Air Carrier E-surance (ACE):

Design of Insurance for Airline EC-261 Claims

Project Final Report

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1.0 Introduction

The European Union (EU) successfully passed a consumer protection regulation for airline passengers. This European Commission Regulation 261/2004 (EC-261/04) is a regulation that establishes common rules for airlines based in the EU or servicing EU airports to compensate and assist passengers for delayed flights, cancelled flights, denied boarding (i.e. oversold flights). The regulation has caused the need for airline adjustments to both their schedule and protocols. With airline costs growing, there are more incentives to improve performance. This regulation also gives consumers recourse to address abuses by airlines. EC-261/04 went into effect in Europe on 17 February 2005.

As consumers become more aware of the regulation, airline costs are going to increase and could exceed 5% of the total direct operating costs. Further, these costs are variable costs and are difficult for the airlines to account for in their budgets. Litigation has resulted in consumer-friendly rulings. This proposal is for airlines to have a way to hedge against excessive compensation and move variable cost to fixed costs.

2.0 Problem Statement

2.1 Given

- European Union (EU) airline passengers' protection regulation EC-261
- Airlines must compensate passengers for delayed flights, cancelled flights, or denied boarding
- As consumers become more aware of the regulation, airline costs are going to increase and could exceed 5% of the total direct operating costs

2.2 Problem Statement

1. Design an EC-261 insurance system for airlines
2. The system shall be automated (automated payout based on real time flight performance data) and web-based
3. The system must yield at least a 5% profit more than 99% of the time

2.3 By choice of

- Burning cost model
- Ruin model
- Insurance premium assessment

2.4 Subject to

- DCA historical flight data
- Real-time flight assessment constraints

3.0 Compensation Rules

The penalties associated with the various compensation events of the EC-261 Regulation are shown in Table 1 below. You are not entitled to compensation if the airline notified you about the cancelation 14 days or more before the scheduled flight (or if the airline offered an alternative for the same route and a similar schedule to the original flight).

For cancellations that occur due to extraordinary circumstances, the airline must still arrange for one of the following:

- A ticket refund (in full or for the part you couldn’t use)
- The soonest possible alternative transport to your final destination
- A new ticket for the later date of your preference, subject to seat availability

Even in extraordinary circumstances, airlines must provide assistance when needed while you are waiting for your alternative transport.

Table 1 EU EC-261 Compensation Rates

DEFINITIONS	DELAY (at final destination after potential rebooking and/or re-routing)					**Flight Type**
	Less than 2 Hours	**More than 2 Hours**	**More than 3 hours**	**More than 4 Hours**	**Never Arrived**	
Delayed	€ 0	€ 0	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 0	€ 400	€ 400	€ 400	Type 2
	€ 0	€ 0	€ 600	€ 600	€ 600	Type 3
Cancelled	€ 0	€ 250	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 200	€ 200	€ 400	€ 400	Type 2
	€ 0	€ 300	€ 300	€ 600	€ 600	Type 3
Overbooked	€ 0	€ 0	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 0	€ 400	€ 400	€ 400	Type 2
	€ 0	€ 0	€ 600	€ 600	€ 600	Type 3

These events are broken down by Flight Type, which are defined in EC-261, in the following sections.

3.1 Flight Type Definitions

3.1.1 Type 1

Type 1 flights are flights that are less than 1,500 kilometers in distance from the airport.

3.1.2 Type 2

Type 2 flights include domestic flights that are greater than 1,500 kilometers or international flights greater than 1,500 kilometers, but less than 3,500 kilometers in distance from the airport. This instance of the project is ignoring international flights for simplicity.

3.1.3 Type 3

Type 3 flights are internationals flights that are greater than 3,500 kilometers in distance from the airport. This instance of the project is ignoring international flights for simplicity.

3.2 Flight Definitions

3.2.1 Delay

1. When an operating air carrier reasonably expects a flight to be delayed beyond its scheduled time of departure:

    (a) For two hours or more in the case of flights of 1,500 kilometers (approx. 932 miles) or less; or

    (b) For three hours or more in the case of all intra-Community flights of more than 1 500 kilometers and of all other flights between 1,500 and 3,500 kilometers (approx. 2,175 miles); or

    (c) For four hours or more in the case of all flights not falling under (a) or (b)

Passengers shall be offered by the operating air carrier:

(i) The assistance specified in Article 9(1) (a) and 9(2); and

(ii) When the reasonably expected time of departure is at least the day after the time of departure previously announced, the assistance specified in Article 9(1)(b) and 9(1)(c); and

(iii) When the delay is at least five hours, the assistance specified in Article 8(1) (a).

2. In any event, the assistance shall be offered within the time limits set out above with respect to each distance bracket.

3.2.2 Cancellation

1. In case of cancellation of a flight, the passengers concerned shall:

    (a) Be offered assistance by the operating air carrier in accordance with Article 8; and

    (b) Be offered assistance by the operating air carrier in accordance with Article 9(1) (a) and 9(2), as well as, in event of rerouting when the reasonably expected time of departure of the new flight is at least the day after the departure as it was planned for the cancelled flight, the assistance specified in Article 9(1) (b) and 9(1) (c); and

    (c) Have the right to compensation by the operating air carrier in accordance with Article 7, unless:

        (i) They are informed of the cancellation at least two weeks before the scheduled time of departure; or

(ii) They are informed of the cancellation between two weeks and seven days before the scheduled time of departure and are offered re-routing, allowing them to depart no more than two hours before the scheduled time of departure and to reach their final destination less than four hours after the scheduled time of arrival; or

(iii) They are informed of the cancellation less than seven days before the scheduled time of departure and are offered re-routing, allowing them to depart no more than one hour before the scheduled time of departure and to reach their final destination less than two hours after the scheduled time of arrival.

2. When passengers are informed of the cancellation, an explanation shall be given concerning possible alternative transport.

3. An operating air carrier shall not be obliged to pay compensation in accordance with Article 7, if it can prove that the cancellation is caused by extraordinary circumstances that could not have been avoided even if all reasonable measures had been taken.

4. The burden of proof concerning the questions as to whether and when the passenger has been informed of the cancellation of the flight shall rest with the operating air carrier.

3.2.3 Denied Boarding

1. When an operating air carrier reasonably expects to deny boarding on a flight, it shall first call for volunteers to surrender their reservations in exchange for benefits under conditions to be agreed between the passenger concerned and the operating air carrier. Volunteers shall be assisted in accordance with Article 8, such assistance being additional to the benefits mentioned in this paragraph.

2. If an insufficient number of volunteers comes forward to allow the remaining passengers with reservations to board the flight, the operating air carrier may then deny boarding to passengers against their will.

3. If boarding is denied to passengers against their will, the operating air carrier shall immediately compensate them in accordance with Article 7 and assist them in accordance with Articles 8 and 9.

3.3 Article Definitions

3.3.1 Article 7 – Right to Compensation

1. Where reference is made to this Article, passengers shall receive compensation amounting to:

   (a) EUR 250 (278.99 USD) for all flights of 1,500 kilometers (approx. 932 miles) or less;

   (b) EUR 400 (446.38 USD) for all intra-Community flights of more than 1,500 kilometers, and for all other flights between 1,500 and 3,500 kilometers (approx. 2,175 miles);

   (c) EUR 600 (669.57 USD) for all flights not falling under (a) or (b).

   In determining the distance, the basis shall be the last destination at which the denial of boarding or cancellation will delay the passenger's arrival after the scheduled time.

2. When passengers are offered re-routing to their final destination on an alternative flight pursuant to Article 8, the arrival time of which does not exceed the scheduled arrival time of the flight originally booked

   (a) By two hours, in respect of all flights of 1,500 kilometers or less; or

   (b) By three hours, in respect of all intra-Community flights of more than 1,500 kilometers and for all other flights between 1,500 and 3,500 kilometers; or

   (c) By four hours, in respect of all flights not falling under (a) or (b), the operating air carrier may reduce the compensation provided for in paragraph 1 by 50 %.

3. The compensation referred to in paragraph 1 shall be paid in cash, by electronic bank transfer, bank orders or bank checks or, with the signed agreement of the passenger, in travel vouchers and/or other services.

4. The distances given in paragraphs 1 and 2 shall be measured by the great circle route method (shortest distance).

3.3.2 Article 8 – Right to Reimbursement or Re-routing

1. Where reference is made to this Article, passengers shall be offered the choice between:

   (a) Reimbursement within seven days, by the means provided for in Article 7(3), of the full cost of the ticket at the price at which it was bought, for the part or parts of the journey not made, and for the part or parts already made if the flight is no longer serving any purpose in relation to the passenger's original travel plan, together with, when relevant, — a return flight to the first point of departure, at the earliest opportunity;

   (b) Re-routing, under comparable transport conditions, to their final destination at the earliest opportunity; or

(c) Re-routing, under comparable transport conditions, to their final destination at a later date at the passenger's convenience, subject to availability of seats.

2. Paragraph 1(a) shall also apply to passengers whose flights form part of a package, except for the right to reimbursement where such right arises under Directive 90/314/EEC.

3. When, in the case where a town, city or region is served by several airports, an operating air carrier offers a passenger a flight to an airport alternative to that for which the booking was made, the operating air carrier shall bear the cost of transferring the passenger from that alternative airport either to that for which the booking was made, or to another close-by destination agreed with the passenger.

3.3.3 Article 9 – Right to Care

1. Where reference is made to this Article, passengers shall be offered free of charge:

(a) Meals and refreshments in a reasonable relation to the waiting time;

(b) Hotel accommodation in cases — where a stay of one or more nights becomes necessary, or — where a stay additional to that intended by the passenger becomes necessary;

(c) Transport between the airport and place of accommodation (hotel or other).

2. In addition, passengers shall be offered free of charge two telephone calls, telex or fax messages, or e-mails.

3. In applying this Article, the operating air carrier shall pay particular attention to the needs of persons with reduced mobility and any persons accompanying them, as well as to the needs of unaccompanied children.

4.0 Deliverables

The following items are the deliverables requested by the project sponsor:

- Document the complete compensation rules for EC-261
- Document the transactions and processes that must be conducted to calculate premiums, sell insurance contracts, and payout the insurance
- Analyze the probabilities of compensation events for each major airline operating at DCA
- Calculate premiums for airline insurance based on their historic flight performance and event probabilities using insurance models (e.g. Burning Cost Model and Ruin Model)
- Conduct a sensitivity analysis on the insurance models to meet profit performance targets
- Design and prototype the Web-based/Automated insurance processing system

These tasks do not include the course deliverables as defined in the syllabus.

5.0 Related Work and Methodologies:

Currently there are no products or services that exist to insure airlines against EC-261/04 claims from passengers. Costs are forecasted internally by airlines to potentially cover any compensation provided to passengers that may file an EC-261/04 claim.

