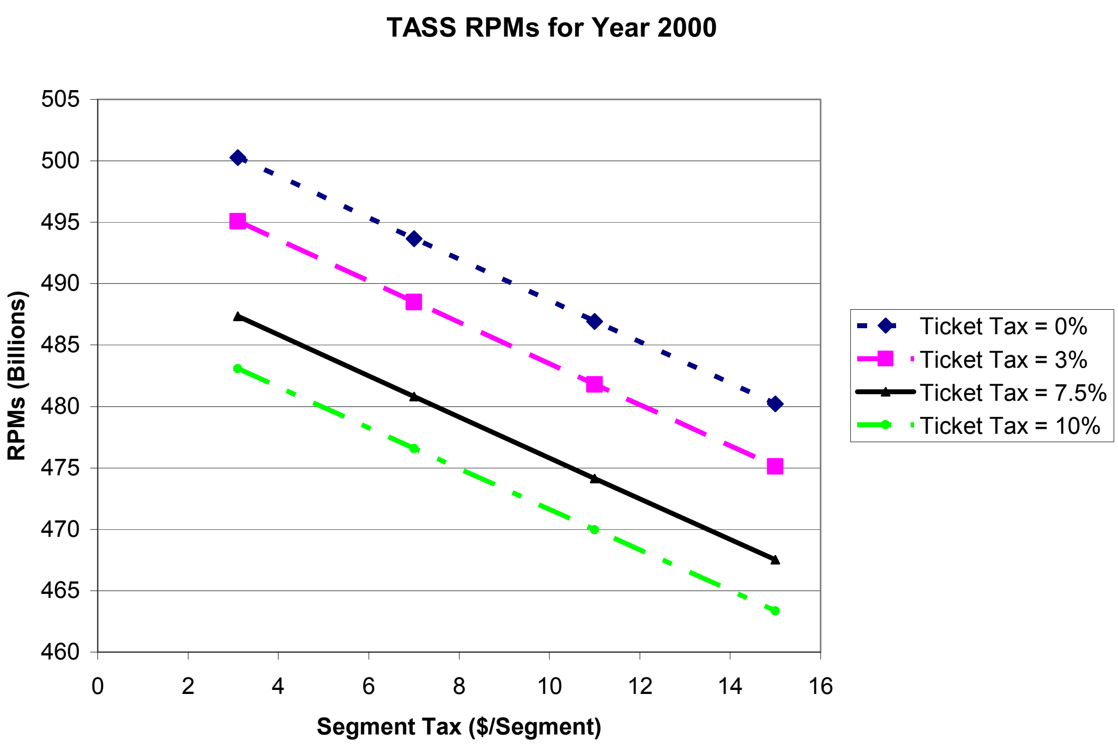
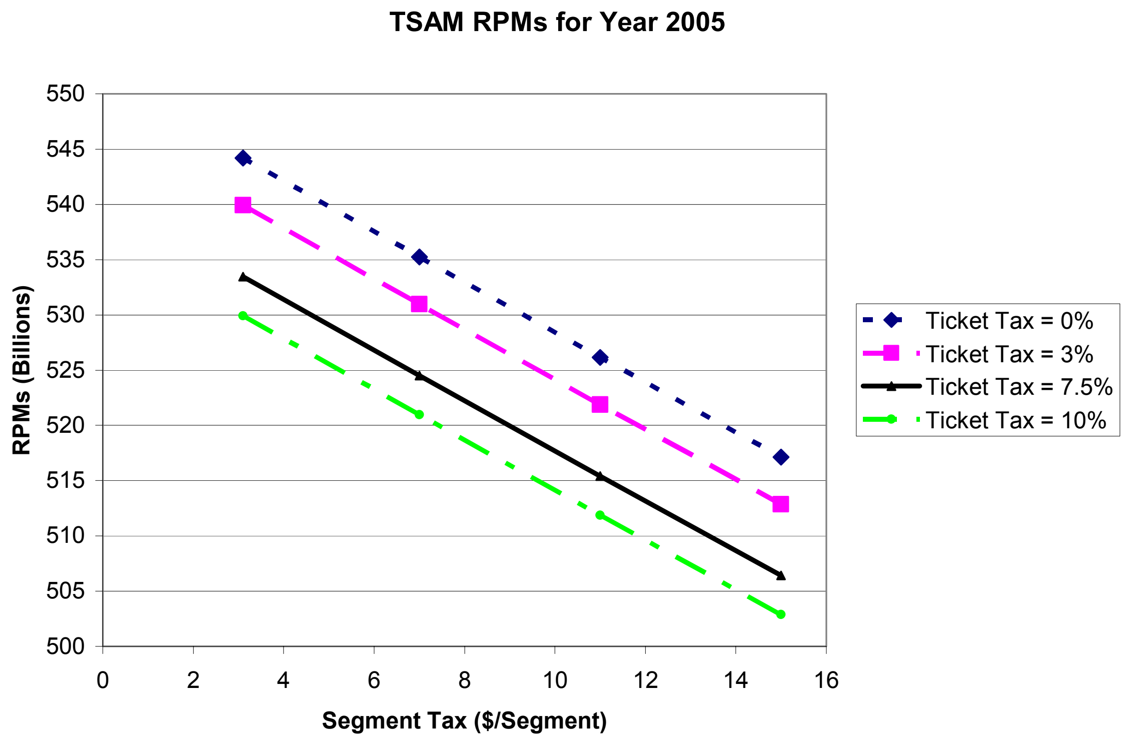


Figure 24. RPM in Billions of Miles for Year 2000 for (a) TSAM, and (b) TASS.



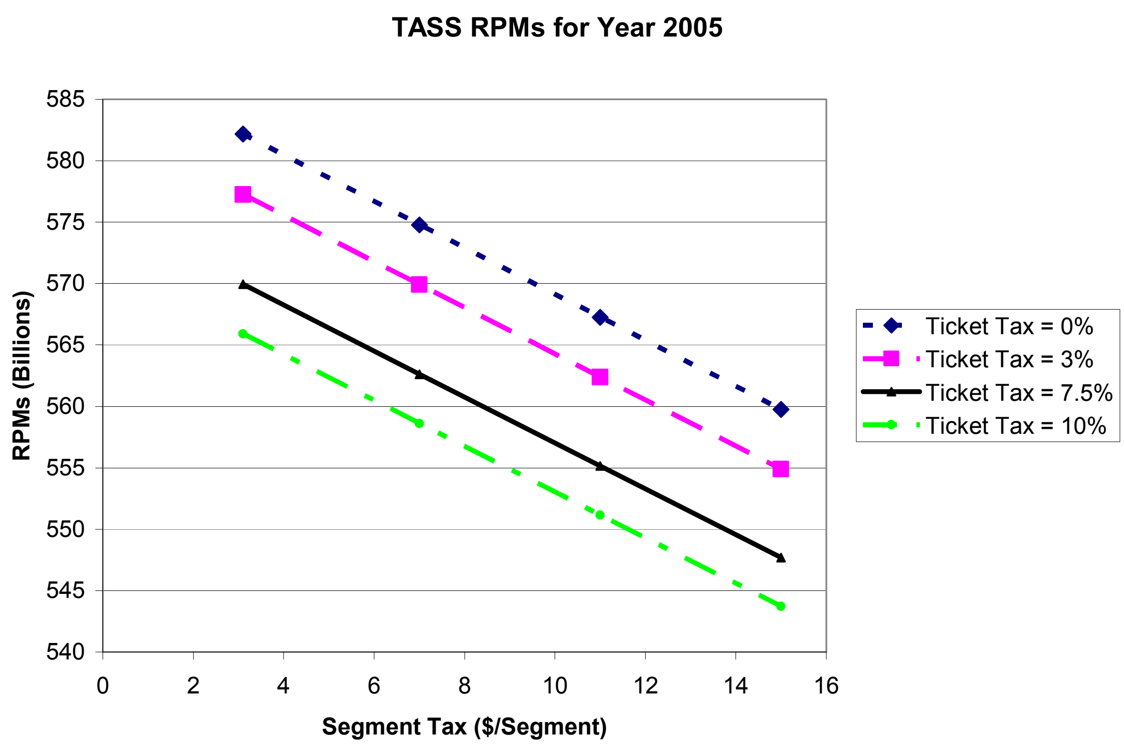
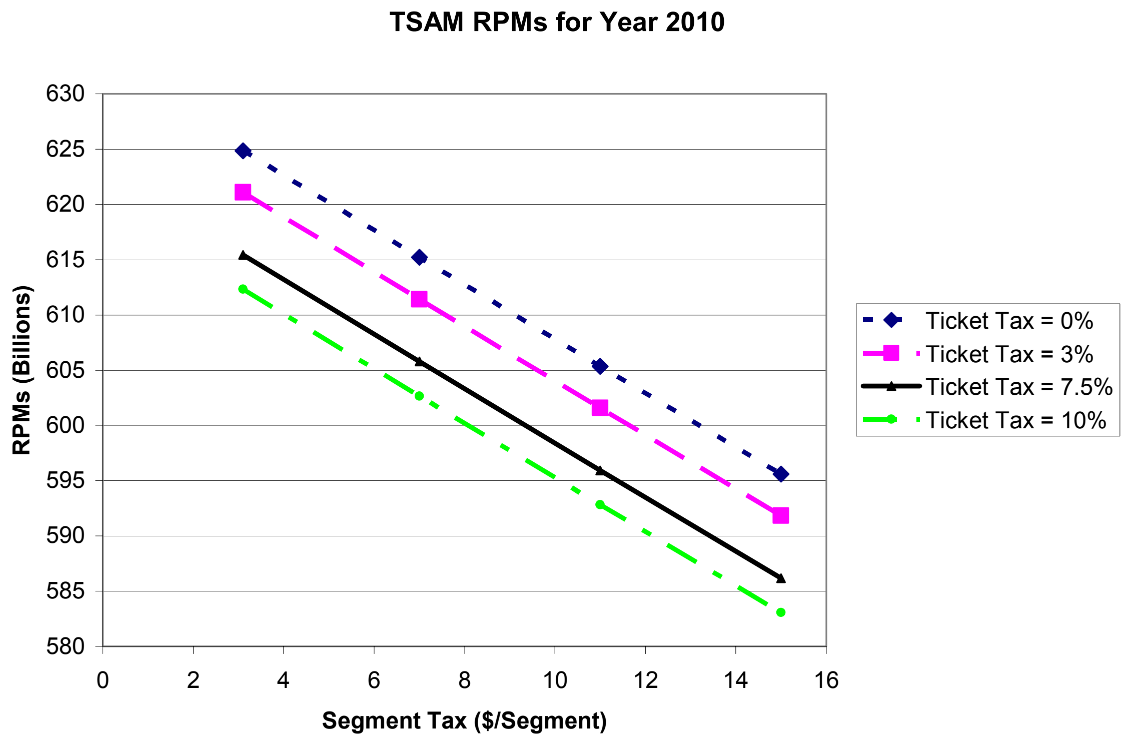


Figure 25. RPM in Billions of Miles for Year 2005 for (a) TSAM, and (b) TASS.



