COVER PAGE

Title of Design: Collaborative Gate Allocation

Design Challenge Addressed: Management and Planning

University Name: University of California, Berkeley

Team Member Names:
(All Undergraduate)

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Executive Summary

Title: Collaborative Gate Assignment

Team: Four undergraduate students from the departments of Civil and Environmental Engineering and Industrial Engineering and Operations Research in the College of Engineering

University: University of California, Berkeley

Summary: When an aircraft arrives at the airport and cannot pull into it gate, expenses rise while the idling aircraft that are filled with passengers burn fuel, deplete aircraft and engine life, and release harmful carbon emissions to the environment. This project proposes a brand new policy to reduce the gate-waiting time of an aircraft: collaboration among airlines and airport operators to share real-time information on gate utilization and share gates among all airlines. We postulate that the act of collaboration for gate allocation will increase the system-utilization, increase the overall efficiency of the airport, lower gate-delay and lower the expenses for airlines who participate in the collaboration. Our policy defers from the classical preferred-use and common-use in the following ways: (1) airlines voluntary collaborate and negotiate and (2) policy is only implemented in airports that need such an action during critical periods. Our team developed an evaluation tool and analyzed our dynamic policy at Boston Logan Airport. The evaluation tool quantifies the benefits of our proposed policy. In our project's evaluation of Boston Logan Airport, we concluded that our proposal generates over $17 million of savings per year. However, this number was obtained using flight data from the year 2010 with the air transportation demand down from normal. We foresee the savings at similar sized airports as well as larger hub airports during increased demand conditions to be far greater than what we observed in our study.

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I. Problem Statement and Background

Aircraft arrival and departure delays have always been a restraint on aviation efficiency. Airport gates are one of the greatest congestion points of the air transportation system. When an arriving flight reaches the destination airport, it is possible that it cannot pull into its gate (Wang, 2011). The amount of time an arrived and grounded aircraft must wait to be gated is deemed "gate-delay." Worldwide, especially at large and medium hub airports, gate-delays occur and drive up the cost of operations by increasing fuel consumption, CO_2, crew cost, and depleting aircraft and engine life. The amount of gate-delays largely depends on peaking patterns, demand type, and the gate allocation policy of an individual airport.

The majority of gate-assignments at airports in North America today are performed by each individual airline. The methods for assigning gates depend on flights scheduled their actual behavior relative to those schedules, aircraft servicing requirements, and capacities of ramp facilities (Bolat, 1998). Each airline leases a number of gates from the airport and individually conducts aircraft to gate assignment. This procedure limits the available gates to the number in which each airline leases rather than considering all possible gates at an airport. Hence, each airline tends to reach its own local optimum in gate utilization, therefore, not allowing an airport as a system to reach its system optimum.

In an attempt to decrease airline gate-delay and increase the number of gates available to each airline, we propose a collaboration program, called Collaborative Gate Allocation (CGA), among all airlines that would improve overall gating assignments and therefore lower the overall airport gate-delay. The collaboration program consists of airlines and airport operators sharing real-time information with each other and allowing gate-sharing with other airlines. This collaboration allows airlines to utilize gates outside their own as well as loan gates to other airlines. The goal of this practice is to prevent any delay caused by a lack of number of gates. It is important to note that operational, tactical, and legal aspects are not a part of our objective and thus, not included in our study. Upon developing the CGA concept, we find that the concept shares many similarities with the Collaborative Decision Making (CDM) program.

For example, under CDM, airlines supply real-time operational information to the Federal Aviation Administration (FAA) to improve air traffic management decision-making (Ball, 2000). Due to CDM's Slot Exchange Program, overall flight scheduling was improved because the FAA held more information on the expected actions of each airline and acted accordingly in rescheduling flight times. For the purposes of increasing airport efficiency, we propose collaboration among all airlines and airport operators in their gate allocations. We postulate that when airlines exchange gating information and allow airport operators to make gate allocation decisions, gating efficiency may be increased thus leading to lower average gate-delay. We found similar logic in CDM, where the establishment of flight information exchange resulted in a decrease in airside delay.