The analysis approach was the following:

1. Analyze existing flight data for DCA arrivals (chosen as representative airport by sponsor)
2. Assess probabilities of compensation events
3. Use compensation probabilities to build cost models and premium assessment
4. Develop lightweight web interface as a prototype
5. Develop charts and descriptive documents to fully detail system functionality (companion to those portions that will be prototyped)

6.0 Schedule and Approach

The schedule for this project was broken down into the following major sections, or task-groupings:

- Deliverables
- Research
- System Analysis
- System Design

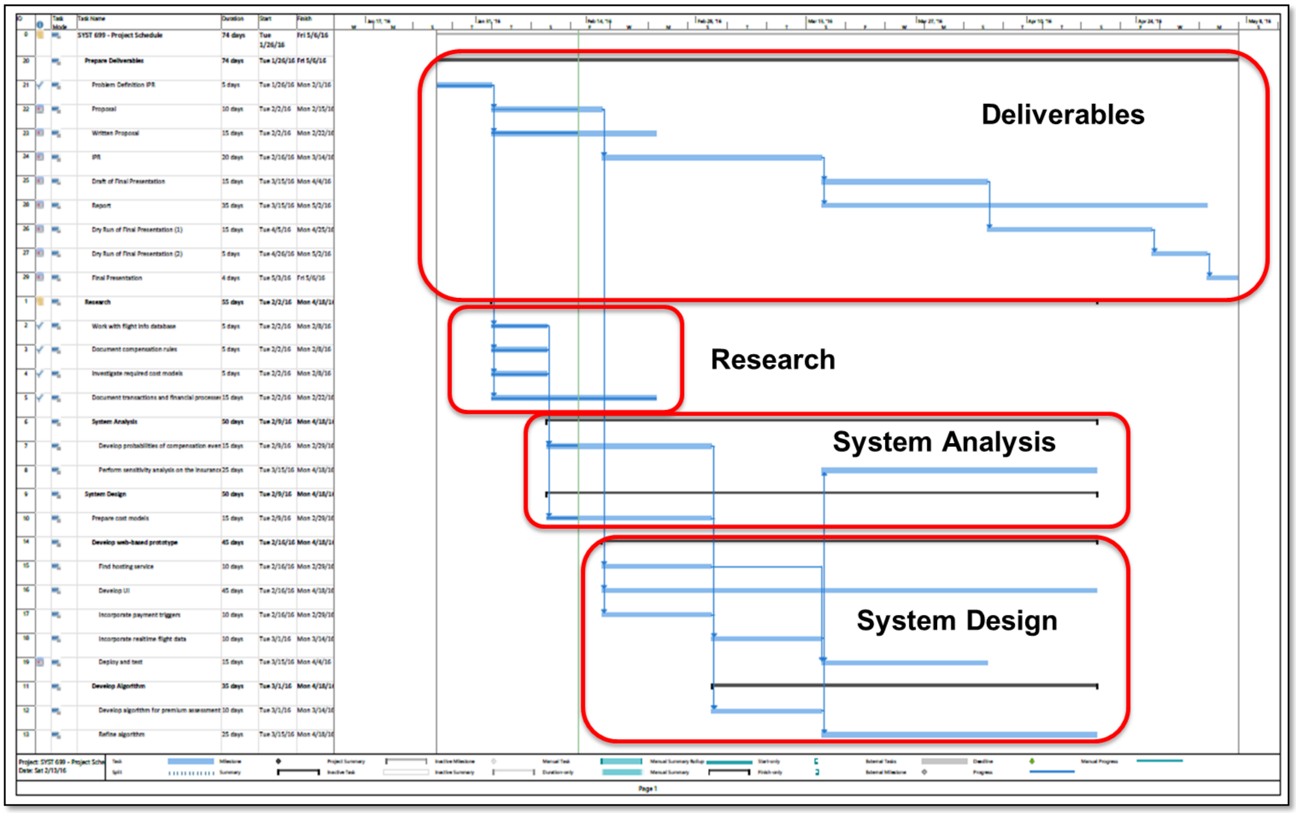


Figure 1 Project Schedule

These groupings were necessarily interconnected, and so tasks from each must be accomplished simultaneously. The schedule for deliverables was dictated by the constraints of the course as outlined in the syllabus. The other groupings were arranged so that course deliverables could be completed in a timely fashion.

The research tasks include the following, and have been completed:

- Work with the flight-information database
- Document compensation rules for EC-261
- Investigate required cost models
- Document transactions and financial processes

The first System Analysis task completed was to develop a set of probabilities for the various compensation events, which was completed in conjunction with the development of the cost models under the System Design umbrella (since the compensation probabilities will be used as the inputs to the cost model). Once these tasks were underway, the team began to develop the web-based prototype of the system (one of the required deliverables for the project sponsor). Part of this development includes designing the web pages, as well as deciding where to host the prototype web server. These tasks were completed by March 1st.

Once preliminary work on the cost models and compensation analysis was completed, the team finalized and tested an algorithm for assessing insurance premiums. This was completed in conjunction with testing the cost models by incorporating “real-time” flight data. Due to payment constraints for many readily available flight-tracking services, initial testing was accomplished by “simulating” such services with historical data (i.e. step through the flight data for a prior year as though it were current). These tasks were completed by March 15th.

The previously listed tasks constitute the bulk of the design work for the system. While they were underway, the team incrementally completed the reports and presentations required as course deliverables. Once the major design work was completed, the team begin sensitivity analyses and testing to ensure that the prototype functions as intended. During this phase of the project, the webpage for the prototype was finalized. This phase of analysis and testing was complete by April 18th so that the team had sufficient time to complete the final report.

This schedule, while ambitious, provided sufficient time to complete the required tasking. The critical path allowed two weeks between the end of the testing phase and the final presentation of the project to absorb any unforeseen delays.

7.0 Overall System Architecture

The following diagram illustrates the high-level design of the system:

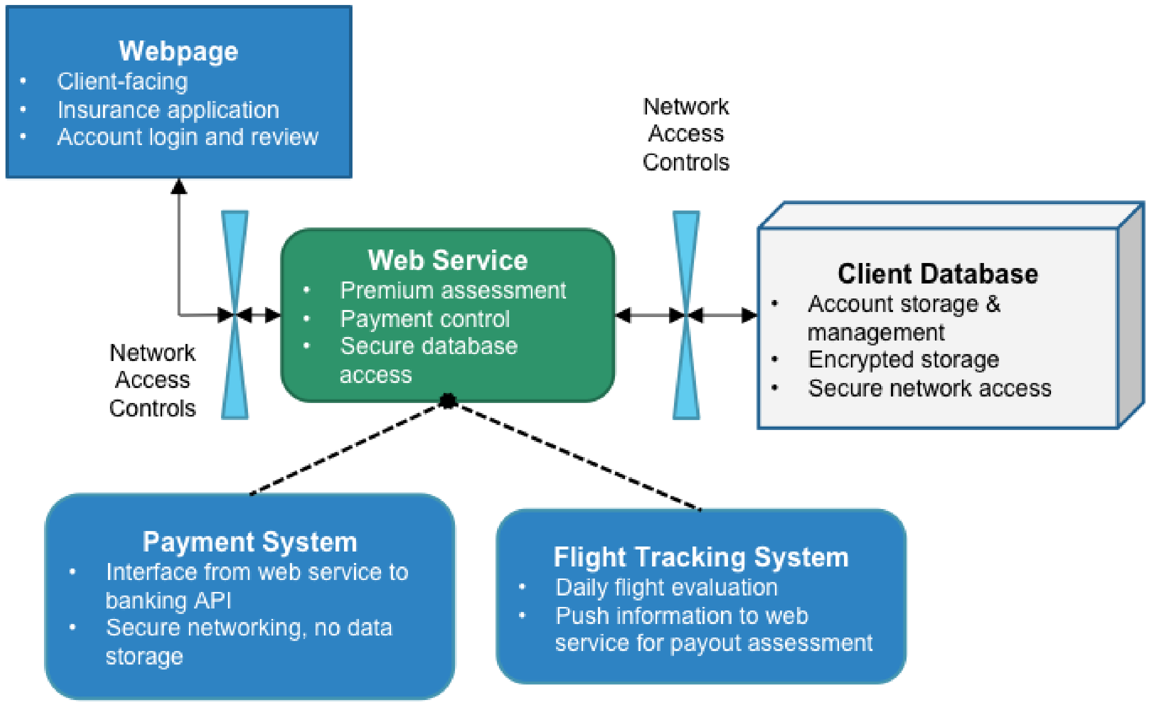


Figure 2 System Design Architecture

7.1 Web Interface

The web interface of this system will consist of a client-facing webpage and a backend web service. Clients will use the webpage to apply for insurance coverage and review their accounts (i.e. contact information, flight and claim status, etc.). When prospective clients apply for coverage, their premiums will be assessed inside the web service, and all subsequent flight tracking and payments will be controlled by the web service. This service will reside behind network access controls to allow for secure, firewall-controlled access through the webpage. The web service will be responsible for the following tasks:

- Premium calculations
- Flight tracking and compensation assessments
- Payment control and processing
- Management of client account database

The current web prototype is a static rendition of what a fully operational web interface could provide. Currently the web prototype does not perform functionality that we would be available in final state (such as premium assessments via web service, communication with a secure database, bill pay, or automatic flight updates), however it provides information about the project and serves to illustrate the potential layout. There are five primary tabs within the webpage:

- Splash Screen (home): The initial web page upon connection. It advertises the website, and asks users to log in or to sign up.
- About Us: Goes into the background of what this project is about, our source for the flight data, provides a summary of EC-261, and goes over the overall system architecture.
- Rates: states the financial mission objective, provides definitions and equations of the burning cost and ruin models.
- Premium Assessment Per Airline: Formatted much like a credit card statement; the premium assessment page lists all of the EC-261 violations over the past quarter, provides the monthly premium amount and statistics on the violation types and average number of passengers per flight (quarterly).
- The Team/Contact us: There is a contact page that list all of our information (picture and contact information) and also shows that ACE is located at George Mason.

Figure 3 Web Prototype

7.2 Payment System

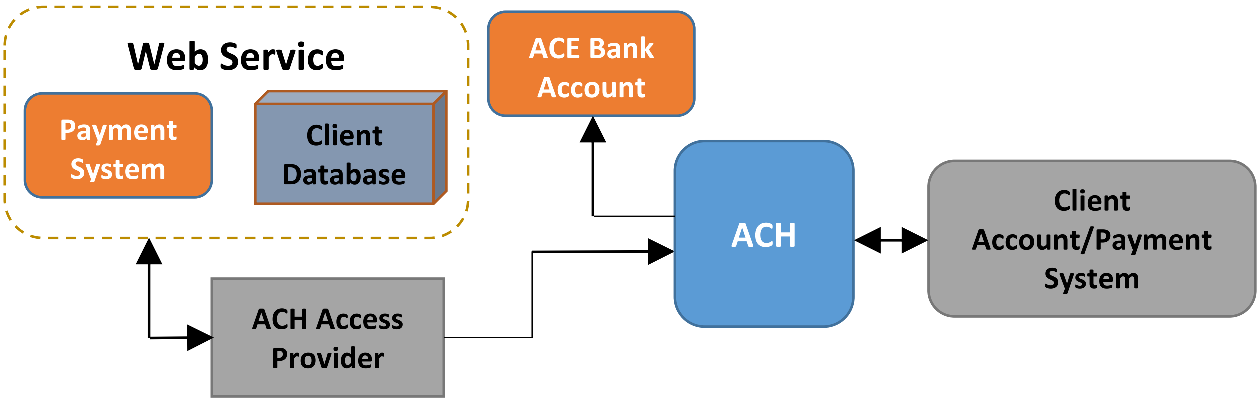
Premium and claims payments will be assessed using Electronic Fund Transfers (EFTs); the initial premium payment used to validate client account information. In the U.S., these payments are made through the Automated Clearing House (ACH) by registered vendors; similar establishments exist for international transactions, for example, electronic payments in the EU are made using the European Automated Clearing House Association (EACHA). Most companies (other than banking institutions) access these clearing-houses indirectly, leveraging intermediary services. The benefit to this approach is that only the intermediaries need to be registered with the clearing-houses, and only they need to stay current on access policies. The clients to these services are then only required to adhere to the interfaces established by the intermediaries. There is a nominal fee associated with using such services, typically a flat-fee assessed on a per-transaction basis (advertised costs are approximately $0.10 per transaction). Banking institutions often offer these services for certain account-types, but the costs are not as openly advertised.

The specific implementation of the payment system is not addressed in this report. However, the requirements of such a system include the following:

- Web-based API for initiating EFTs
- Ability to assess daily, bulk payments (to reduce transaction costs)
- Transmission security (should support encrypted transmissions to protect client account information, or use similar data security techniques)

These requirements constitute a minimum, high-level set of features that a selected payment system should offer. A full prototype would require further elucidation of requirements, especially related to interoperability with the web-service architecture. The architecture of payment system is expected to match the general design in Figure 4.

Figure 4 Proposed Payment System Architecture



7.3 Client Database

To quickly and automatically process claims, the system will be required to store client bank account information. Such storage always poses a monumental security risk due to the sensitivity of the information. The account information will be stored in a secure database, which should provide, at minimum, the following features:

- Network Security
  - Firewall rules
    - Between web server(s) and the open internet
    - Between web server(s) and database storage
    - Between machines inside the local network (behind the client-facing firewall) and the web server(s)
  - Port security for client-facing web interface
  - SSL interaction with the database
- Data Security
  - Encryption of either the full database or specific database fields
  - Multi-layer password hashing and “salt”-ing to prevent against dictionary attacks

Further investigation and consultation with information security professionals is required before a prototype system is built, but this list details the high-level requirements of storing sensitive but web-accessible information.