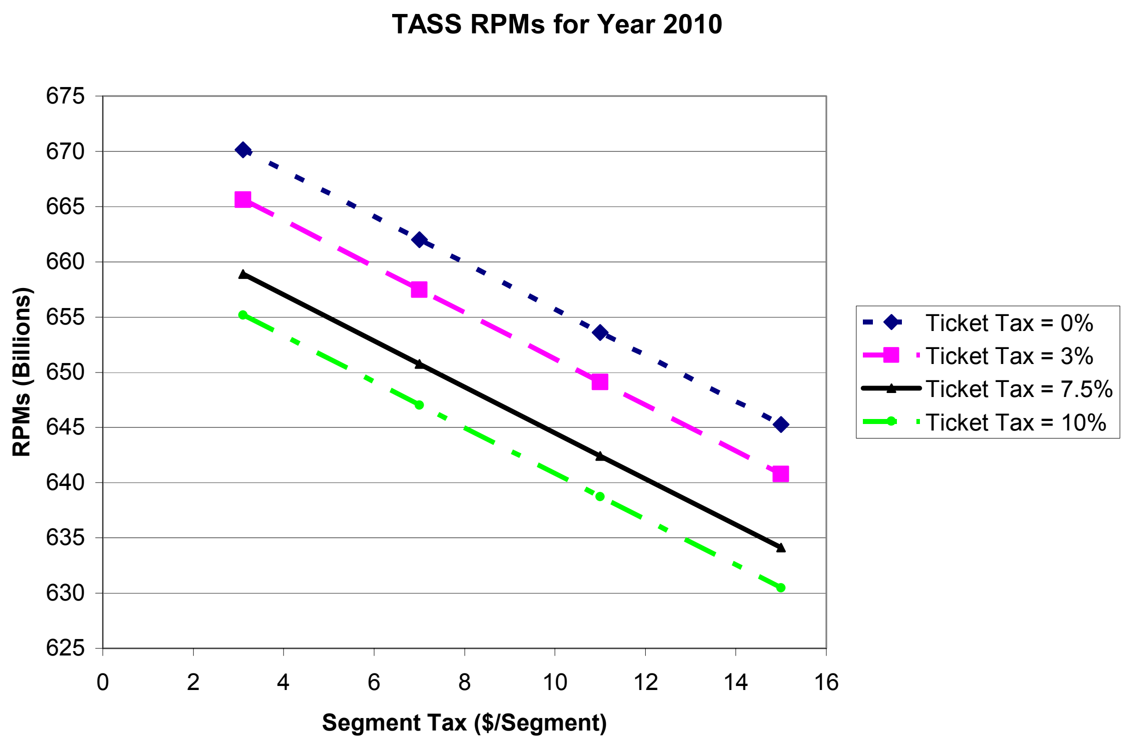
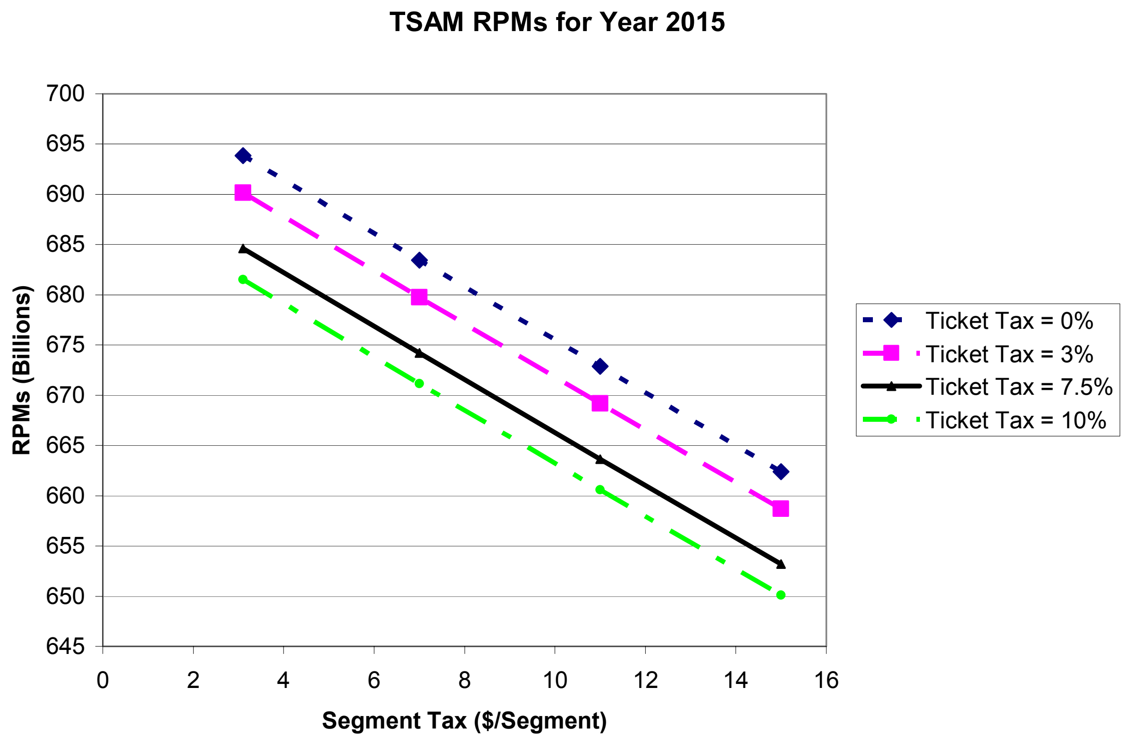


Figure 26. RPM in Billions of Miles for Year 2010 for (a) TSAM, and (b) TASS.



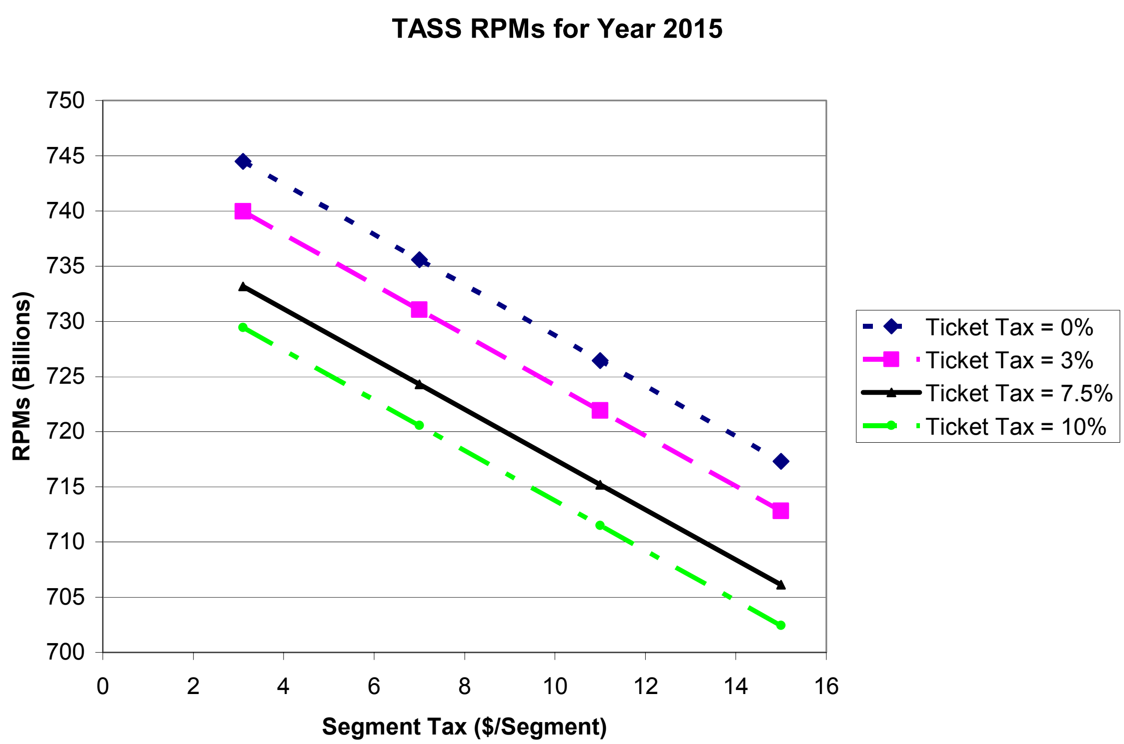
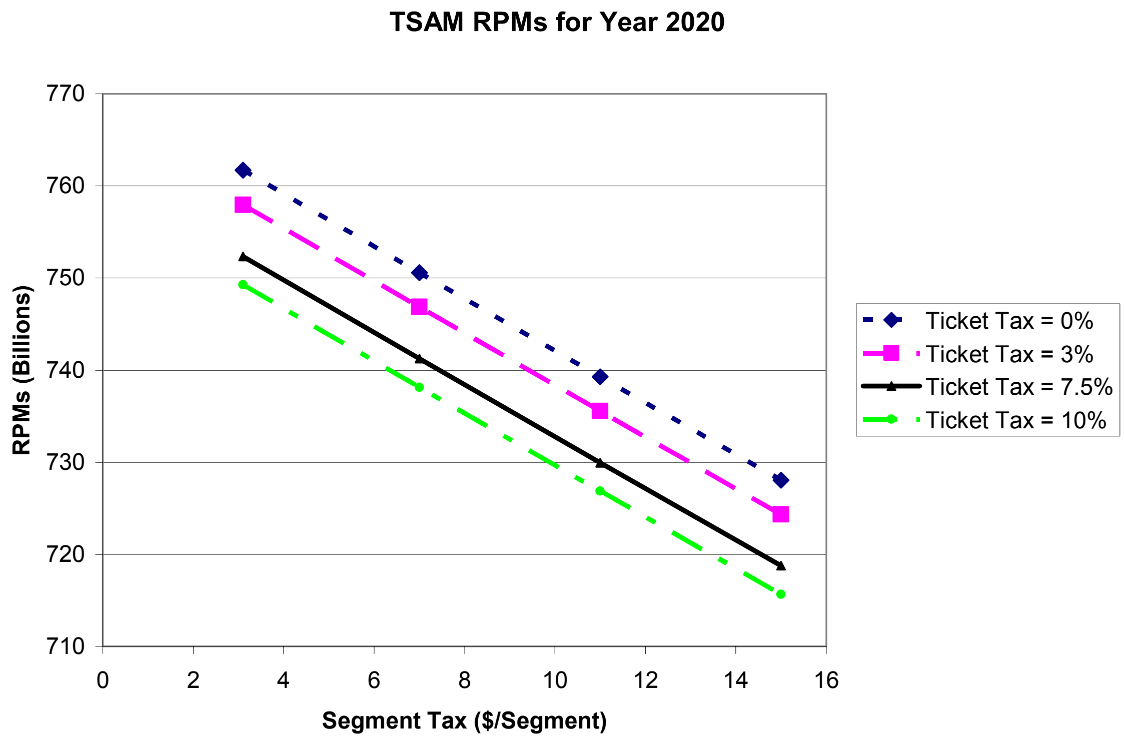


Figure 27. RPM in Billions of Miles for Year 2015 for (a) TSAM, and (b) TASS.