Our vision of gate-sharing is that an unused gate by one airline can be used by another airline. In most current airport operations within the U.S., airlines (or alliances) exclusively own their own gates without any gate sharing outside their airline (or alliance). For example, American Airlines' (AA) gates are at full capacity with additional aircraft coming in at peak hours. In this situation, under current gating practices at the majority of U.S. airports, each additional AA aircraft arrival will experience "gate-delay." This means that the aircraft waits on the ground for an AA gate to open in order to be serviced. Suppose that during this time, Southwest Airlines is under-capacity, meaning that they have unused gates. Under the current system, the American Airline aircraft does not consider using Southwest Airline's gate unless specifically negotiated.

Our proposed concept titled Collaborative Gate Allocation (CGA), suggests that all airlines and airport operators collaborate, so that they can loan their gates to other airlines in order to increase their gate utilization and overall efficiency. In developing the CGA concept, we found our program implementation to be similar of CDM's Slot Exchange. The implementation timeline of our CGA program is shown in Figure 1.

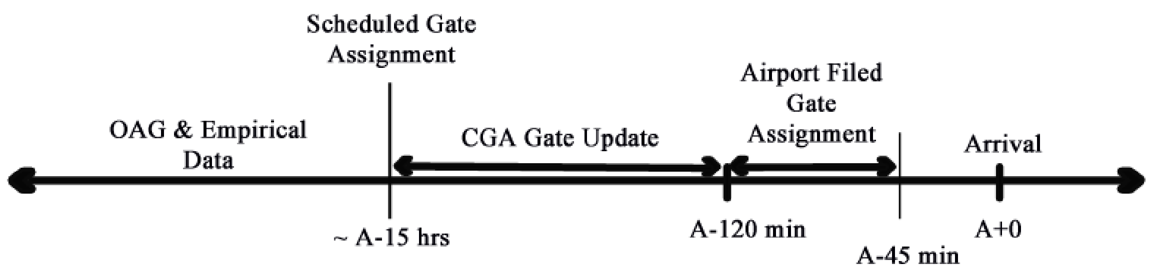


Figure 1 - CGA Implementation Timeline

As shown in Figure 1, 15 hours prior to arrival at the destination airport, users of the National Airspace System (NAS) submit their flight information. Between the 15 hour and 2 hour mark, airlines submit the expected gate assignments. If necessary, within 2 hours of arrival, the CGA system activates to resolve issues of unexpected gate-delays caused by increased demand, aircraft mechanical problems, the Ground-Delay Program, or any unforeseen circumstances.

Our proposed concept includes an evaluation tool, which is used to determine the gate-delay savings by comparing the gate-delay costs under two policies: (1) the exclusive-use gate assignment, and (2) Collaborative Gate Allocation policy. This cost value is then used to determine if implementing the concept is practical at a given airport. The evaluation tool consists of a simulation model that also includes a module for cost-delay analysis. The simulation model, as an evaluation tool, is generic and can be used for any airport. For the purpose of this study, we evaluated Boston Logan Airport (BOS) as a representative example.

II. Literature Review

II.1 Introduction

In an age of energy crisis, economic downturn, and environmental concerns, it is necessary to analyze current practices and make any reforms necessary to improve our airport system. As society grows towards more sustainable and green systems, it is critical to consider a paradigm shift that moves aircraft gate operations from airline-centric to more airport/collaborative-centric. The objective of this literature review is to identify the current gating practices and to analyze the problems and attempted solutions. Thus, we investigate the current gate-assignment problems, the CDM program, and the practice of sharing facilities.

II.2 Gate Assignments

Efficient gate assignments for arriving aircraft are critical in ensuring the safe, effective operation of daily airport activities. As the demand for air transportation and travel have increased, so have the number of airports and airlines. Because of different airports and airlines, there are different gating policies used today. The dynamic operational environment in modern busy airports, increasing number of flights and volumes of traffic, uncertainty in arrival and departure times, its multi-objective nature, and its combinatorial complexity make the flight-gate allocation a very complicated decision both from a theoretical and a practical point of view (Yu, 2011).