8.0 Cost Models

One of the main purposes of this project is to document how historical flight data can be used to forecast penalty assessments under EC-261 regulations, and then determine how to calculate potential insurance premiums based on the forecasted costs. The Burning Cost and Ruin models can be used in this capacity to assess the required premiums and maximum expected losses for possible compensation events. The premiums calculated from the Burning Cost Model (or indeed, any other premium assessment technique such as Monte Carlo simulation) can be applied to the Ruin Model to determine the amount of money a company should keep in a holding account to prevent bankruptcy in the 99.5th percentile, worst-case scenario. The details of these two models are discussed below.

8.1 Burning cost model

Burning Cost is the estimated cost of claims in the forthcoming insurance period, calculated from previous years' experience and adjusted for changes in the level of coverage (for example, the number of insured flights).

The fee for the insurance protection, *F*, must take into account the cost of processing the claims. In addition to disruption event service providers also include additional costs to account for variability in the underlying distribution, cost of capital, profit, and a risk management adjustment. The fee is equal to the sum of the Expected Payout (also known as the Burning Cost), the 99.5th percentile risk, cost of capital and claim processing fees, as in the following equation:

$$F = E[CP] + RCC + C_{CP} + P + MRA \tag{1}$$

Where

- **F** = Fee
- **E[CP]** = Burning Cost = Probability of the Event P(e) * Claim Payout (CP)
- **RCC** = Risk and Cost of Capital, 99.5th Percentile of Variance in P(e) * Claim Payout (CP) * Cost of Capital (where Cost of Capital is approximately 6% of *F*)
- **C_{CP}** = Cost of Claim Processing, fixed cost per claim, approximately € 0.30
- **P** = Profit, typically expressed as % of *F*
- **MRA** = Management Risk Adjustment, typically expressed as a percentage of *F* at MRA=0

This equation could be simplified to describe the contribution of a single event-type to the overall premium, as follows:

$$F_1 = E[CP_1] + RCC_1 \tag{2}$$

There are 12 categories for compensation events, each with a unique distribution and penalty fee. To evaluate the overall premium required, equation (2) can be summed for all event types to account for the overall expected cost, and applied to (1) and expressed as follows:

$$F = MRA' * (1 + P') * \sum_{i=1}^{12} F_i \tag{3}$$

In (3), *MRA'* and *P'* are the percentage-based equivalents to *MRA* and *P* respectively. When expressed in this way, their values can be set without *a priori* knowledge of the resulting premium (i.e. *P'* can be set to 0.05 to effect a desired profit margin of 5%, and *MRA'* can be left as 1.0% to indicate that no management adjustment need be applied).

Example Calculation of premium using the Burning Cost Model:

<u>Itinerary: Round trip Direct</u>

<u>Event: Flight Delayed > 2hrs</u>

<u>Payout: $100</u>

*Burning Cost = Probability of the Event * Payout*

*Burning Cost = 2.94% * $100 = $2.94*

*Risk/Capital Cost = 99.5th Percentile * Payout * Cost of Capital*

*Risk/Capital Cost = 5.03% * $100 * 6% = $0.30*

Management Adjustment (CR = 100) = (Burning Cost / CR) – Burning Cost

Management Adjustment (CR = 100) = ($2.94 /100) – $2.94 = $0

Management Adjustment (CR = 80) = ($2.94 /100) – $2.94 = $0.74

Premium (for CR = 100) = $1.33 + $0.30 + $0 = $2.94

Premium (for CR = 80) = $1.33 + $0.30 + $0.33 =$3.97

Section 9.5 (Simple Cost Models) details the application of the Burning Cost Model with regard to historical flight date, and discusses how the occurrence rates of penalty events were calculated. For all Burning Cost Model calculations, the following constant values were used:

- Cost of capital: 6%
- Cost of claim processing: € 0.30
- Profit margin: 5%
- Management adjustment: 100%

The premiums calculated from the Burning Cost equation can be used in Ruin Model Calculations to estimate the amount required in escrow account for the insurance company. This model is discussed further in the following section.

8.2 Ruin Model

Risk theory (here embodied by the use of the Ruin Model for costing) is a field of study relating to the risk associated with insurance contracts. Of particular interest to this project is the determination of risk associated with "total ruin", or the point at which the balance of an insurance company's holdings become negative. The general form of the Ruin Model is the following:

$$U(t) = u + c * t - S(t) \tag{4}$$

Equation (4) represents the insurer's surplus $U(t)$ at time t, where $S(t)$ represents the aggregate loss between 0 and t, and c represents the rate at which premiums are received, given an initial surplus u.

Typically, the aggregate claims process $S(t)$ is analyzed as a compound Poisson process. After analysis of the penalty events associated with the EC 261 regulation, it was determined that the random occurrences could not accurately be modeled s Poisson processes due to the dependency on the number of flights and the lack of independence between the events (for example, a flight could not be both delayed by 2 hours and 3 hours and qualify for both events – a flight can result in at most one penalty event, which precludes some assumptions of independence). However, the general form of the equation can be simplified in such a way that the aggregate loss process can be represented by the expected loss over a single period of time t (which, for this investigation, was assumed to be one operating quarter). With this simplification, the model reduces to the following expression (for quarter 1):

$$U(1) = u_0 + c * (1) - S(1) \tag{5}$$

Where

- $\mathbf{u_0}$ = Initial amount in escrow,
- **S(1)** = Aggregate expected loss for a single quarter (99.5th Percentile Risk Cost)
- **c** = Levied premium (Premium resulted from Burning Cost Model)

The design point for equation (5) is to prevent $U(1)$ from becoming negative. Re-arranging terms, it becomes clear that the minimum amount required in an escrow account to cover the "worst case" loss is given by the following:

$$u_0 \geq S(1) - c \tag{6}$$

This indicates that the initial amount required in a holding account must be at least the difference between the expected 99.5th percentile of loss and the assessed premium (note that this is the amount required to cover a single client, but could be aggregated to address multiple accounts). While this is simplified form of the general Ruin Model, it provides a relevant and conservative design point. The following section discusses specifically how Burning Cost and Ruin models were used to analyze historical flight data.

9.0 Flight Data analysis

In order to understand the amount at which premiums are assessed, historical flight data analysis will be used to evaluate an airlines individual performance. The assessment will be weighed by number cancelations, arrival delays, and denied boarding (as well as other performance factors such as inventory and number of flights) as it compares against the industry. The source of the acquired data comes from the United States Department of Transportation: Bureau of Transportation Statistics. The data covers all relevant flight information statistics since 1987, however is limited to a 2-month delay from real-time flight information.

A comparative baseline must be established to understand how the airline industry is performing. Trend analysis will provide insight on systematic irregularities in delays/scheduling. Current analytical efforts have shown that there are more delays over November and December time frame, and further analysis is underway. All of the findings will have to be considered as a part of the premium assessment process.

The following sections detail the steps taken to analyze flight details associated with the compensation events described above, and how the flight data was used to develop and drive a cost model for expected, carrier-specific penalty rates. The purpose of this description is to document the analysis approach in such a way that an arbitrary dataset could be used to drive the same cost model.

Table 2 illustrates the specific compensation events considered for the analysis in this section. As discussed in this section of this report, only Type 1 and domestic Type 2 events are considered for the cost model due to the lack of availability of international arrival delays. Additionally, due to the low occurrence rate and resulting cost of overbookings, these events are likewise ignored in the cost model analysis.

Furthermore, the “Never Arrived” delay events are assumed to describe the same flights as the “Never Arrived” cancellation events. For that reason, these occurrences will be assessed as “cancellation” events.

Table 2 Considered Compensation Rules

Definitions	DELAY (at final destination after potential rebooking and/or re-routing)					**Flight Type**
	Less than 2 Hours	**More than 2 Hours**	**More than 3 hours**	**More than 4 Hours**	**Never Arrived**	
Delayed	€ 0	€ 0	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 0	€ 400	€ 400	€ 400	Type 2
	€ 0	€ 0	€ 600	€ 600	€ 600	Type 3
Cancelled	€ 0	€ 250	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 200	€ 200	€ 400	€ 400	Type 2
	€ 0	€ 300	€ 300	€ 600	€ 600	Type 3
Overbooked	€ 0	€ 0	€ 250	€ 250	€ 250	Type 1
	€ 0	€ 0	€ 400	€ 400	€ 400	Type 2
	€ 0	€ 0	€ 600	€ 600	€ 600	Type 3

Will be considered

No-penalty events (no need to evaluate)

Will not be accounted for in this model

9.1 Flight Database Information

For the initial investigation into the potential costs associated with EC-261 regulations and associated penalties, this group was asked to analyze the penalty rates for arrivals to Ronald Reagan International Airport in Arlington, Virginia (airport code DCA). The data was obtained from the Bureau of Transportation Statistics (BTS) database for "On-Time Performance". The BTS interface provided monthly statistics for all domestic flights; the following data analysis efforts utilized all domestic data from DCA from January, 2010 to November, 2015[1]. The data was provided in *.csv file format, and was merged into a single Microsoft Excel-readable file prior to performing the analysis. Microsoft Excel was the main software tool used to develop the cost model for this study; the source flight-data was prepared in a single workbook (referred to hereafter as the "source" workbook), and the relevant fields were copied to second workbook for the purposes of cost modeling (referred to hereafter as the "cost model" workbook).

[1] Information for December, 2015 was not available as of the beginning of this study.

In addition to domestic on-time arrival information, this study required the average loading rates for flights arriving at DCA. This was obtained from a separate BTS database (the "Air Carrier Statistics" database), and the information was included as an additional worksheet for the source workbook.

Since the BTS databases do not track itemized delays for international arrivals to U.S. airports, this study will address compensation events for only Type 1 and domestic Type 2 flights (see section Compensation Events for definitions of these flight types).

9.2 Loading Rates

A preliminary assessment of the loading rates for DCA determined that passenger flights typically had a loading rates of between 70% and 80%. This information was then used to inform the analysis of cancellation rates for various compensation events. Carrier-specific loading rates were determined later for use in the cost model.

9.3 Event Occurrences

The first step after merging all of the required database information was to assess the occurrence rates of the various penalty scenarios associated with arrival delays. Delayed arrival events were simple to analyze, as the flight database automatically provided the difference between scheduled and actual arrival times; for the study, these delays were binned into the two relevant simple-delay categories (three and four hour delays – see

Table 2 and the corresponding description in section 3.0 Compensation Rules section) and cross-sectioned by the corresponding flight type.

The occurrence rates of delays associated with cancellations were more complicated, since the database only provided information on outright cancellations and not subsequent re-booking of passengers. Based on the on the average load for flights arriving at DCA, it was conservatively assumed that, in the event of a flight being cancelled, a subsequent flight could accommodate up to 5% of the passengers on the cancelled flight. Using Table 1, the penalty rate of a delay incurred due to a cancellation is the same for the following two events:

- A delay of greater than four hours
- A passenger never arriving at his destination

Therefore, when separating the occurrence of cancelled fight into arrival-delay bins, each subsequent arrival within two or three hours was assumed to increase the cancellation rate in that category by 5% of a cancellation, while decreasing the combined four hour/never arrived events by the same amount. For example, if a flight from John F. Kennedy Airport in New York (JFK) was cancelled, and there were two flights that each arrived 2.5 hours later and 1 that arrived 3.5 hours later, the occurrence rates were assessed as follows:

- 10% of a cancellation in the two-hour delay category
- 5% of a cancellation in the three-hour delay category
- 85% of a cancellation between the four-hour/never arrived categories (since these events have the same penalty, they can be assessed as a single, combined event)

Since the cost associated with any given event is actually assessed by multiplying the cost of the penalty by the number of passengers affected, these “partial events” can be used as an additional multiplier to lower the effective number of passengers to be compensated. Therefore, taken at an aggregate level, these “partial events” could be used to assess the overall occurrence rates and associated penalty fees.

All of these events were summarized in the source-data Excel workbook, and should be considered an example of the input required for the cost model analysis that follows (i.e. flight information for a different airport – or from an international data source – could be analyzed to provide the same set of inputs and the applied to the cost-model workbook).