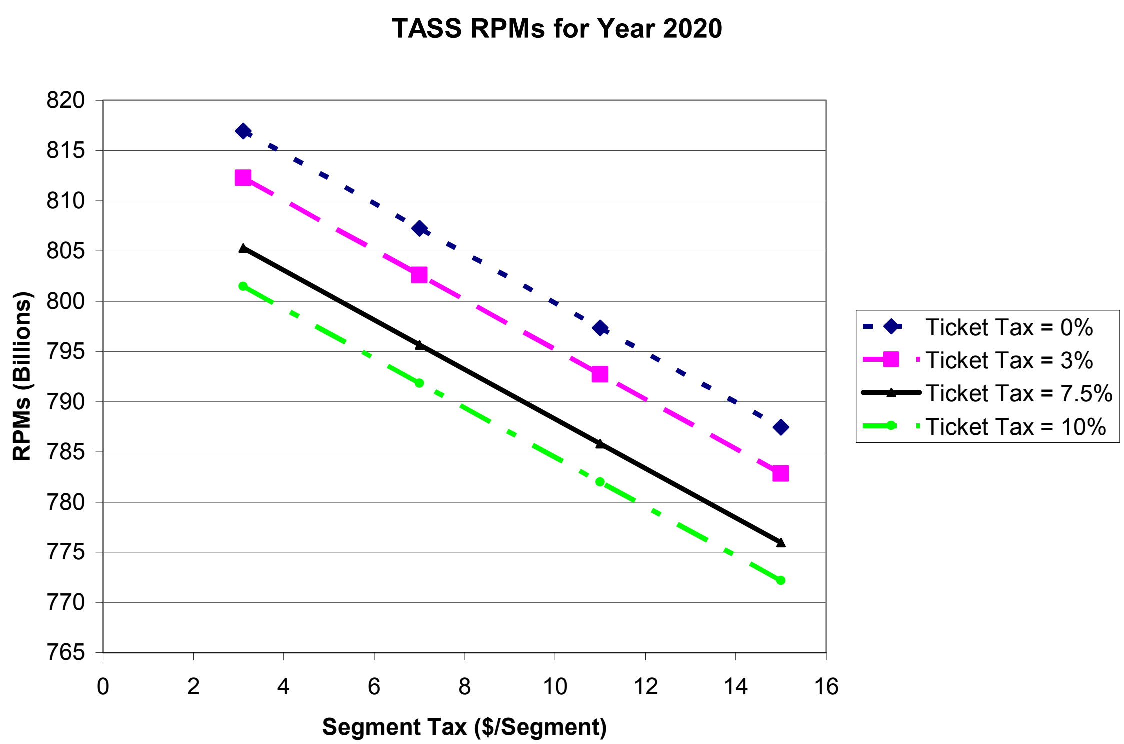
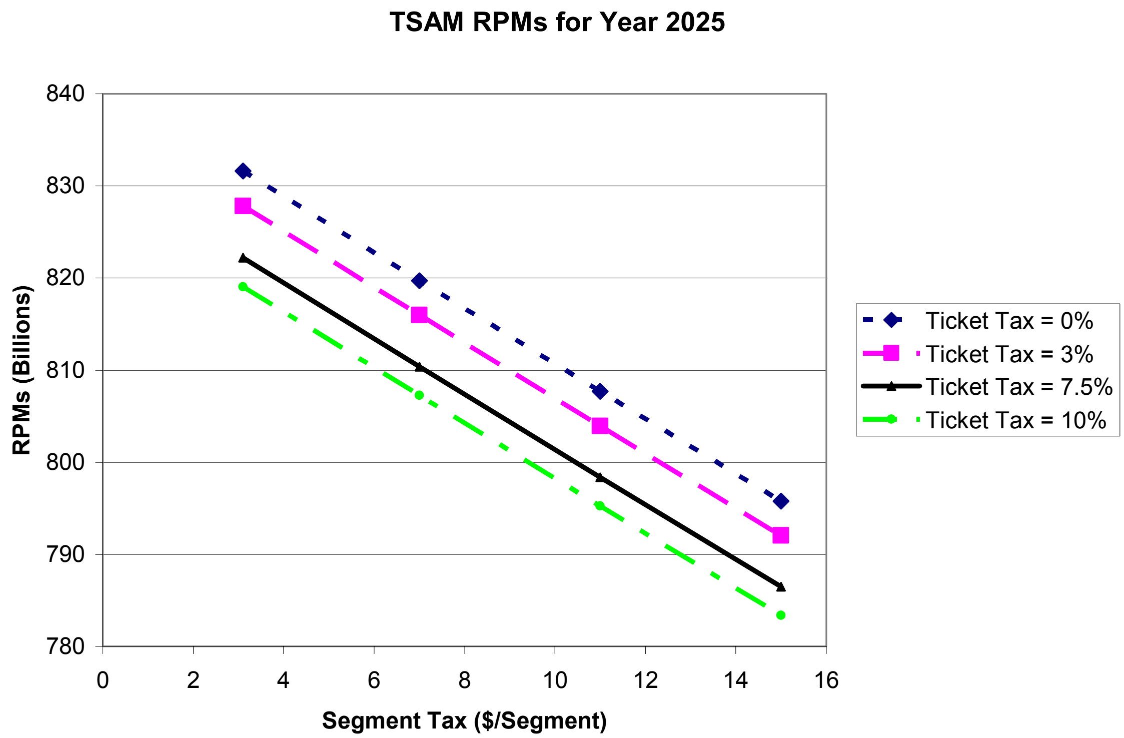


Figure 28. RPM in Billions of Miles for Year 2020 for (a) TSAM, and (b) TASS.



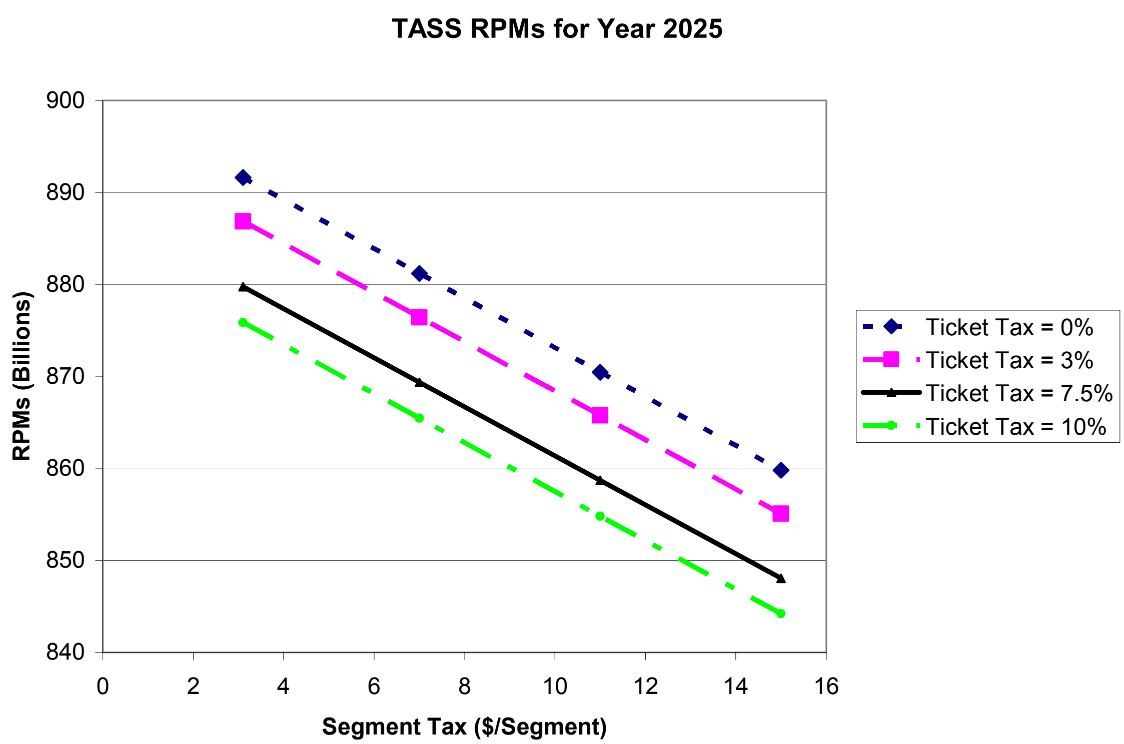
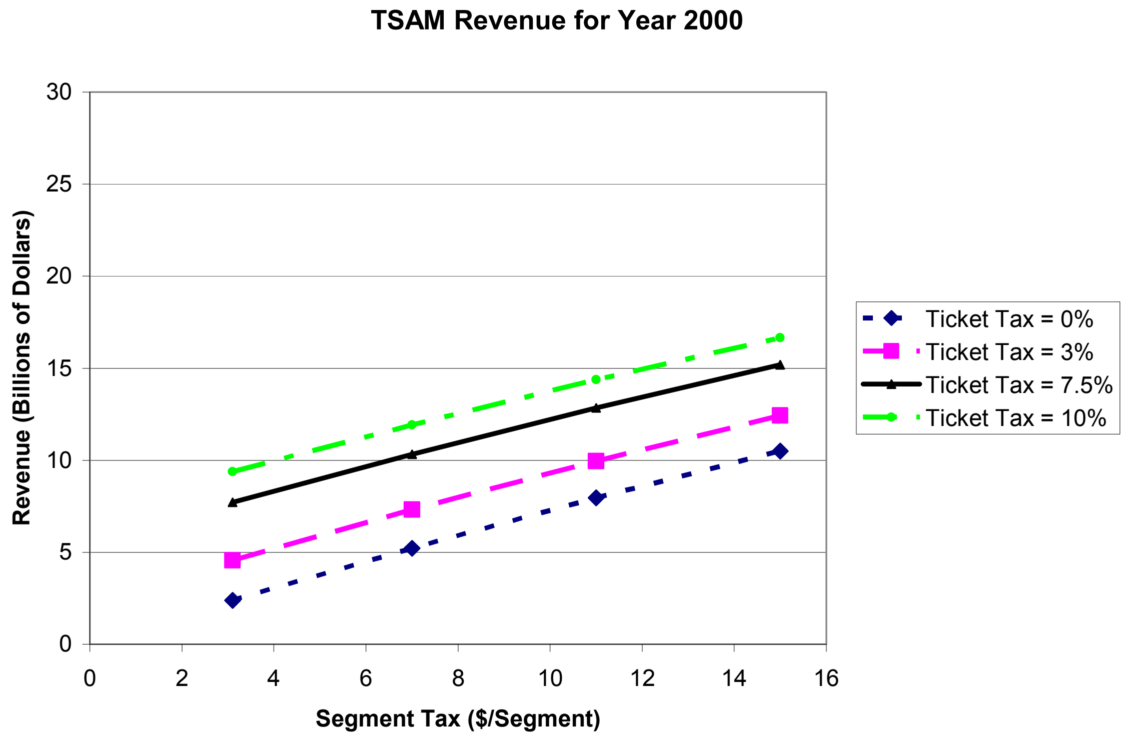


Figure 29. RPM in Billions of Miles for Year 2025 for (a) TSAM, and (b) TASS.