For some airports, the responsibility of assigning gates rests on the airlines while for other airports, the task rests on the airport. In North America, most airports lease gates to their customer airlines on long-term contracts. In these cases, the airlines make gate allocations for their own flights. In other cases where gates are not leased to airlines, gate allocation is conducted by a team of gate-allocation-officers who work under the airport (Yu, 2011).

When conducting gate-assignment, airlines and airports aim to provide efficient service to their customers while maximizing its own profit. In conducting gate allocations, officials consider an aircraft's flight schedule, the actual behavior relative to those schedules, aircraft servicing requirements and capacities of ramp capacities. Whether gate allocation is performed by an individual airline or airport gate-allocation-officers, it can have a major impact on the efficiency of the airport and the level of service (Bolat, 1997).

When aircraft demand is higher than capacity, airport gates often become a congestion point of the air transportation system. Gate unavailability occurs when an airline's demand for gates exceeds the number of gates the airline has leased from the airport. Gate delays are fundamentally related to one of four issues: (a) higher scheduled demand than capacity or over-scheduling, (b) a larger arrival rate than scheduled, (c) a lower service rate than scheduled, or (d) a smaller number of servers than scheduled. The gates are servers and the service rate is the rate that aircraft can be turned at the gate (Wang, 2011).

A method that the Department of Transportation (DOT) initiated in the past to encourage airlines to change their operational practices that contribute to air traffic congestion at high density airports during peak hours was by publishing monthly reports that compare airline on-time arrival performance (Haeme, 1988). The belief was that if once this information was provided to the customers, customers will choose airlines with higher punctuality ratings. This, in turn, will encourage airlines to improve their performance. Although numerous approaches such as these have been made in attempt to resolve delay problems, the solutions are not satisfactory due to the complexity of the problem. For an efficient gate assignment, it is important to have the ability to cope with sudden changes in the ever-changing operation environment and provide the solutions in time to meet the needs of real-time requirements. Therefore, an efficient gate assignment should be explicit, intelligible, capable of accepting changes, and capable of being monitored (Cheng, 1997).

Overall, traditional approaches utilizing classic operations research techniques have difficulty with uncertain information and multiple performance criteria, and do not adapt well to the needs of real-time operations (Su, 1993).

II.3 Collaborative Decision Making

The vision of Collaborative Decision Making (CDM) was to improve air traffic flow management by combining information from the FAA with the information from the National Airspace System (NAS) users and distributing it to both the FAA and NAS users. Created in 1993, the data exchange program proved that having airline submit real-time operational information to the FAA improves air traffic management decision making (Ball, 2000). The sharing of information assured that all stockholders hold the same data which can lead to a more accurate response to capacity/demand imbalance. With a more accurate and earlier response, both response efficiency and effectiveness increased. For some years, CDM has been regarded as an efficient way to improve the use of the available capacity without having to invest too much in expensive technical support (Eriksen, 2002).

The most important aspect of CDM that we wish to transfer into our gate-allocation policy is the idea of sharing information. For example, prior to the implementation of CDM, airlines are exclusively assigned take-off and landing time slots at each airport. Without the practice of information sharing, when an airline canceled a flight at a certain time slot, the time slot would become unused and the slot would be wasted. With the implementation of CDM under the Slot Exchange Program, when an airline cancels a flight, information is given early enough to all NAS users such that the time slot can be given to another airline that wishes to use that time slot for a take-off or landing. The pairing of sharing information among all airlines and the FAA with the Slot Exchange Program has significantly reduced the assigned ground delay in certain airports (Ball, 2000).

Previously, information was not available to airline operation planners or was only available “after-the-fact,” when it could no longer be used to influence decision-making (Ball, 2000). The implementation of CDM has led to an increase in efficiency of air transportation by giving officials the chance to make adjustments in an ever-changing system. Furthermore, because of CDM, consequences of poor utilization are beginning to be understood by airlines, airports, and Air Traffic Control Service Providers (Eriksen, 2002). Due to its great benefits, the implementation of CDM is now considered an inevitable part of future airport operations if the demand for growth and customer shall be achieved.