9.4 Quarterly Occurrence Rates

At this point, the relevant fields of the data-source workbook were copied into the cost-model workbook for further analysis. These fields included the events described above and the associated metadata required for filtering by time and carrier (i.e. airline codes, dates, etc.). An Excel Pivot Table was created using this minimized dataset, and the various events were then summarized by quarter to produce the mean occurrence rate (along with standard deviation) for each event. Histograms of the quarterly data showed that the occurrence rates could be approximately described using lognormal distributions to produce estimates of required stochastic percentiles[2] (for example, the Burning Cost model requires an estimate of the 99.5th percentile of the occurrence rates).

[2] Since the lognormal distribution describes a dataset from 0 to positive infinity, the obvious caveat here is that since an event cannot occur more than 100% of the time the distribution would be inherently bounded by 0 and 1. To use the lognormal distribution to describe these datasets (and predict the rates of occurrence for the

At this point, alternatives to quarterly summaries were also considered. Weekly and monthly rates were produced, and while the average occurrence rates were similar to that of the quarterly data, the variances were much higher. Since the initial task was to develop quarterly premium rates, it was assessed that using either the weekly or monthly data would result in over-conservative cost estimates; using either of these data sets would include more variance in the calculations, which would result in higher cost estimates and therefore higher premium rates, which could in turn result in fewer customers.

9.5 Simple Cost Models

Once the quarterly occurrence rates were determined, the following cost models were established:

- Burning Cost Model
- Ruin Model

These were intended to be used in concert; the Burning Cost Model would provide an estimate of the premium required to yield an average, target profit margin, and the Ruin Model would use that premium assessment to provide the amount of money required in a holding account for an insurance company to withstand the worst-case scenario for anticipated costs.

The equations for these models are discussed in section 8.0 Cost Models. The approach taken at this stage was to calculate the expected cost associated with each compensation event by multiplying the probability of occurrence by the number of flights and the expected passenger count per flight (information obtained from the load-factor analysis described above). It was assumed that the events were independent so that the overall expected cost could be calculated by summing the expected costs of each event type. The following values were assumed as inputs to the Burning Cost Model based on expert advice:

- Cost of capital: 6%
- Cost of claim processing: € 0.30
- Profit margin: 5%
- Management adjustment: 100%

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compensation events at certain percentiles), it was assumed that events would occur << 100% of the time, and so the lognormal distribution could be used without loss of accuracy.

The “management adjustment” was initially left at 100% (no adjustment applied) to establish a baseline calculation for the cost model.

For the Ruin Model, S(1) – the 99.5th percentile of expected operational costs in a single quarter – was calculated by summing the corresponding cost percentile of each compensation event. The results of the Burning Cost Model were used as the premium for the Ruin Model, and the amount required in escrow to survive a “worst-case” quarter was taken to be the difference between S(1) and the premium.

Once the calculations were in place, filters were applied to the data so that a single carrier could be examined for a single quarter.

9.6 Monte Carlo Projections

To validate the results of the simple calculations for the Burning Cost and Ruin Models, a Monte Carlo simulation was created. Using 1,000 trials, the lognormal distributions for each of the relevant events in Table 1 were seeded with uniform random draws to produce a randomized output of lognormal random variables. The output values – the simulated occurrence rates for each event type – were then multiplied by the cost of the respective events and the expected number of passengers for a given carrier in a specified quarter (the same values used for the Burning Cost and Ruin Models described above) to produce the expected cost of each event in each trial. By summing the costs per trial and averaging the total across all of the trials, it was possible to produce a Monte Carlo-based prediction of the expected costs on an airline and quarter-specific basis. The outputs of the Monte Carlo simulation were also used to calculate the expected probability of loss (the number of trials where the simulated costs were larger than a given premium) and the average profit margin (the average cost over all of the trials subtracted from a given premium).

9.6.1 Minimum Profitability

Since the output of the Monte Carlo simulation could itself be modeled using a lognormal distribution, it was also possible to calculate the premium required to achieve a given profit margin with a specific confidence level (i.e. the premium required to achieve a 5% profit margin in 90% of all operational quarters). It was also possible to calculate the 99.5th percentile of the Monte Carlo results, and use that value for S(1) in a separate Ruin Model calculation rather than the simple calculation described earlier in this report. The resulting amount required in escrow to withstand a worst-case quarter is then the difference between S(1) and the calculated premium.

9.6.2 Average Profitability

A more specific instance of designing for minimum profitability – calculating the premium required to achieve an average profit margin of a given value – was also considered. This premium was calculated by simply multiplying the average cost of the Monte Carlo simulation by the desired profit margin. The Ruin Model component, S(1), is then calculated exactly as it was for the Minimum Profitability case, and the amount required in escrow was again the difference between S(1) and the assessed premium.

9.7 Analysis of Results

The calculations described above resulted in three possibilities for the premium calculation:

- Simple Burning Cost and Ruin Model
- Monte Carlo-based Minimum Profitability
- Monte Carlo-based Average Profitability

Table 3[3] below summarizes these values for American Airlines[4] in the first quarter, using a target profit margin of 5% and a confidence interval of 90% for the minimum profitability calculation:

Table 3 Example Cost Model Calculation

	Required Premium	Required Holding	Probability of Loss	Expected Average Profit
Simple Cost Model	€ 10,219,074.46	€ 0.00	35.4%	6.09%
Minimum Profitability	€ 14,201,562.75	€ 5,618,029.40	7.60%	31.95%
Average Profitability	€ 10,186,705.01	€ 9,632,887.14	36.7%	5.14%

[3] Values for all but the premium and holding amounts for the Simple Cost Model are subject to random seeding of the Monte Carlo simulation

[4] These values include flights listed under the AA and US carrier codes, accounting for the recent merger between American Airlines and US Airways

The first important aspect of the data summarized above is that the simple cost model yielded a holding value of € 0, which indicates that S(1) for the Ruin Model was less than the premium calculated from the Burning Cost Model. The next important aspect is that the respective sums of the premium and holding values for the minimum profitability and average profitability calculations are the same – this is due to the fact that the holding amounts are calculated from the same S(1) value. The difference between the two calculations is where the risk is absorbed; in the minimum profitability case, the risk is captured by the premium assessment; in the average profitability case, the risk is captured by the holding account.

The most important conclusion that can be drawn from Table 3 is that the Simple Cost Model projects only *half* the expected costs that the Monte Carlo-based models projects. This is a result of how the two approaches incorporate event probability: the Simple Cost Model uses a sum of the expected cost for each event to calculate the premium, but the Monte Carlo-based models incorporate the total variance of the system as assessed through simulation; essentially, the Monte Carlo simulation accounts for a wider variance in operating costs due to the random combinations of "worst-case" events, i.e. when multiple categories of events see abnormally high occurrence rates during the same quarter.

Based on these results, the recommended design points are either the Minimum or Average Profitability Models, and *not* the Simple Cost Model, due to the fact that the Monte Carlo-based models provide a more conservative estimate of expected operational costs.

9.8 Cost Model Sensitivity

The results of the Monte Carlo-based cost-model were analyzed for sensitivity with regard to expected profitability. The two design points described above (probability of minimum profit and average expected profit) were analyzed for their sensitivity to adjustments in the levied premium in the following ways, respectively:

1. Comparing the percentage of time that the Monte Carlo simulation produced a quarter in which the profit was below a target threshold against a range of premium values (i.e. for any given premium, the analysis would compute the expected percentage of quarters that would yield the target profit margin)
2. Comparing the expected profit (as a percentage of a given premium) to a range of premium values (i.e. for any given premium, the analysis would compute the expected profit margin as a percentage of that premium)

Each approach was then added to cost-model spreadsheet in such a way that it would update anytime a new airline or quarter was selected for computation. Using the same example as above (American Airlines in Q1), the plots for each approach are show below in Figure 5 and Figure 6:

Figure 5 Probability of Minimum Profitability

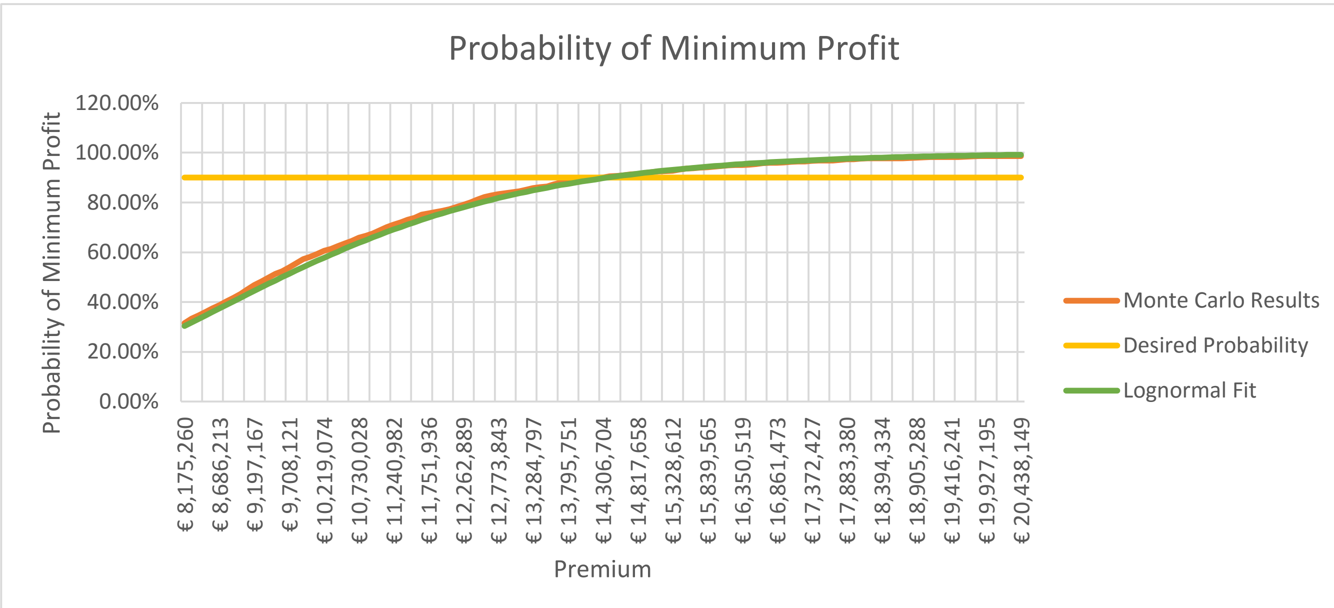
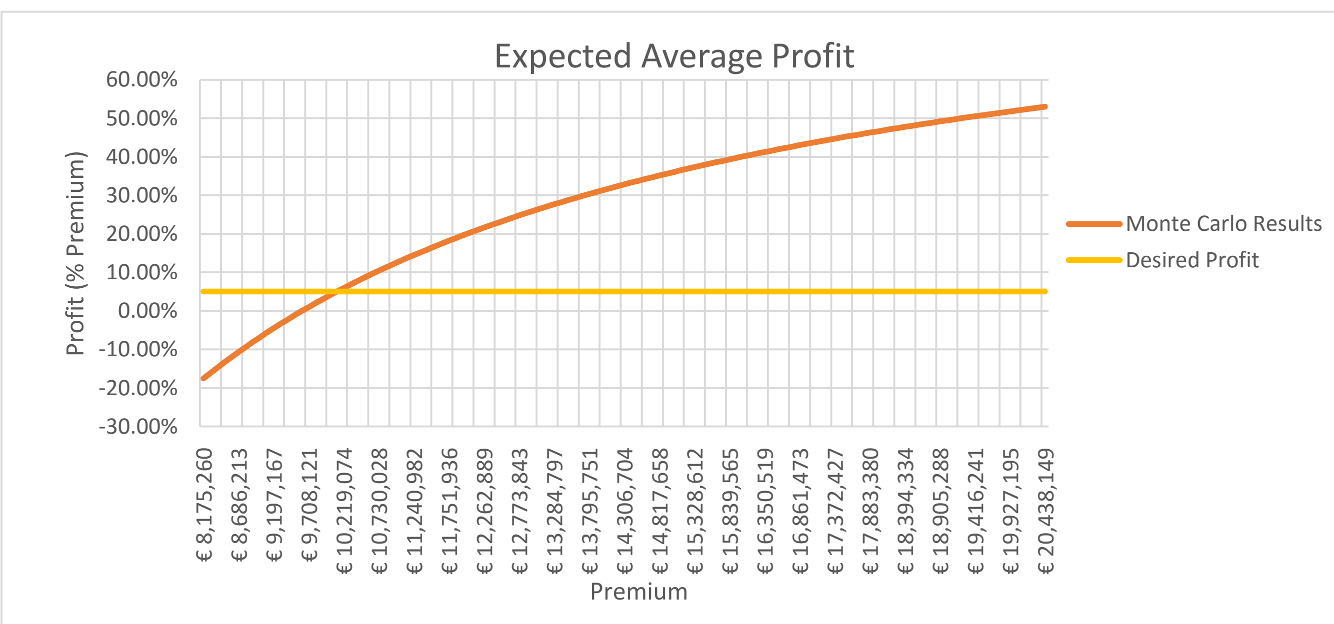


Figure 6 Expected Average Profitability



We can clearly see where the results of the simulation cross the lines representing design-points. As expected, both the probability of minimum profit and the expected average profit increase as the premium is increased, but the approaches achieve their design goals at very different premium values. These charts could be used to determine the most effective value for the assessed premium to satisfy requirements for both models, but, at minimum, show the relationship between the premium and the design goals.