Revenue



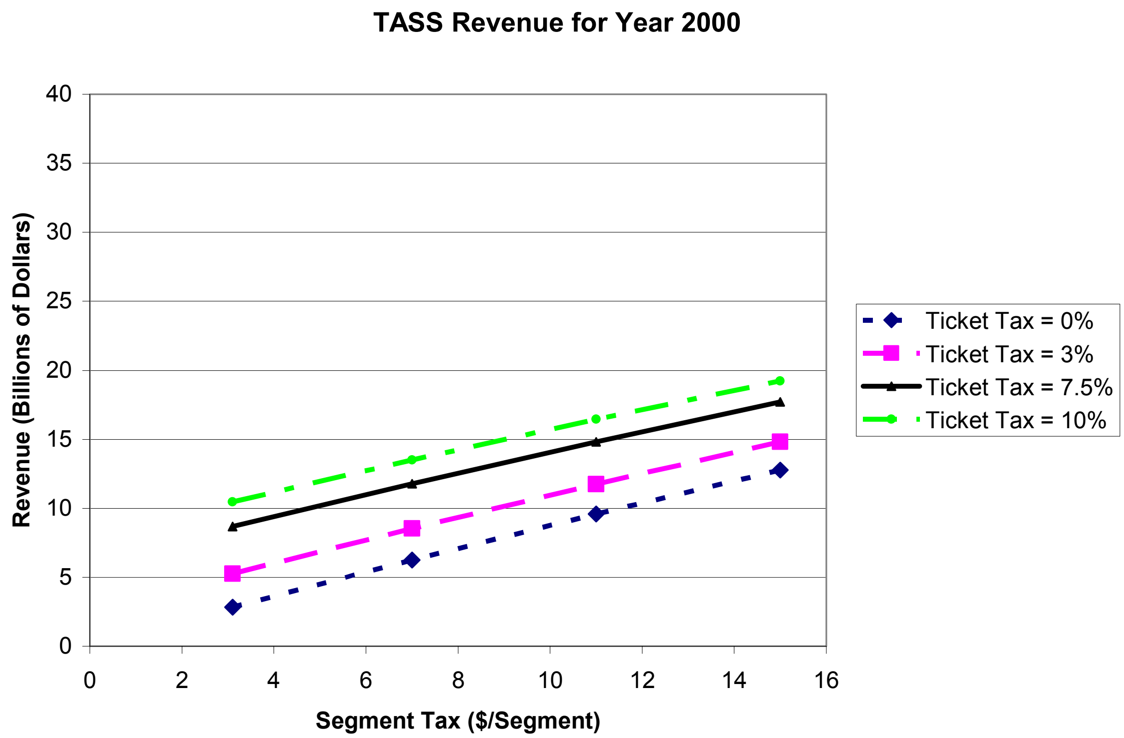
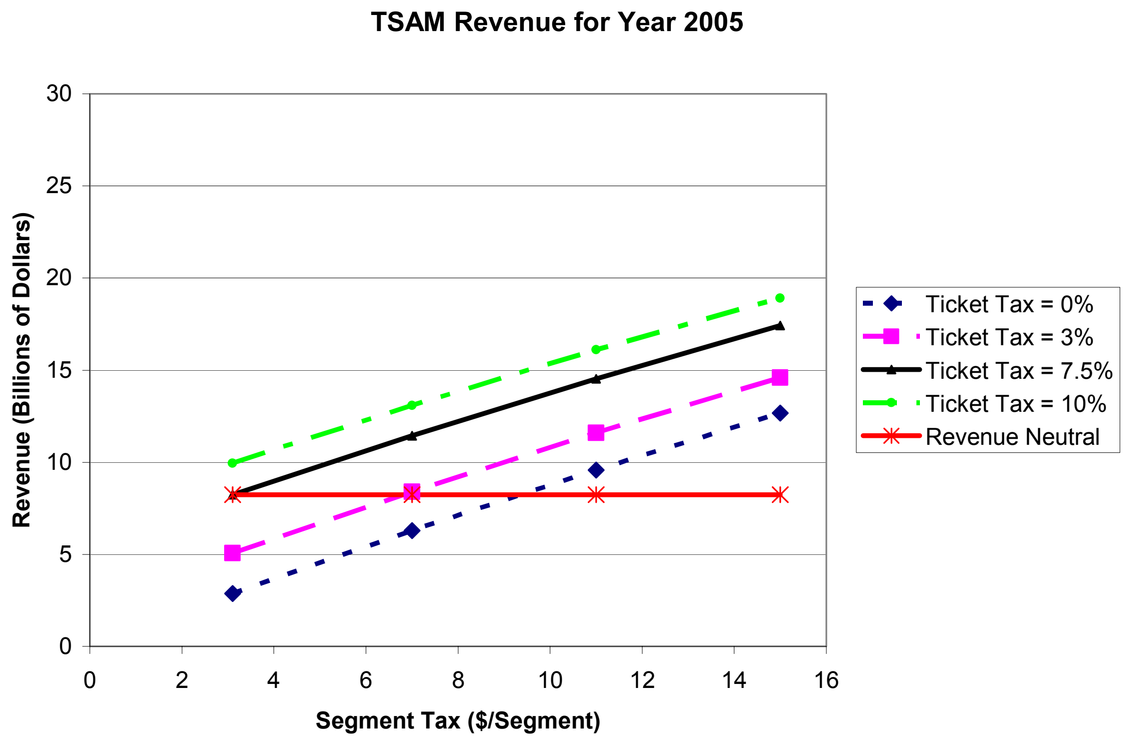


Figure 30. Revenue in Billions of Dollars for Year 2000 for (a) TSAM, and (b) TASS.



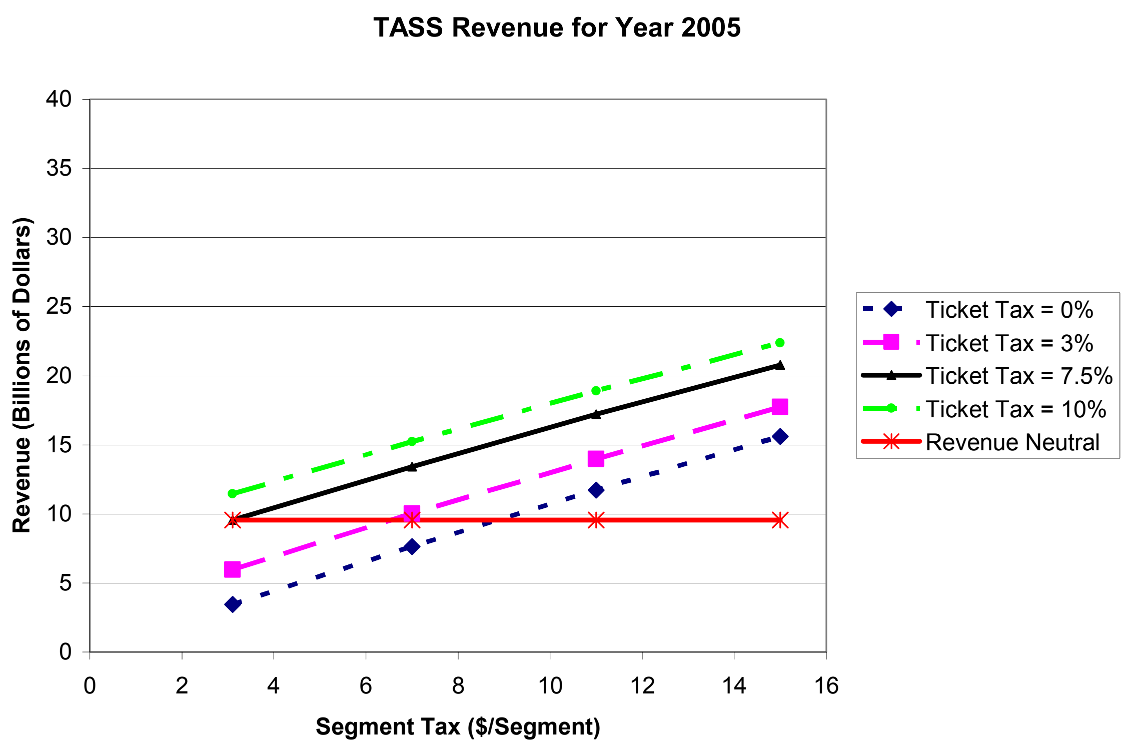


Figure 31. Revenue in Billions of Dollars for Year 2005 for (a) TSAM, and (b) TASS.