II.4 Shared Facilities

Due to the growth of air transportation, airport gate capacity has become a major concern for the airline industry since the lack of gate facilities or inefficiencies in gate utilization are not keeping up with demands (Su, 1993). In gating operations where airports lease their gates to individual airlines, some airlines are surpassing their gate capacity. This lack of sufficient gates, particularly at busy airports, is a big problem that airlines need to deal with day to day.

In scheduled commercial airline operations, aircraft arrive at an airport in batches (or banks) due the demand at specific times (Haeme, 1988). That is, passengers from other originating cities also want to arrive at the popular destination city at the same time. This causes certain airlines to crowd their gates at certain time blocks of the day while other hours are more relaxed. Drivers for sharing facilities include peaking of traffic at different times and uncertainty in the level of type of traffic (de Neufville, 2002). The belief is that a relaxed time block of one airline may be peak time block of another airline. In this scenario, the idea is that the facilities of the relaxed airline can be loaned to the peaking airline. This practice will reduce the overall number of facilities that airports need to provide to the demand.

From the flight bank phenomenon, sharing passenger terminal facilities among airlines prove to be beneficial as it increases available passenger lounge space for each airline. The efficient use of gates by aircraft is becoming more important as air traffic increases, traffic scheduling and airline flight route patterns change, and the need to continuously improve productivity and passenger service quality become paramount (Srihari, 1991). Since it is becoming more and more difficult to expand existing airports, shared gates are becoming more and more attractive. Sharing facilities also significantly increase both the utilization of facilities, thus reducing the amount needed for any level of traffic; and the flexibility of the building, thus enabling it to accommodate easily variations in traffic composition (de Neufville 2002).

According to de Neufville, two main obstacles prevent the widespread incorporation of shared-use, multifunctional facilities into the design of airport passenger buildings. The first obstacle is the traditional practice of focusing single-use and the second obstacle is the lack of a comprehensive analytic approach to the design of multifunctional spaces. First, airline passenger buildings were historically relatively inexpensive compared to other airport investments. Second, designers did not perceive much opportunity to reduce costs by sharing. When airports were built, sharing facilities did not seem necessary or beneficial.

II.5 Conclusion

Upon reviewing literature, we found that literature lacks any form of collaboration among airlines to target gate-delay. Collaboration among airlines is superior to construction of new infrastructure because of the current economic crisis. Additionally, gate-delay occurs usually in peak-hours, meaning that new infrastructure is un-used during off-peak-hours. Collaboration proves to be beneficial in CDM practices as it improves air transportation through policy changes and no new infrastructure. Thus, collaboration among airlines for gate allocation is beneficial as it addresses current gate-delay problems under our current economic, energy, and environmental situation.

III. Problem Solving Approach

For an efficient gate assignment, it is important to have the ability to cope with sudden changes and provide solutions in time to meet the needs of real-time requirements (Cheng, 1997). In general, the increase of air travel demand and airport building regulations requires higher airport efficiency. In an effort to improve overall airport efficiency at airports experiencing gate-delay, our team evaluated the benefits of implementing a new gating policy called Collaborative Gate Allocation (CGA).

Our project first began under the close guidance of Dr. Rakas who exposed us to the current issues of gate-delay and the practice of CDM's Slot Exchange Program while our team members were students in an Airport Design class (CE153) at UC Berkeley in the Civil and Environmental Engineering Department. During this time, the team conducted extensive literature review in the current gating assignment issues, CDM, and practices of gate sharing.

Our process and concept development behind our newly developed program is shown in Figure 2.