9.9 Assessed Premiums

The following table shows tabulated results for several major airlines at DCA using their previous year's average flight counts and passenger loading:

Table 4 Calculated assessed premiums by quarter by airline

Flights/Quarters/Results		Simple Cost Model	Minimum Profitability	Average Profitability
United Airlines	Quarter 1	€ 1,463,575.31	€ 1,494,822.64	€ 994,235.96
	Quarter 2	€ 871,068.72	€ 812,905.06	€ 617,802.84
	Quarter 3	€ 837,262.03	€ 830,284.09	€ 621,000.28
	Quarter 4	€ 609,839.35	€ 598,866.75	€ 396,565.89
Delta Airlines	Quarter 1	€ 3,256,193.95	€ 4,443,375.39	€ 2,651,957.59
	Quarter 2	€ 1,012,405.53	€ 1,225,787.97	€ 841,147.10
	Quarter 3	€ 1,155,189.79	€ 1,440,498.60	€ 948,292.25
	Quarter 4	€ 1,101,331.37	€ 1,509,991.34	€ 805,865.21
Southwest/ AirTran Airways	Quarter 1	€ 3,993,957.96	€ 5,513,544.37	€ 3,437,178.39
	Quarter 2	€ 1,082,777.18	€ 1,302,645.49	€ 932,944.76
	Quarter 3	€ 1,227,999.34	€ 1,398,093.94	€ 1,076,397.98
	Quarter 4	€ 1,371,656.28	€ 1,948,223.34	€ 1,104,885.44
JetBlue Airways	Quarter 1	€ 3,943,340.62	€ 5,144,276.28	€ 3,256,004.06
	Quarter 2	€ 949,446.64	€ 1,125,563.94	€ 787,311.15
	Quarter 3	€ 1,546,060.94	€ 1,886,985.11	€ 1,252,032.85
	Quarter 4	€ 1,114,731.44	€ 1,485,794.74	€ 855,165.11
SkyWest Airlines/ ExpressJet Airlines	Quarter 1	€ 1,515,661.12	€ 2,008,193.01	€ 1,238,182.40
	Quarter 2	€ 1,020,973.29	€ 1,255,739.18	€ 776,902.84
	Quarter 3	€ 843,040.47	€ 1,074,689.42	€ 676,997.15
	Quarter 4	€ 599,294.10	€ 764,484.23	€ 477,369.51
Endeavor Airlines	Quarter 1	€ 532,701.84	€ 608,160.80	€ 472,977.15
	Quarter 2	€ 250,265.32	€ 330,901.72	€ 183,865.74
	Quarter 3	€ 366,629.84	€ 371,923.23	€ 335,237.53
	Quarter 4	€ 399,981.12	€ 510,263.37	€ 338,792.82
Envoy Air	Quarter 1	€ 406,963.35	€ 539,199.90	€ 334,006.58
	Quarter 2	€ 247,896.18	€ 317,569.21	€ 202,981.17
	Quarter 3	€ 221,329.39	€ 246,276.63	€ 194,946.52
	Quarter 4	€ 140,341.48	€ 176,812.56	€ 113,384.94

9.10 Comparison to Historical Data

To validate the premiums computed using the Monte Carlo-based cost model, several historical scenarios were used for comparison. Premiums and required holding amounts were calculated separately for all quarters of operation (from 2010-2015) and compared to the penalty that would have been assessed had the compensation events been covered by the EC-261 regulation. The results for American Airlines and United Airlines are shown in the charts below (using the Minimum Profitability cost model):

Figure 7 Coverage Amounts vs. Incurred Penalties (American Airlines)

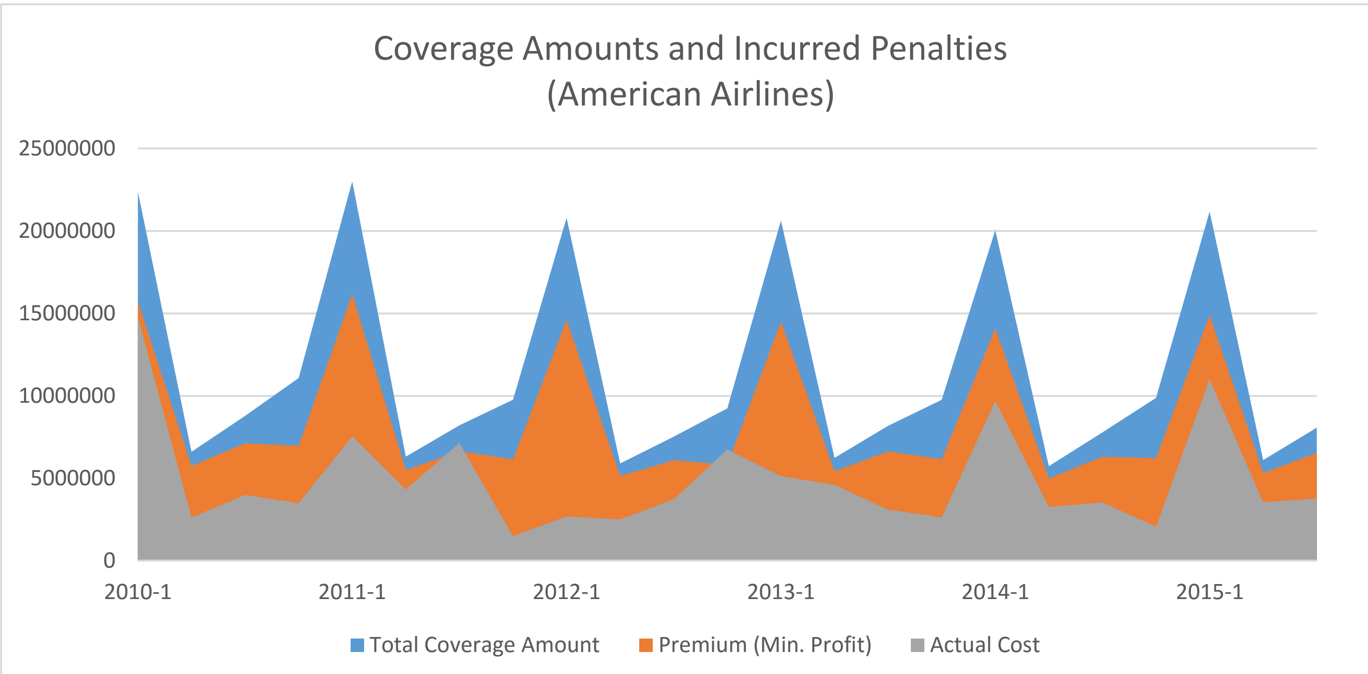
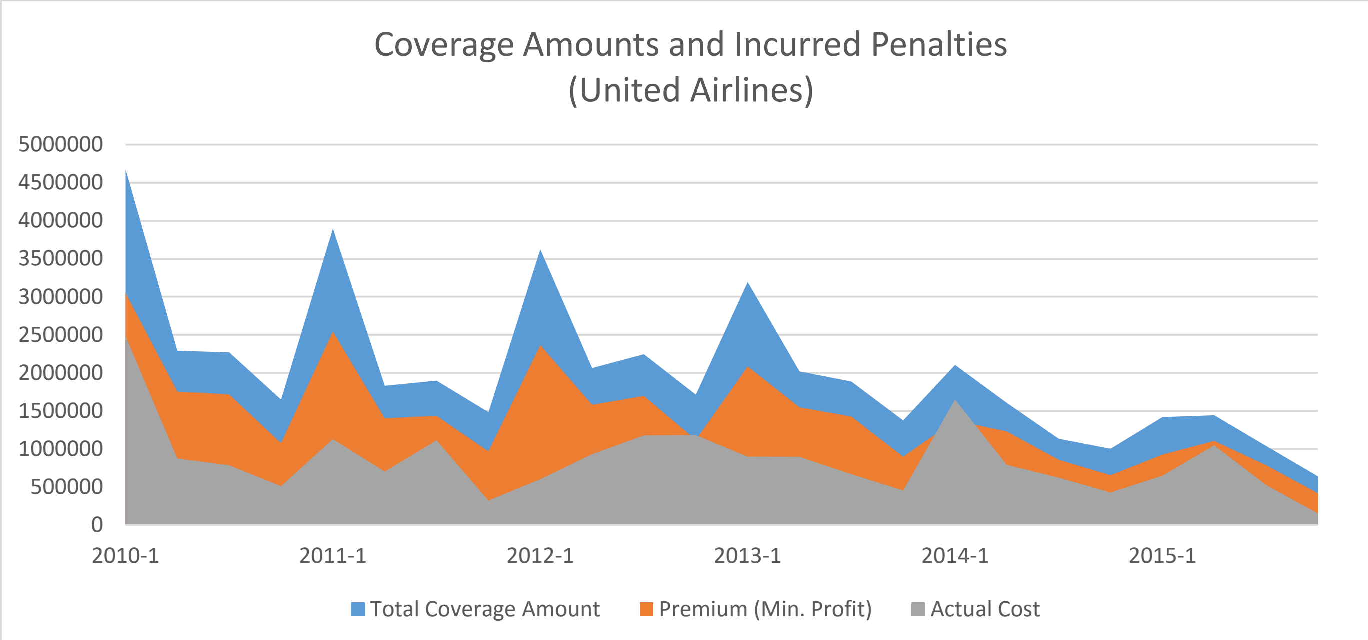


Figure 8 Coverage Amounts vs. Incurred Penalties (United Airlines)



It is clear from these charts that the premium and associated amount in holding adequately cover the incurred penalties in a vast majority of the quarters. In fact, in both scenarios, the total profit margin is approximately 40% of the assessed premiums. Both results are expected, based on the previous discussion of how the premium rates were calculated. The average profit margin would be expected to decrease if the Average Profitability model were used to assess the premiums, but it would be bound between the target profitability (5%) and the profit margin of the Minimum Profitability scenario.

10.0 Use Case Scenarios

This section goes over a few different scenarios and what the system will do in those different cases.

10.1 Account Creation

Use Case: Account Creation

Actors: Airline, Air Carrier E-surance (ACE), Financial Institution

Type: Primary

Description: An airline wants to be covered by ACE. The airline creates an account online on the ACE website and pays the initial premium assessment for the first quarter.