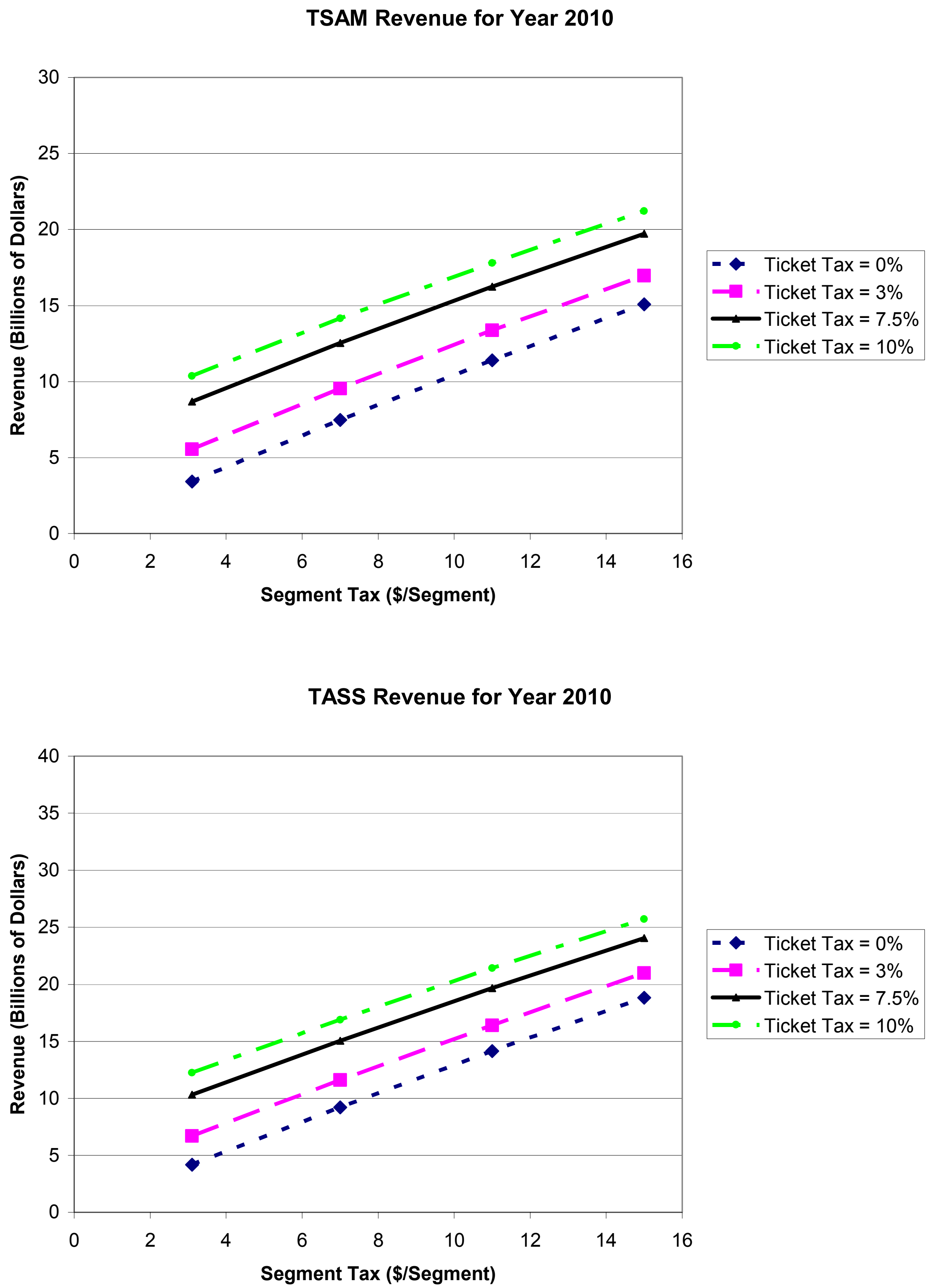
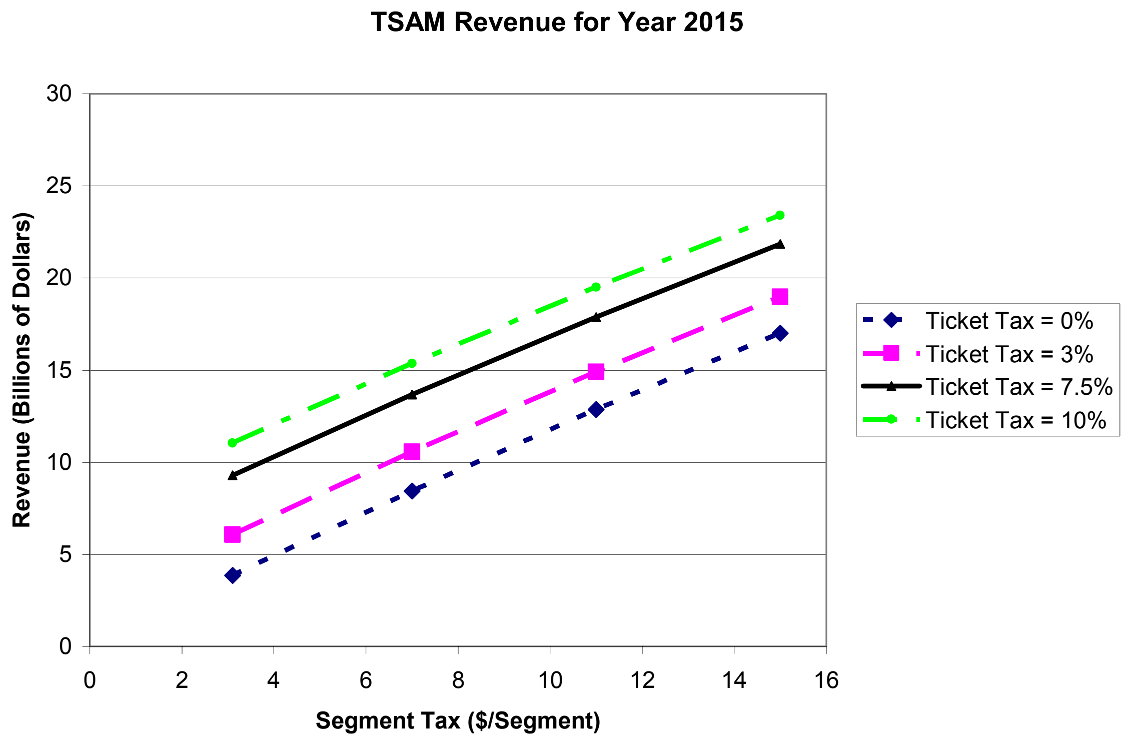


Figure 32. Revenue in Billions of Dollars for Year 2010 for (a) TSAM, and (b) TASS.



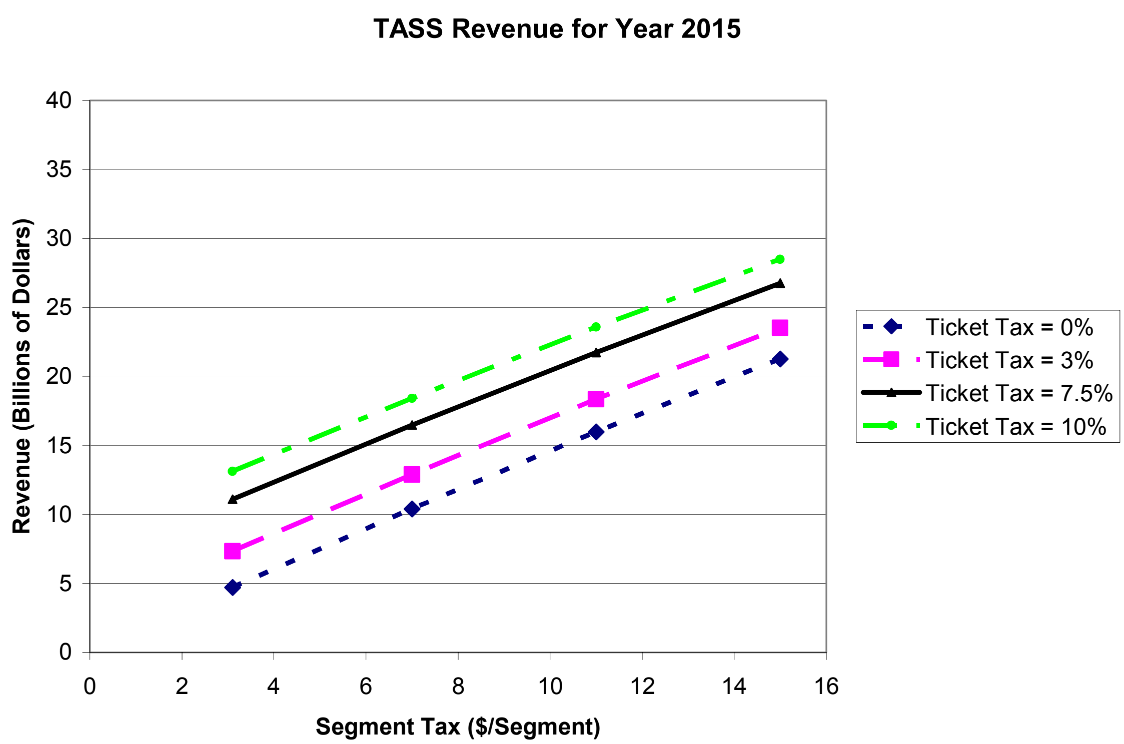
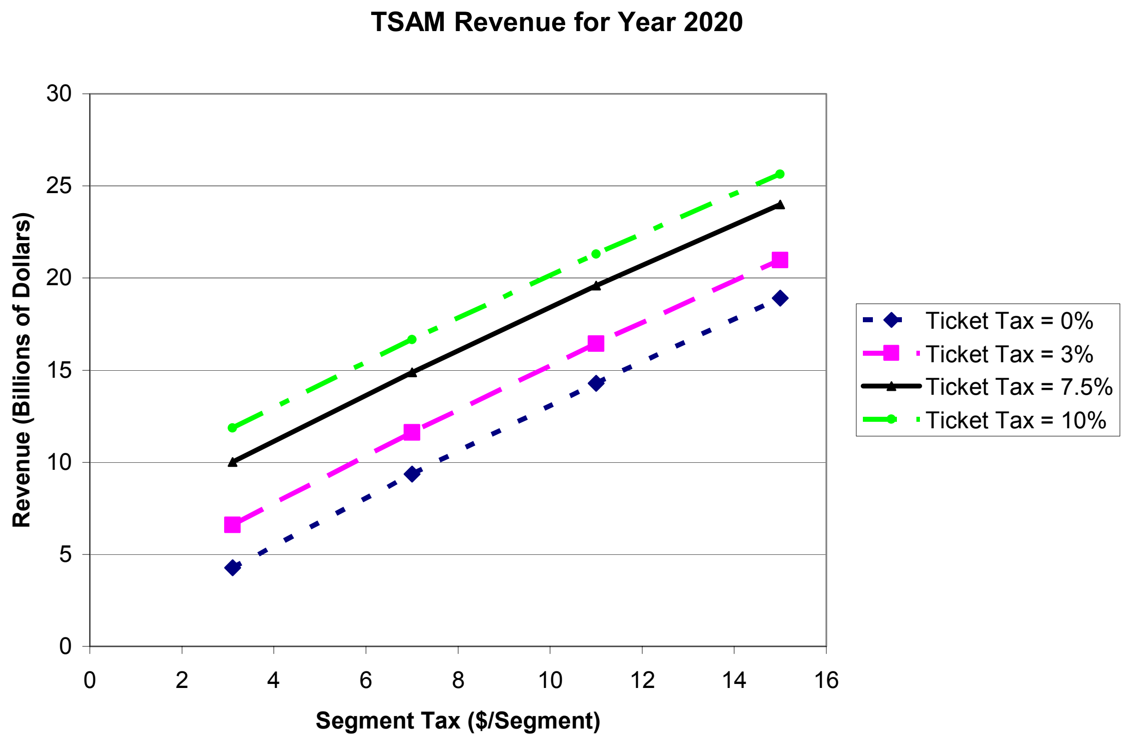


Figure 33. Revenue in Billions of Dollars for Year 2015 for (a) TSAM, and (b) TASS.