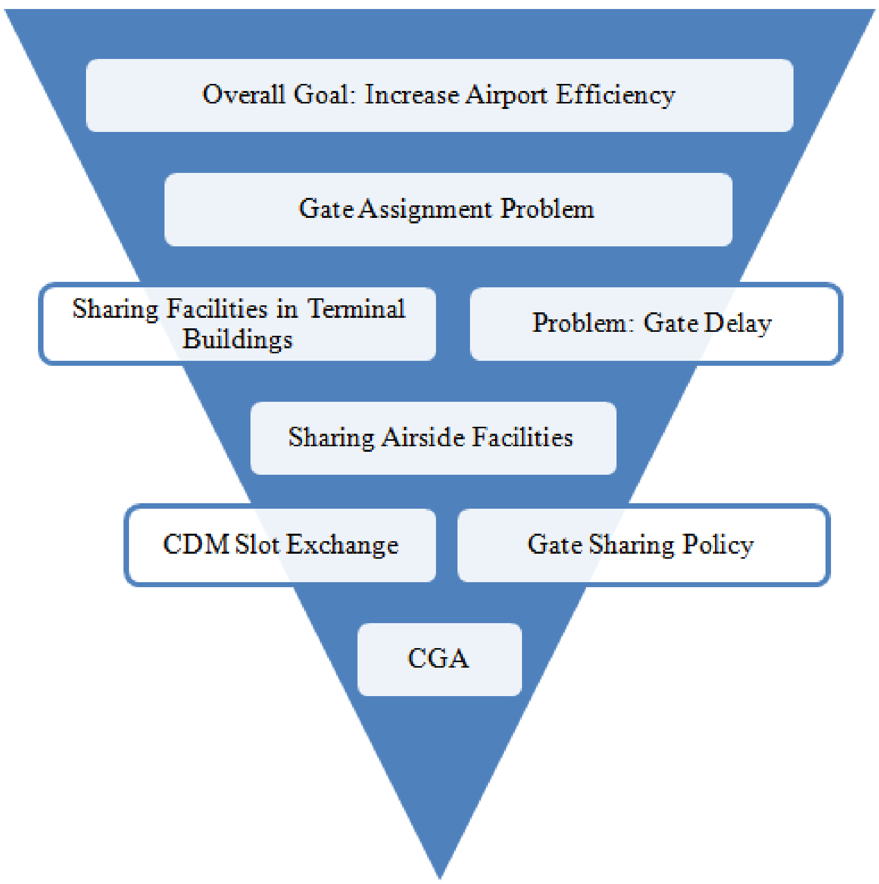


Figure 2 - Concept Development

From Figure 2, it is shown that in developing our concept, our team first identified an overall objective of increasing airport operation efficiency. Through our own research and discussions with our advisor, we targeted the inefficiency in gate assignment. We recognized that a simple deviation from a gating schedule may create a ripple effect to impose a huge economical cost to both the airline and airport. After learning about the economic benefits by implementing sharing facilities in terminal buildings (such as lounge sharing), we quickly shifted our attention to the possibility of sharing airside facilities. A successful implementation of Collaborative Decision Making (CDM) helped us further narrow down our final proposal – Collaborative Gate Assignment (CGA). Figure 3 shows comparisons between our developed CGA concept with certain characteristics of the current CDM program.

Collaborative Gate Allocation (CGA)	Collaborative Decision Making (CDM)
1. Gate Exchange - The airport operators can assign the participating airlines to different gates in accordance with the availability of the airport's gates and the day-to-day schedules of each participating airline.	**1. Slot Exchange - The participating airlines can exchange flight slots in accordance with their day-to-day varying flight schedules.**
2. Information Share / Live Time Update - Airport operators are given access to a live database that gives real time updates on each airline's arrival and departure information.	**2. Information Share / Live Time Update - There is a system implemented so that airport operators and all participating airlines have live update on each other's flight information.**
3. Voluntary Collaboration - Airlines volunarily participate in the CGA program.	**3. Voluntary Collaboration - Airlines volunarily participate in the CDM program.**

Figure 3 – CGA and CDM Comparison

As shown in Figure 3, by voluntarily sharing information, exchanges can be made among airlines. Flexibility by airlines allows airlines to take advantage of unused slots and increase the utilization of a system.

Our methodology is to have airlines and airport operators work together during peak hours or any other ad hoc situations when airlines are experiencing gate-delay due to insufficient number of gates. We propose that the airlines and airport operators make gate allocation decisions together to maximize gate utilization and airport efficiency.