Table 5 Account Creation

Step	Actor	Action
1	Airline	Accesses ACE website
2	Airline	Requests account registration
3	ACE	Opens register form via secure connection
4	Airline	Enters required account information
5	Airline	Requests payment authorization from Financial Institution
6	Financial Institution	Sends payment authorization to Airline
8	ACE	Calculates premium assessment rate for Airline
9	ACE	Provides premium assessment rate to Airline
10	Airline	Sends premium assessment payment to Financial Institution
11	Financial Institution	Collects premium assessment payment from Airline
12	ACE	Activates Airline account
13	ACE	Returns to home page
14	Airline	Logs out of website

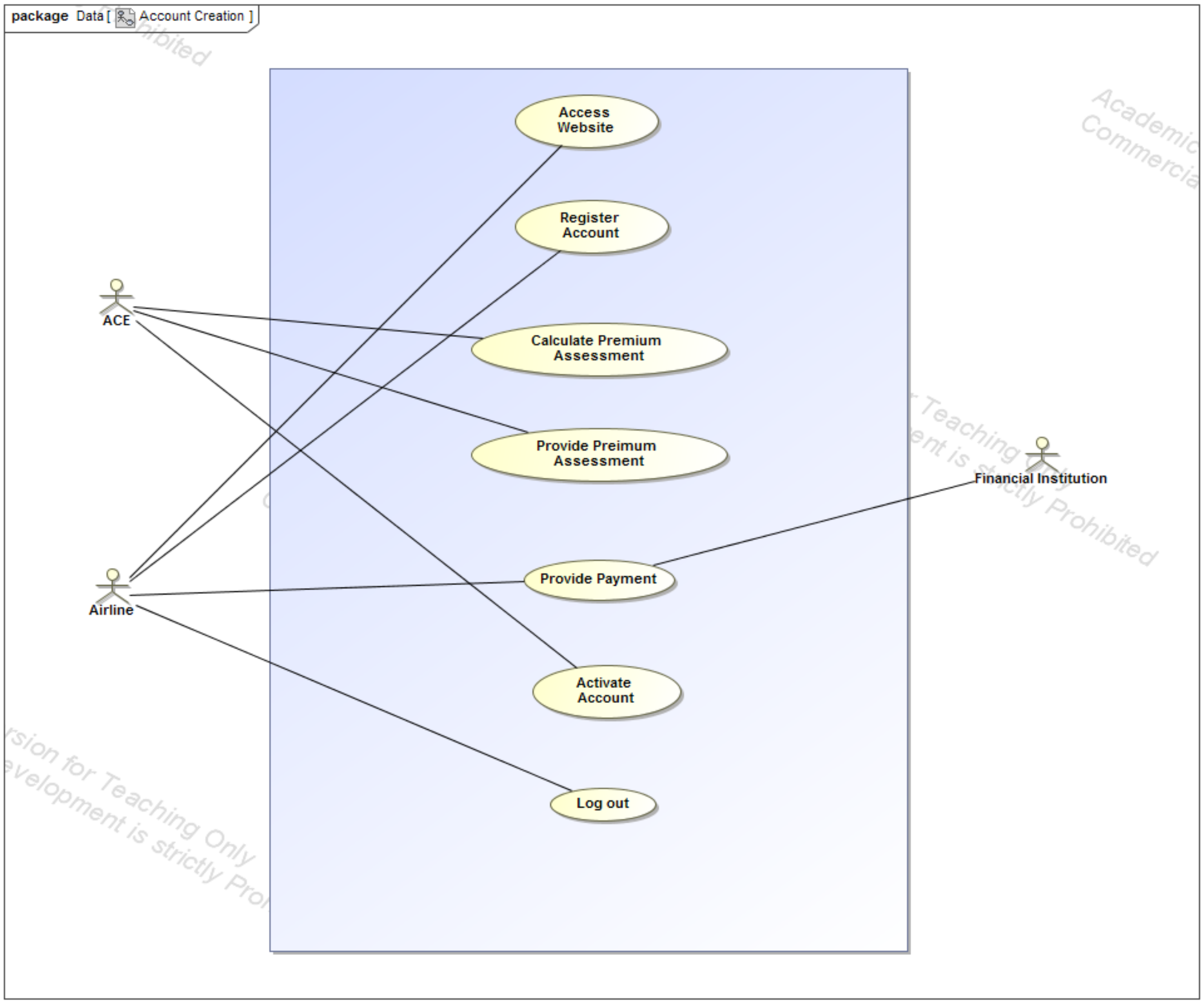


Figure 9 Use Case Diagram for Account Creation

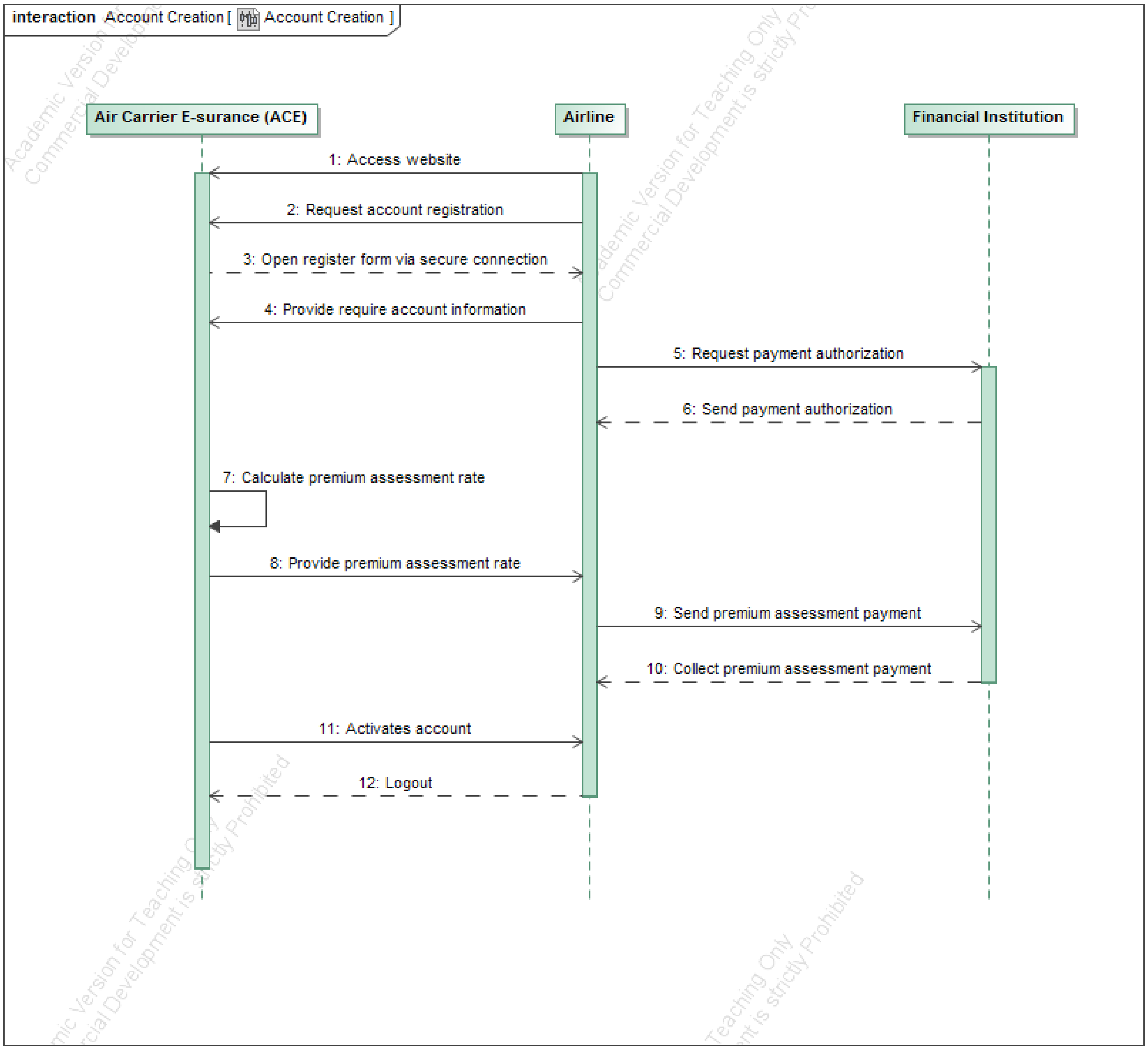


Figure 10 Sequence Diagram for Account Creation

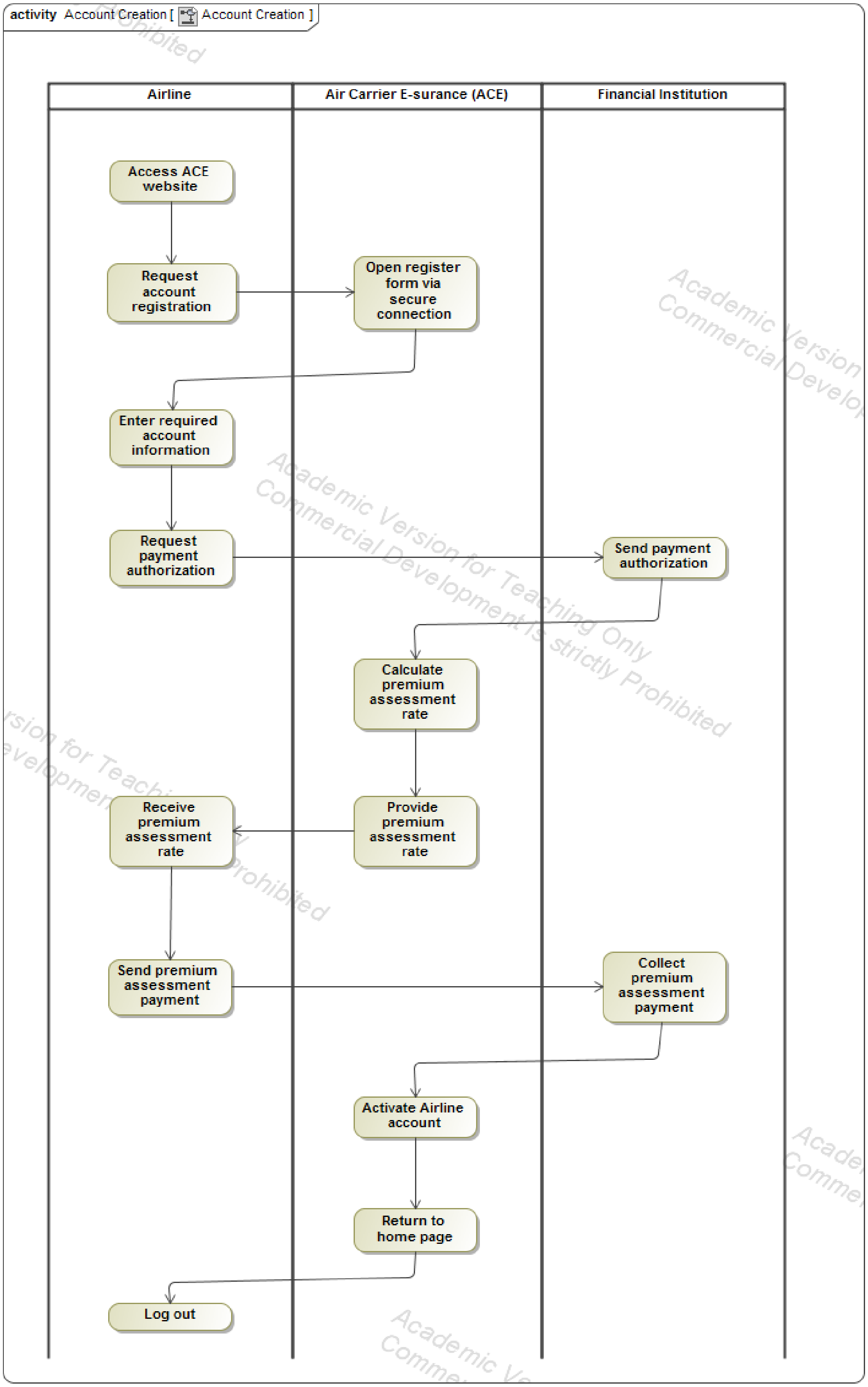


Figure 11 Activity Diagram for Account Creation

10.2 Delayed Arrival Claim – Auto

Use Case: Delayed Arrival Claim (auto)

Actors: Airline, Air Carrier E-surance (ACE), Financial Institution, Passenger

Type: Primary

Description: A flight arrives > 2 hours late at a European destination. ACE insurance company detects a delay event via a real-time flight data feed. On completion, ACE pays the Airline compensation rate and the Airline compensates the passengers.