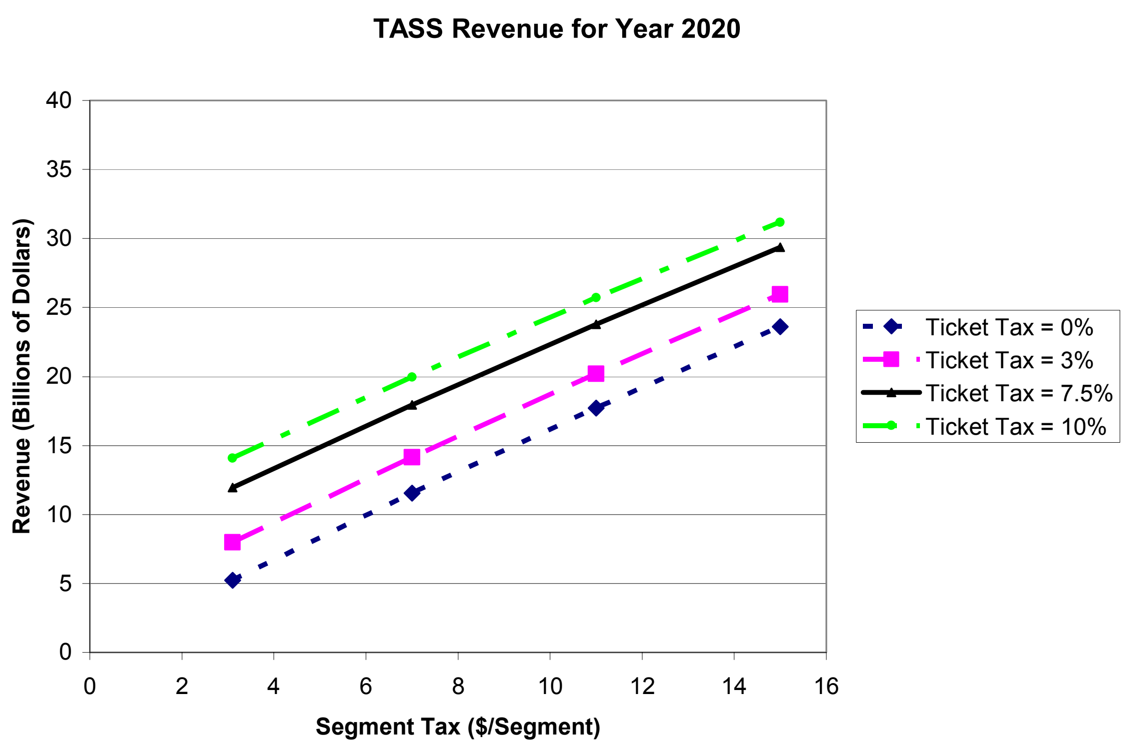


Figure 34. Revenue in Billions of Dollars for Year 2020 for (a) TSAM, and (b) TASS.

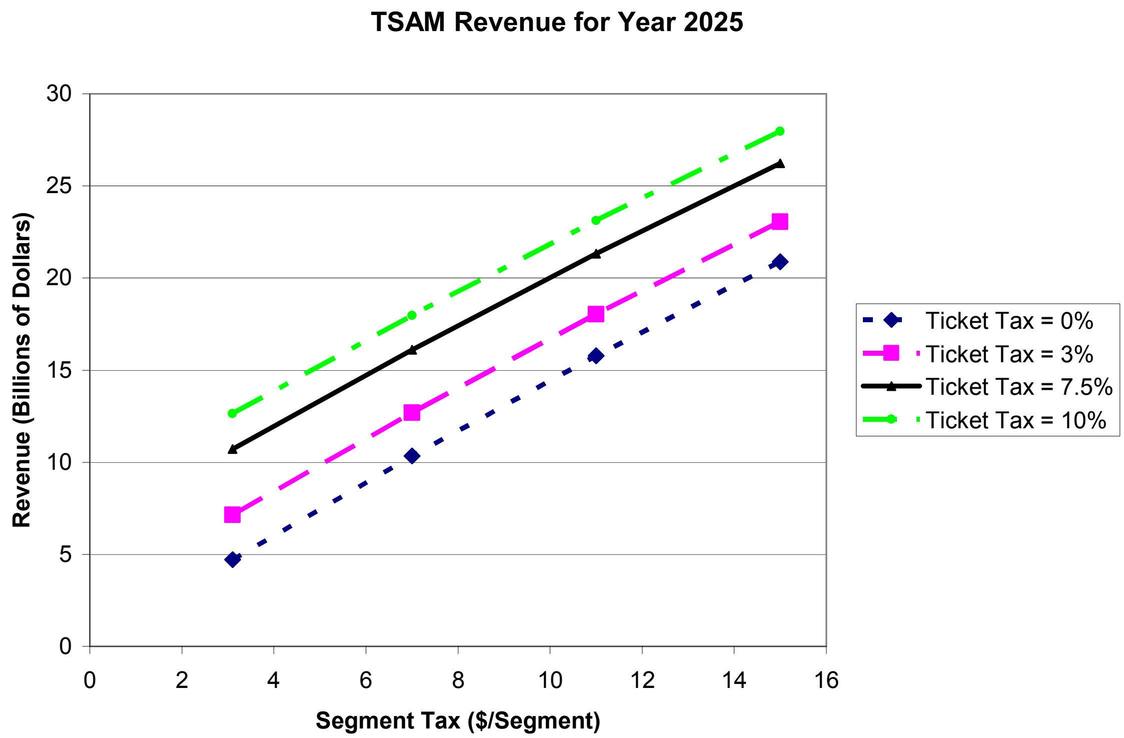


Figure 35. Revenue in Billions of Dollars for Year 2025 for (a) TSAM, and (b) TASS.

Appendix D Demand Elasticities

Table 6. TSAM Demand Elasticities for Years 2000 through 2025.

TSAM Demand Elasticities								
Elasticities Across Segment Taxes				Elasticities Across Ticket Taxes				
Year 2000				*Year 2000*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.579	-0.606	-0.635	0% -> 3%	-0.564	-0.586	-0.607	-0.629
3%	-0.594	-0.622	-0.650	3% -> 7.5%	-0.574	-0.596	-0.618	-0.639
7.50%	-0.617	-0.645	-0.673	7.5% -> 10%	-0.599	-0.621	-0.643	-0.663
10%	-0.630	-0.658	-0.685					
Year 2005				*Year 2005*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.484	-0.510	-0.538	0% -> 3%	-0.478	-0.499	-0.521	-0.542
3%	-0.496	-0.523	-0.551	3% -> 7.5%	-0.487	-0.508	-0.530	-0.551
7.50%	-0.515	-0.542	-0.570	7.5% -> 10%	-0.507	-0.528	-0.550	-0.572
10%	-0.525	-0.552	-0.580					
Year 2010				*Year 2010*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.402	-0.427	-0.452	0% -> 3%	-0.403	-0.422	-0.442	-0.462
3%	-0.411	-0.436	-0.462	3% -> 7.5%	-0.410	-0.430	-0.450	-0.469
7.50%	-0.425	-0.451	-0.477	7.5% -> 10%	-0.425	-0.445	-0.466	-0.486
10%	-0.433	-0.459	-0.485					
Year 2015				*Year 2015*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.370	-0.393	-0.417	0% -> 3%	-0.373	-0.391	-0.410	-0.428
3%	-0.378	-0.401	-0.426	3% -> 7.5%	-0.379	-0.397	-0.416	-0.435
7.50%	-0.390	-0.414	-0.439	7.5% -> 10%	-0.392	-0.410	-0.430	-0.449
10%	-0.397	-0.421	-0.446					
Year 2020				*Year 2020*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.351	-0.373	-0.396	0% -> 3%	-0.355	-0.371	-0.389	-0.406
3%	-0.358	-0.380	-0.403	3% -> 7.5%	-0.359	-0.376	-0.394	-0.412
7.50%	-0.369	-0.391	-0.415	7.5% -> 10%	-0.371	-0.389	-0.407	-0.425
10%	-0.375	-0.397	-0.421					
Year 2025				*Year 2025*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.333	-0.353	-0.375	0% -> 3%	-0.338	-0.353	-0.369	-0.385
3%	-0.339	-0.360	-0.382	3% -> 7.5%	-0.341	-0.357	-0.373	-0.390

7.50%	-0.349	-0.370	-0.392	7.5% -> 10%	-0.352	-0.368	-0.385	-0.401
10%	-0.354	-0.375	-0.398					

Table 7. TASS Demand Elasticities for Years 2000 through 2025.

TASS Demand Elasticities								
Elasticities Across Segment Taxes				Elasticities Across Ticket Taxes				
Year 2000				*Year 2000*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.596	-0.620	-0.644	0% -> 3%	-0.772	-0.802	-0.831	-0.861
3%	-0.611	-0.634	-0.658	3% -> 7.5%	-0.786	-0.815	-0.844	-0.873
7.50%	-0.633	-0.656	-0.680	7.5% -> 10%	-0.821	-0.849	-0.878	-0.907
10%	-0.645	-0.668	-0.692					
Year 2005				*Year 2005*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.504	-0.528	-0.552	0% -> 3%	-0.655	-0.685	-0.716	-0.747
3%	-0.517	-0.540	-0.565	3% -> 7.5%	-0.669	-0.699	-0.730	-0.760
7.50%	-0.536	-0.559	-0.584	7.5% -> 10%	-0.698	-0.728	-0.759	-0.789
10%	-0.546	-0.570	-0.594					
Year 2010				*Year 2010*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.415	-0.439	-0.464	0% -> 3%	-0.538	-0.569	-0.601	-0.633
3%	-0.426	-0.450	-0.475	3% -> 7.5%	-0.551	-0.582	-0.614	-0.645
7.50%	-0.443	-0.467	-0.492	7.5% -> 10%	-0.576	-0.608	-0.639	-0.670
10%	-0.452	-0.476	-0.500					
Year 2015				*Year 2015*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.379	-0.403	-0.428	0% -> 3%	-0.489	-0.521	-0.552	-0.584
3%	-0.389	-0.413	-0.438	3% -> 7.5%	-0.502	-0.533	-0.565	-0.597
7.50%	-0.404	-0.428	-0.453	7.5% -> 10%	-0.525	-0.556	-0.588	-0.619
10%	-0.412	-0.437	-0.461					
Year 2020				*Year 2020*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.356	-0.380	-0.405	0% -> 3%	-0.460	-0.491	-0.523	-0.555
3%	-0.366	-0.390	-0.415	3% -> 7.5%	-0.472	-0.503	-0.535	-0.567
7.50%	-0.381	-0.405	-0.429	7.5% -> 10%	-0.494	-0.525	-0.557	-0.588
10%	-0.389	-0.413	-0.437					
Year 2025				*Year 2025*				
	Segment Tax				Segment Tax			
Ticket Tax	$3.10 -> $7	$7 -> $11	$11 -> $15	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	-0.334	-0.358	-0.383	0% -> 3%	-0.430	-0.461	-0.493	-0.525
3%	-0.344	-0.368	-0.392	3% -> 7.5%	-0.442	-0.473	-0.505	-0.537
7.50%	-0.357	-0.381	-0.406	7.5% -> 10%	-0.462	-0.493	-0.525	-0.557
10%	-0.365	-0.389	-0.414					

Appendix E PPM versus RPM Tables

Table 8. TSAM PPM versus RPM Table for Each Year.

TSAM PPM and RPM Table for Each Year							
Index:	Reference number assigned to PPM and respective RPM value when PPM is ordered in ascending order						
PPM:	Price per passenger mile						
RPM:	Revenue passenger miles (miles)						
Tax Index:	Reference number for which ticket and segment taxes were applied (see table below)						
			Segment Tax				
	Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg		
	0%	1	2	3	4		
	3%	5	6	7	8		
	7.50%	9	10	11	12		
	10%	13	14	15	16		
YEAR 2000							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.26781	4.68E+11	467.80	1			
2	0.27347	4.63E+11	463.04	5			
3	0.27647	4.60E+11	459.59	2			
4	0.28194	4.56E+11	455.91	9			
5	0.28215	4.55E+11	454.84	6			
6	0.28527	4.51E+11	451.25	3			
7	0.28663	4.52E+11	451.96	13			
8	0.29064	4.48E+11	447.73	10			
9	0.29097	4.47E+11	446.52	7			
10	0.29399	4.43E+11	443.03	4			
11	0.29535	4.44E+11	443.79	14			
12	0.29949	4.39E+11	439.44	11			
13	0.2997	4.38E+11	438.31	8			
14	0.30421	4.36E+11	435.51	15			
15	0.30825	4.31E+11	431.26	12			
16	0.313	4.27E+11	427.36	16			
YEAR 2005							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.2355	5.44E+11	544.20	1			
2	0.24033	5.40E+11	539.91	5			
3	0.24417	5.35E+11	535.25	2			
4	0.24752	5.33E+11	533.47	9			
5	0.24899	5.31E+11	530.96	6			
6	0.2515	5.30E+11	529.90	13			

7	0.25294	5.26E+11	526.15	3			
8	0.25619	5.25E+11	524.52	10			
9	0.25778	5.22E+11	521.86	7			
10	0.26018	5.21E+11	520.95	14			
11	0.26162	5.17E+11	517.14	4			
12	0.26499	5.15E+11	515.43	11			
13	0.26646	5.13E+11	512.85	8			
14	0.26898	5.12E+11	511.86	15			
15	0.27369	5.06E+11	506.44	12			
16	0.27769	5.03E+11	502.88	16			
YEAR 2010							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.20528	6.25E+11	624.85	1			
2	0.20934	6.21E+11	621.08	5			
3	0.21398	6.15E+11	615.19	2			
4	0.21539	6.15E+11	615.44	9			
5	0.21803	6.11E+11	611.42	6			
6	0.21873	6.12E+11	612.31	13			
7	0.22278	6.05E+11	605.35	3			
8	0.22409	6.06E+11	605.78	10			
9	0.22684	6.02E+11	601.59	7			
10	0.22743	6.03E+11	602.64	14			
11	0.23146	5.96E+11	595.60	4			
12	0.23289	5.96E+11	595.94	11			
13	0.23552	5.92E+11	591.83	8			
14	0.23624	5.93E+11	592.81	15			
15	0.24158	5.86E+11	586.19	12			
16	0.24493	5.83E+11	583.06	16			
YEAR 2015							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.19408	6.94E+11	693.85	1			
2	0.19787	6.90E+11	690.14	5			
3	0.20285	6.83E+11	683.45	2			
4	0.20352	6.85E+11	684.61	9			
5	0.20663	6.80E+11	679.75	6			
6	0.20664	6.82E+11	681.53	13			
7	0.2117	6.73E+11	672.88	3			
8	0.21227	6.74E+11	674.22	10			
9	0.21539	6.71E+11	671.16	14			
10	0.21548	6.69E+11	669.19	7			
11	0.22042	6.62E+11	662.39	4			
12	0.22111	6.64E+11	663.66	11			
13	0.2242	6.59E+11	658.70	8			
14	0.22423	6.61E+11	660.59	15			
15	0.22984	6.53E+11	653.18	12			
16	0.23296	6.50E+11	650.11	16			

YEAR 2020							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.18823	7.62E+11	761.72	1			
2	0.19188	7.58E+11	757.96	5			
3	0.19706	7.51E+11	750.57	2			
4	0.19733	7.52E+11	752.35	9			
5	0.20034	7.49E+11	749.25	13			
6	0.20071	7.47E+11	746.84	6			
7	0.20597	7.39E+11	739.26	3			
8	0.20614	7.41E+11	741.25	10			
9	0.20914	7.38E+11	738.15	14			
10	0.20961	7.36E+11	735.54	7			
11	0.21475	7.28E+11	728.05	4			
12	0.21504	7.30E+11	729.96	11			
13	0.21804	7.27E+11	726.87	15			
14	0.21839	7.24E+11	724.34	8			
15	0.22382	7.19E+11	718.76	12			
16	0.22682	7.16E+11	715.67	16			
YEAR 2025							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.18227	8.32E+11	831.62	1			
2	0.18579	8.28E+11	827.83	5			
3	0.19103	8.22E+11	822.19	9			
4	0.19119	8.20E+11	819.72	2			
5	0.19393	8.19E+11	819.07	13			
6	0.1947	8.16E+11	815.97	6			
7	0.19992	8.10E+11	810.37	10			
8	0.20018	8.08E+11	807.68	3			
9	0.20281	8.07E+11	807.26	14			
10	0.20367	8.04E+11	803.95	7			
11	0.20888	7.98E+11	798.37	11			
12	0.20902	7.96E+11	795.76	4			
13	0.21177	7.95E+11	795.27	15			
14	0.21251	7.92E+11	792.04	8			
15	0.21772	7.86E+11	786.47	12			
16	0.2206	7.83E+11	783.38	16			

Table 9. TASS PPM versus RPM Table for Each Year.

TASS PPM and RPM Table for Each Year

Index:	Reference number assigned to PPM and respective RPM value when PPM is ordered in ascending order
PPM:	Price per passenger mile
RPM:	Revenue passenger miles (miles)
Tax Index:	Reference number for which ticket and segment taxes were applied (see table below)

		Segment Tax		
Ticket Tax	$3.10/leg	$7/leg	$11/leg	$15/leg
0%	1	2	3	4
3%	5	6	7	8
7.50%	9	10	11	12
10%	13	14	15	16

YEAR 2000							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.36574	5.00E+11	500.26	1			
2	0.37034	4.95E+11	495.06	5			
3	0.37408	4.94E+11	493.66	2			
4	0.37683	4.87E+11	487.34	9			
5	0.37847	4.88E+11	488.49	6			
6	0.38022	4.83E+11	483.08	13			
7	0.38242	4.87E+11	486.92	3			
8	0.38465	4.81E+11	480.81	10			
9	0.38661	4.82E+11	481.78	7			
10	0.38788	4.77E+11	476.58	14			
11	0.39055	4.80E+11	480.22	4			
12	0.39248	4.74E+11	474.15	11			
13	0.39453	4.75E+11	475.11	8			
14	0.39555	4.70E+11	469.95	15			
15	0.40011	4.68E+11	467.53	12			
16	0.40301	4.63E+11	463.35	16			
YEAR 2005							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.33223	5.82E+11	582.17	1			
2	0.33727	5.77E+11	577.25	5			
3	0.34189	5.75E+11	574.79	2			
4	0.34448	5.70E+11	569.93	9			
5	0.34673	5.70E+11	569.90	6			
6	0.34829	5.66E+11	565.90	13			
7	0.35155	5.67E+11	567.25	3			
8	0.35363	5.63E+11	562.62	10			
9	0.35618	5.62E+11	562.38	7			
10	0.35729	5.59E+11	558.61	14			
11	0.36097	5.60E+11	559.74	4			

12	0.36278	5.55E+11	555.14	11			
13	0.3654	5.55E+11	554.89	8			
14	0.36628	5.51E+11	551.15	15			
15	0.37171	5.48E+11	547.70	12			
16	0.37505	5.44E+11	543.73	16			
YEAR 2010							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.29376	6.70E+11	670.16	1			
2	0.29895	6.66E+11	665.63	5			
3	0.30479	6.62E+11	661.98	2			
4	0.30644	6.59E+11	658.88	9			
5	0.30979	6.57E+11	657.47	6			
6	0.31046	6.55E+11	655.15	13			
7	0.31583	6.54E+11	653.61	3			
8	0.31701	6.51E+11	650.75	10			
9	0.32064	6.49E+11	649.12	7			
10	0.32087	6.47E+11	647.04	14			
11	0.3266	6.45E+11	645.26	4			
12	0.32758	6.42E+11	642.43	11			
13	0.33123	6.41E+11	640.79	8			
14	0.3313	6.39E+11	638.74	15			
15	0.3379	6.34E+11	634.14	12			
16	0.34147	6.30E+11	630.47	16			
YEAR 2015							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.27591	7.44E+11	744.49	1			
2	0.28105	7.40E+11	739.94	5			
3	0.2875	7.36E+11	735.56	2			
4	0.28851	7.33E+11	733.17	9			
5	0.29246	7.31E+11	731.04	6			
6	0.29252	7.29E+11	729.43	13			
7	0.2991	7.26E+11	726.43	3			
8	0.29965	7.24E+11	724.29	10			
9	0.30352	7.21E+11	720.57	14			
10	0.30388	7.22E+11	721.92	7			
11	0.31043	7.17E+11	717.31	4			
12	0.31081	7.15E+11	715.20	11			
13	0.31454	7.12E+11	711.50	15			
14	0.31504	7.13E+11	712.82	8			
15	0.3217	7.06E+11	706.14	12			
16	0.32529	7.02E+11	702.45	16			
YEAR 2020							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.26451	8.17E+11	816.94	1			
2	0.26959	8.12E+11	812.27	5			

3	0.27643	8.07E+11	807.26	2			
4	0.27697	8.05E+11	805.30	9			
5	0.28095	8.01E+11	801.46	13			
6	0.28133	8.03E+11	802.61	6			
7	0.28836	7.97E+11	797.35	3			
8	0.28846	7.96E+11	795.67	10			
9	0.2923	7.92E+11	791.84	14			
10	0.29309	7.93E+11	792.72	7			
11	0.29997	7.86E+11	785.81	11			
12	0.30001	7.87E+11	787.46	4			
13	0.30367	7.82E+11	782.00	15			
14	0.30457	7.83E+11	782.85	8			
15	0.3112	7.76E+11	775.97	12			
16	0.31477	7.72E+11	772.18	16			
YEAR 2025							
Index	**PPM**	**RPM**	**RPM**	**Tax Index**			
	($/mile)	**(miles)**	**(miles [billions])**				
1	0.25271	8.92E+11	891.62	1			
2	0.2577	8.87E+11	886.86	5			
3	0.26496	8.81E+11	881.18	2			
4	0.26497	8.80E+11	879.76	9			
5	0.2689	8.76E+11	875.84	13			
6	0.26978	8.76E+11	876.44	6			
7	0.27681	8.69E+11	869.37	10			
8	0.27723	8.70E+11	870.48	3			
9	0.28062	8.65E+11	865.46	14			
10	0.2819	8.66E+11	865.76	7			
11	0.28868	8.59E+11	858.71	11			
12	0.28922	8.60E+11	859.80	4			
13	0.29235	8.55E+11	854.83	15			
14	0.29372	8.55E+11	855.09	8			
15	0.30027	8.48E+11	848.08	12			
16	0.30381	8.44E+11	844.21	16			

Appendix F Procedure for Setting up TSAM Runs

The procedure to create the fare tables that TSAM requires and to set up TSAM runs for the Strategy Simulator project are listed below.