Table 6 Automatic Delayed Arrival Claim

Step	Actor	Action
1	ACE	Detects delay event via real-time flight data feed
2	ACE	Evaluates flight details
3	ACE	Calculates necessary compensation rates
4	ACE	Provides compensation rates to Airline
5	Airline	Receives compensation rates from ACE
6	ACE	Requests payment authorization from Financial Institution
7	Financial Institution	Sends payment authorization to ACE
8	ACE	Sends compensation rates payment to Financial Institution
9	Financial Institution	Collects compensation rates payment from ACE
10	Airline	Sends compensation payment to Passengers
11	Passenger	Receives compensation payment from Airline
12	ACE	Provides claim statement to Airline
13	Airline	Receives claim statement from ACE

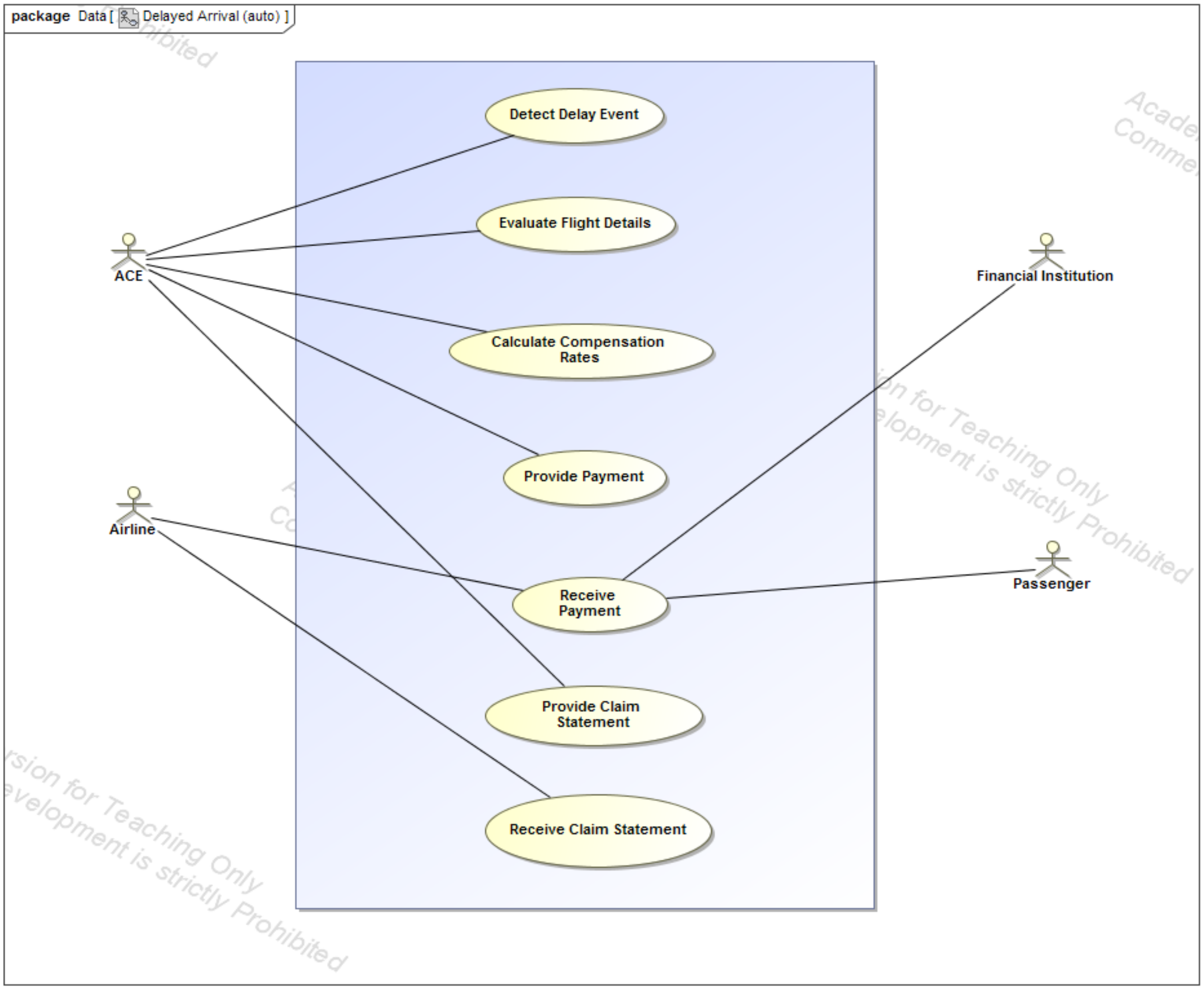


Figure 12 Use Case Diagram for Delayed Arrival (auto)

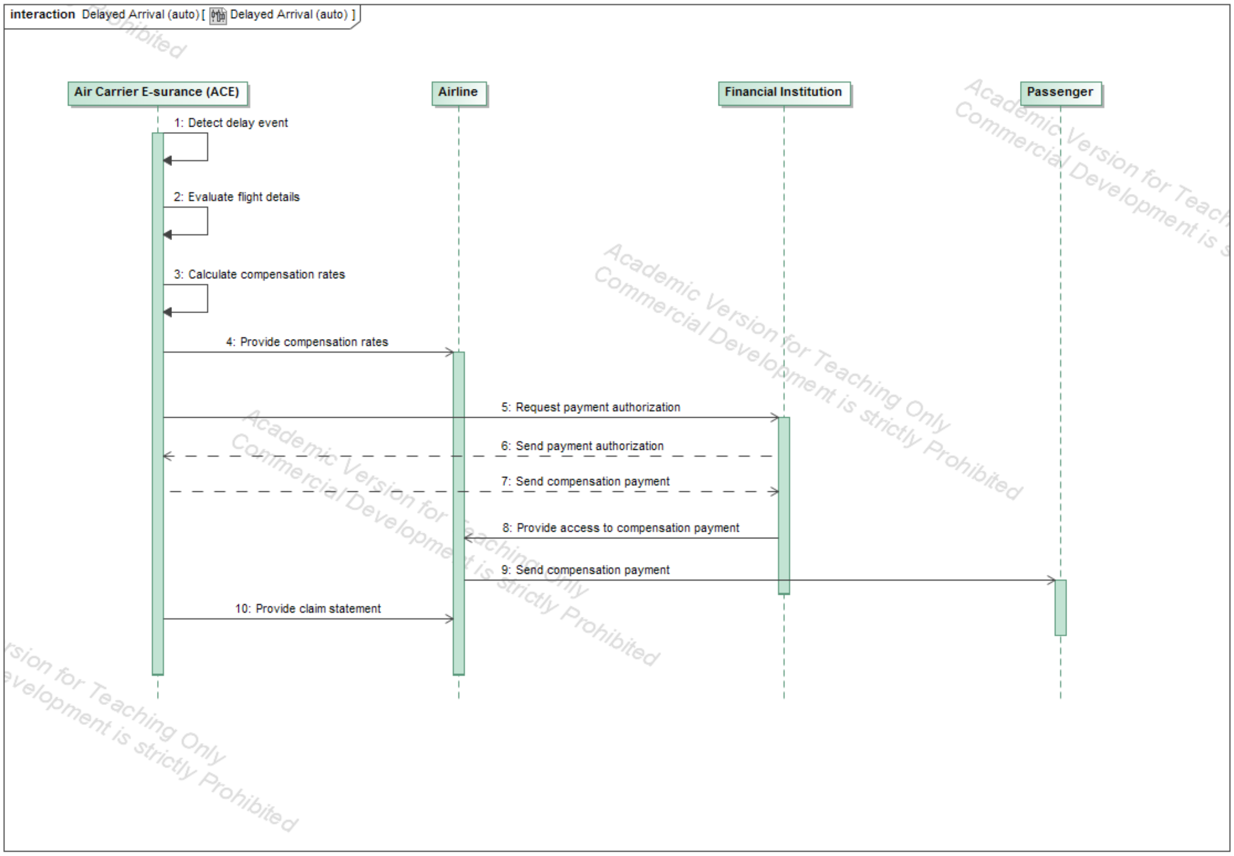


Figure 13 Sequence Diagram for Delayed Arrival (auto)

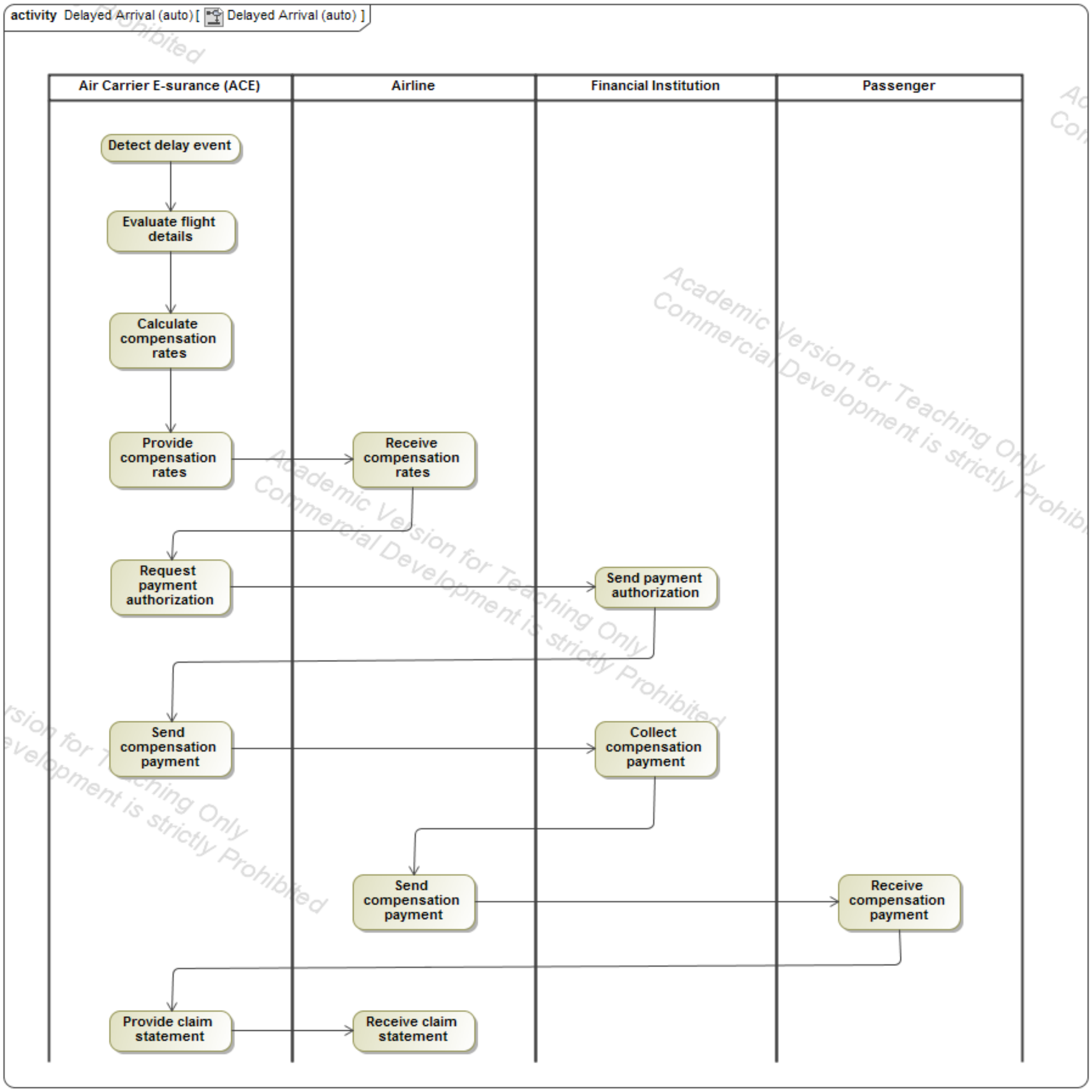


Figure 14 Activity Diagram for Delayed Arrival (auto)

10.3 Delayed Arrival Claim – Disputed

Use Case: Delayed Arrival Claim (disputed)

Actors: Airline, Air Carrier E-surance (ACE), Financial Institution, Passenger

Type: Secondary

Description: A flight arrives late at a European destination. ACE does not detect the late arrival automatically. The airline believes this event should be paid for and files a claim with ACE. ACE validates the claim to be either paid out or denied.