1. Change the following variables in the Matlab M-file "compute_fares_withtax.m" as needed:
    a. *input_dir* = the input directory that contains the following files required to run "compute_fares_withtax.m":
        i. averageFare_CA_Business_TSAM.mat = the original 5 x 443 x 443 business fare table from TSAM
        ii. averageFare_CA_NonBusiness_TSAM.mat = the original 5 x 443 x 443 non-business fare table from TSAM
        iii. avesegments_roundtrip.mat = a 443 x 443 matrix of the average number of segments for each O-D pair
    b. *output_dir* = the output directory that all output files will be saved
    c. *ticket_tax* = a 1 x 4 matrix that contains four different ticket taxes to be tested
    d. *segment_tax* = a 1 x 4 matrix that contains four different segment taxes to be tested
    e. *fare_factor* = the fare scaling factor for each year
    f. *tixtax_name* = a 1 x 4 cell array that contains strings for the name of each ticket tax, i.e., {'0' '3' '7p5' '10'}. This variable is used when saving each tax scenario.

g. *segtax_name* = a 1 x 4 cell array that contains strings for the name of each segment tax, i.e., {'3p1' '7' '11' '15'}. This variable is used when saving each tax scenario.

2. Run the Matlab M-file "compute_fares_withtax.m" by typing "compute_fares_withtax" in the Matlab command window. The program should generate all the fare tables for every tax and year scenario and store them in the output directory.
3. Go to the output directory that stores all the new fare tables. Copy the business and non-business fare tables that will be run in TSAM.
4. Go to the mode choice input folder. The mode choice input directory is typically found in the directory " C:\Program Files\TSAM for SATS 3.42\data\mode_choice\input". Delete the existing fare tables in this folder; the business fare table is called "averageFare_CA_Business.mat", and the non-business fare table is called "averageFare_CA_NonBusiness.mat". *NOTE*: Instead of completely deleting the original TSAM fare tables, it is recommended that these files be copied into a separate folder.
5. Copy the fare tables with new taxes included into the TSAM mode choice input folder.
6. Rename the new fare tables to averageFare_CA_Business.mat" and "averageFare_CA_NonBusiness.mat".
7. Open the TSAM program.
8. Go to File -> Open Project... Open the project called "SATS Project".

9. Go to Mode Choice -> All Counties to All Counties -> Create New Case Folder... Create a new folder for the tax and year scenario being analyzed. One suggestion for an appropriate case folder name is "TSAMrun_Ttax7p5_Stax3p1_2005", which represents the scenario where ticket tax is 7.5%, segment tax is $3.10/segment, and the year is 2005.
10. Go to the newly created case folder and select "Run New Case". Click "OK" for the warning that states that a "No SATS" case must be run first - the Strategy Simulator does not consider the SATS scenario as yet and therefore does not require SATS considerations.
11. Select "No SATS Case", the year being analyzed, and "Business". Add this scenario to the batch process by clicking on the button "Add to Batch Process". Do the same for the trip type "Non-Business". *NOTE*: TSAM will automatically default to "SATS Case" once one case has been added to the batch process. Unless a SATS case is required, make sure to choose "No SATS Case" in order to reduce computation time and to obtain relevant results for the Strategy Simulator project.
12. Click on the button "Run Batch Process". Make sure that the scenarios listed in the batch process are the correct scenarios. Click "Run Batch Process" in the pop-up window that appears.

Appendix G   TSAM and TASS Matlab Files

The following table lists the Matlab programs used to generate input files for TSAM and TASS, the files required to run TASS, and files that analyze and display TSAM and TASS output. The Matlab program name and description are included in the table. All of these files can be found on the ATSL server under "Users -> stephaniechung -> Public -> Drop Box -> SSresearch -> Matlab(SS)".

Table 10. Matlab Programs Used for TSAM and TASS Runs.

Variable Name	**Description**
Matlab Programs that Generate TSAM Input	
compute_fares_withtax.m	Generates fare tables for TSAM • includes ticket tax and segment tax • includes fare scaling factor for every year
Matlab Programs that Generate TASS Input	
aggregate_tripdistribution.m	Aggregates TSAM trip distribution into TASS county clusters for multiple years
TSAMdatamanipulation.m	Manipulates TSAM data into TASS structure: • aggregates TSAM trip distribution into TASS county clusters • averages TSAM fare tables into one fare table for TASS •
SSdatamanipulation.m	Creates and formats input files required for TASS: • assigns all counties to closest airport • reformats county cluster file to airport-centric struct array • assign three candidate airports for each airport-centric cluster based on TSAM candidate airport data files • find driving distance and time from airport-centric cluster to its candidate airports • find hub type of candidate airports • assign an MSA indicator to airport
Matlab Programs Required to Run TASS	
TASS_modechoice.m	Main function of TASS that is called from the command window. Loads and defines all files and variables required to run TASS

createModeChoiceTable_SS.m	Calculates necessary data for nested logit function and calls various functions: • computes drive distance time for automobile • calls function "selectcandidateairports_CA_SS.m" • calls function "nestedLogitFunction_SS.m" • adjusts airfare for different tax scenarios • saves output data
selectcandidateairports_CA_SS.m	Calculates travel time and cost data for candidate airports: • calculates inbound and outbound flight times for every combination of candidate airports • calculates access and egress times and costs for every combination of candidate airports • calculates fares for every combination of candidate airports
nestedLogitFunction_SS.m	Calculates probabilities for each mode choice (auto and commercial aviation) and for each route for commercial aviation mode
Matlab Programs that Analyze TSAM Output	
analyze_TSAMrunyears.m	Calculates output variables from TSAM results: • loads all tax and year scenarios • calculates demand (number of round trips), RPMs, PPMs, revenue, and weighted average fare • calculates elasticities between tax scenarios for demand, RPMs, and revenue • saves output variables
Matlab Programs that Analyze TASS Output	
analyze_TASSruns.m	Calculates output variables from TASS results: • loads all tax and year scenarios • calculates demand (number of round trips), RPMs, PPMs, revenue, and weighted average fare • calculates elasticities between tax scenarios for demand, RPMs, and revenue • saves output variables

Appendix H TASS Inputs

The following table lists the TASS inputs that users are able to change. The variable name, type, and description of the variable are included in the table.

Table 11. TASS Inputs.

Variable Name	Type	Description
Constants and Vectors		
Input_Dir	string	input directory containing all input files
main_output_dir	string	output directory where all output files are saved
base_tickettax	number	original ticket tax (Year 2000)
new_tickettax	1 x 4 matrix	4 new ticket taxes
base_segmenttax	number	original segment tax (Year 2000)
new_segmenttax	1 x 4 matrix	4 new segment taxes
years	1 x 6 cell array (filled with strings)	6 strings for 6 years, i.e., 2005 is '2005'
fare_factor	1 x 6 matrix	6 fare factors to apply to fare table for each year
biz_percentage	number (decimal)	percent business air travelers
nonbiz_percentage	number (decimal)	percent non-business air travelers
income_percentages	1 x 5 matrix (decimal)	5 percentages for each income bracket (should total 1)
oneDayLodgingCost_biz	number	cost for one day of lodging for business travelers
oneDayLodgingCost_nonbiz	number	cost for one day of lodging for non-business travelers
additionalDay_auto	number	number of hours penalty if auto trip exceeds maximum daily number of hours driving
waitingAtOriginAirport_CA	1 x 4 matrix	waiting time in hours for each origin airport hub type
waitingAtDestntAirport_CA	1 x 4 matrix	waiting time in hours for each destination airport hub type
avgOccupancy_auto	number	average occupancy in an automobile
Data Files		
APTcluster_APTlist	1 x 443 struct array	struct array of airport clusters with the following fields: • airport number • airport ID

		• airport hub type • yearly departures • county FIPS that airport is in • county number of counties grouped to airport • county FIPS of counties grouped to airport • drive distance (empty) • drive time (empty)
parameters	8 x 1 matrix	
APTclust_trip_distribution_(year)	443 x 443 matrix	number of trips distributed between each airport cluster
averageall_fares	443 x 443 matrix	weighted average fare table between each airport
avesegments_roundtrip	443 x 443 matrix	average segments between each airport
A2A_CA_TravelTime	443 x 443 matrix	flight time between each airport
A2A_CA_Schedule_Delay	443 x 443 matrix	schedule delay between each airport
distA2A_CA_443	443 x 443 matrix	GCD distance between each airport
APT2APT_driveinfo	file of 3 variables: • APT2APT_drivedist (443 x 443 matrix) • APT2APT_drivetime (443 x 443 matrix) • APT2APT_triptime (443 x 443 matrix)	file containing 3 variables: • drive distance between each airport • drive time between each airport • trip time between each airport
APTmsaindicator	443 x 2 matrix	matrix that stores whether an airport is within an MSA area or not (if unknown, value is -999; 0 or 1 otherwise)
APTclust_candAPT100_APTnum	443 x 3 matrix	3 candidate airports assigned to airport cluster (100-mile radius)
APTclust_candAPT100_drivedist	443 x 3 matrix	drive distance from candidate airports to airport in airport cluster (100-mile radius)
APTclust_candAPT100_drivetime	443 x 3 matrix	drive time from candidate airports to airport in airport

		cluster (100-mile radius)
APTclust_candAPT100_hubtype	443 x 3 matrix	hub type of candidate airports assigned to airport cluster (100-mile radius)
APTclust_candAPT200_APTnum	443 x 3 matrix	3 candidate airports assigned to airport cluster (200-mile radius)
APTclust_candAPT200_drivedist	443 x 3 matrix	drive distance from candidate airports to airport in airport cluster (200-mile radius)
APTclust_candAPT200_drivetime	443 x 3 matrix	drive time from candidate airports to airport in airport cluster (200-mile radius)
APTclust_candAPT200_hubtype	443 x 3 matrix	hub type of candidate airports assigned to airport cluster (200-mile radius)