Table 7 Disputed Delayed Arrival Claim

Step	Actor	Action
1	Airline	Arrives late at a European destination
2	Airline	Detect no automated insurance coverage
3	Airline	Logs into ACE website
4	Airline	Request form to file a delay claim
5	ACE	Opens delay claim
6	Airline	Enters required flight details
7	ACE	Receives required flight details
8	ACE	Evaluates flight details
9a	ACE	Denies claim (jump to 18)
9b	ACE	Calculates necessary compensation rates
10	ACE	Provides compensation rates to Airline
11	ACE	Requests payment authorization from Financial Institution
12	Financial Institution	Sends payment authorization to ACE
13	ACE	Send compensation rates payment to Financial Institution
14	Financial Institution	Collects compensation rates payment from ACE
15	Airline	Sends compensation rates payment to passengers
16	Passenger	Receives compensation rates from Airline
17	ACE	Provides claim statement to Airline
18	ACE	Return to home page
19	Airline	Logs out of website

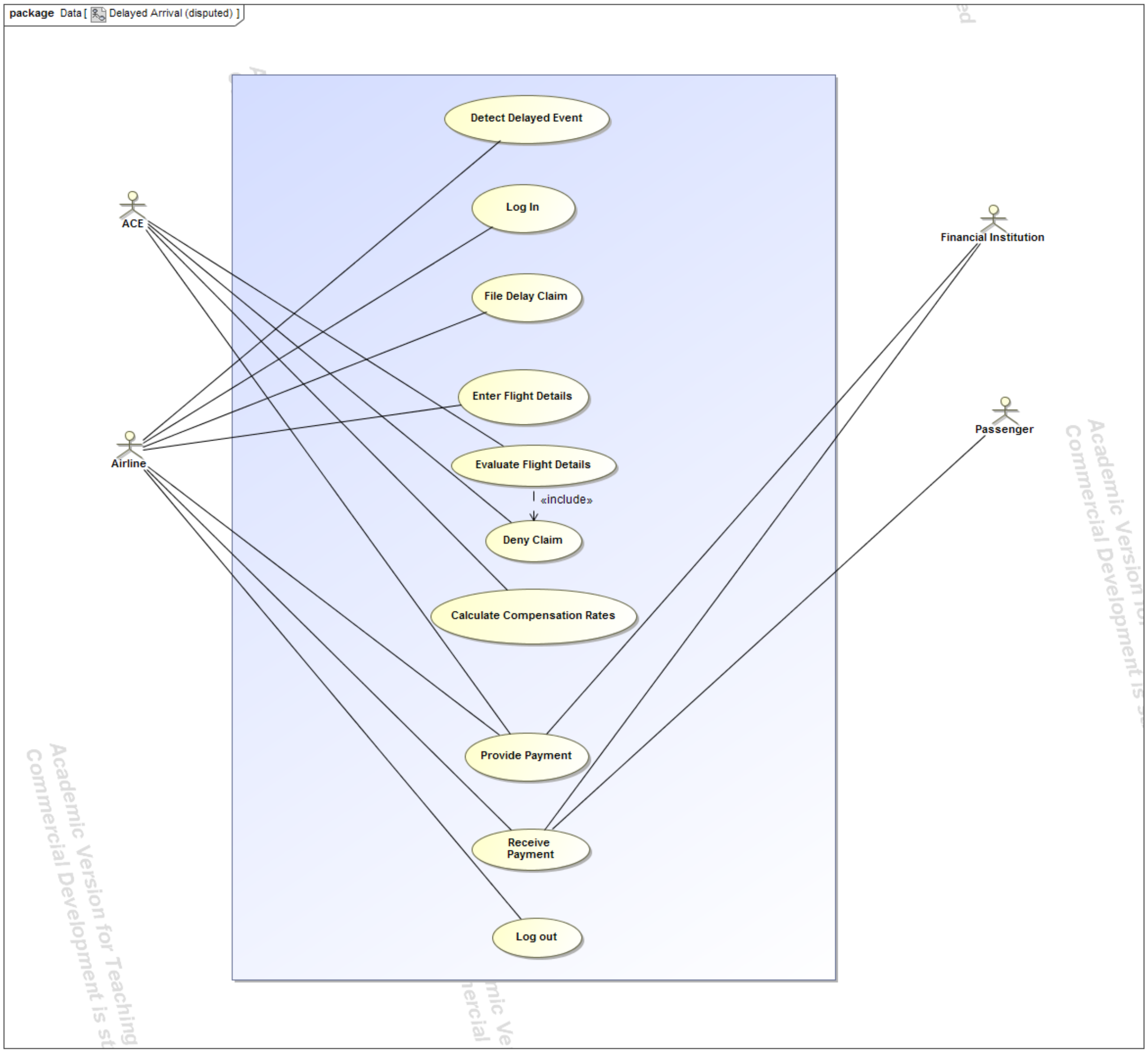


Figure 15 Use Case Diagram for Delayed Arrival (disputed)

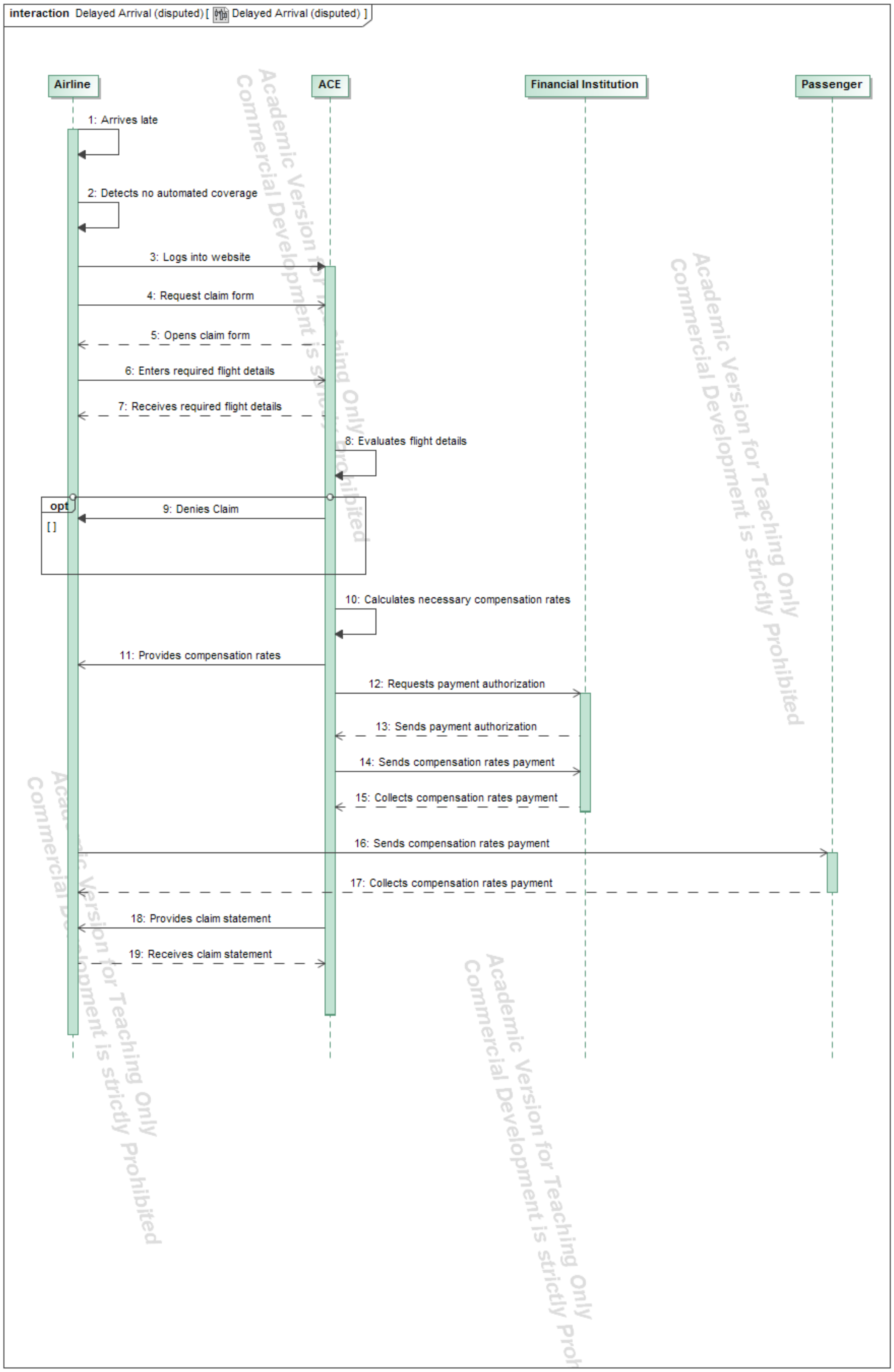


Figure 16 Sequence Diagram for Delayed Arrival (disputed)

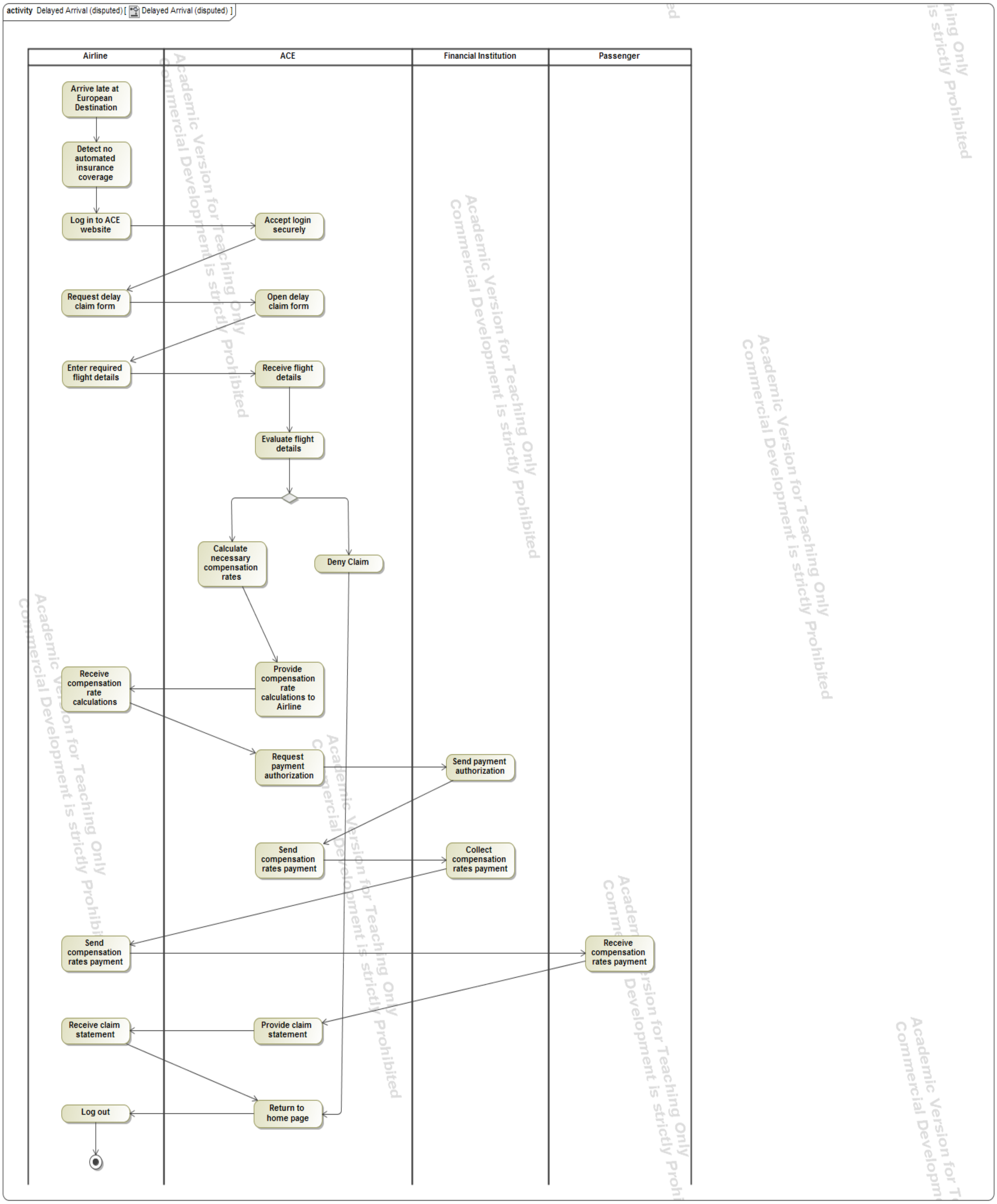


Figure 17 Activity Diagram for Delayed Arrival (disputed)

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