With this concept development, it was determined that an evaluation tool must be created to analyze the benefits of an airport implementing our proposed concept. This led to the development of our Sigma Simulation Model.

As a small design group, it was easy for us to remain organized using Google Documents to share our information and progress with each other. Our frequent meetings assured that every member was contributing towards the project.

IV. Safety and Risk Management

Since our proposal does not include the construction or physical alteration to the airports, there are no inherent physical risks or safety concerns. Rather, our proposal will improve safety and risk management in multiple ways. The main goal of Collaborative Gate Allocation is to decrease the amount of gate-delay at an airport. This means decreasing the number of idling aircraft that have to wait in the penalty-box and also the amount of time an aircraft has to wait in a dead-zone. When aircraft idle at the penalty-box, they burn fuel, engine life, crew cost, passenger cost, and opportunity cost to be in another flight. In short, there is nothing positive about a loaded aircraft with its engines on waiting to be gated. Our proposal is meant to decrease all of these costs as well as decrease multiple risks that are caused by traffic congestion, backlog, fuel burn and depleting engine life.

Traffic congestions lead to several issues including possible traffic incursions, traffic delays, and additional manpower to manage the problem. Since traffic incursions are caused by mismanaged traffic directions, when traffic congestion is lowered on the tarmac, there is less probability for traffic incursion. Reducing gate-delay also reduces the necessity for the aircraft to travel to and from the penalty box after landing. If there is no gate-delay, aircraft will be able to travel directly to the gate without stopping. This reduces the amount of time an aircraft needs to spend traveling on the tarmac and possibly crossing the paths of other travelling aircraft. With the reduction in necessary movement, airport operators will be able to focus on other operations and provide better service elsewhere where required.

Safety and risk management is also improved through the process of minimizing fuel burn and prolonging engine life. By minimizing the amount of time an aircraft engine remains running, we are reducing the chances of any mishap. By reducing the amount of fuel burned, the amount of undesirable gases and CO_2 released by is reduced, lowering the risk of workers breathing in toxic gases. Understanding that an aircraft engine has a finite lifetime, reducing the amount of unnecessary engine use will prolong the engine life.

In abiding with the FAA Advisory Circular 150/5200-35 and the FAA Management System Manual, our proposal suggests no new hazards. In an assessment of our proposal, our proposal provides a safer way of gate allocation by reducing aircraft congestion and bringing more aircraft into a stable state compared to the current practices. When an aircraft is gated earlier, there is less risk and thus no additional risk analysis is needed nor is any additional risk treatment needed.

V. Technical Aspects Addressed

V.1. Simulation

In our analysis of Collaborative Gate Allocation policy, we decided to utilize simulation as a tool rather than a system optimization. During our literature review, we found several studies that implemented linear programming techniques to analyze gate capacity issues, but in the end, those studies were focused on details falling within the current gate policy, while we wanted to develop an overarching policy to maximize efficiency instead; so in our approach, we decided to employ a simulation model in conjunction with detailed output analysis.

A linear program would assume that the system can be optimized using linear constraints and linear objective functions, but in reality, network systems such as an airport are dynamic and constantly changing that deal with unplanned issues. If we were to run a linear programming optimization of an airport, many assumptions would have to be made about the system, and the results would be biased according to our current beliefs about airport constraints such as demand and capacity. Optimal solutions acquired from linear optimization would only be practical if real life constraints were assumed linear and non-dynamic, but since this is not the case, optimal solutions derived from this method are almost never the ones that get implemented.

Simulation, however, can be used in conjunction with sensitivity analysis techniques such as constantly changing inputs on the simulation model. For example, we can double the amount of arriving flights to see how our simulated airport would operate under non-regular emergency situations. In addition to performing sensitivity analysis, we were able to include randomness and stochastic processes in terms of the types of planes/flights arriving and the gate occupancy times of those flights. By generating randomly distributed flights in our model, we were able to account for ‘random’ delay and give airport operators a tool to decide how many and which gates to allocate to this CGA policy if they decide to implement it. We believe that our simulation approach, which models the problem of gate delays, provides a much stronger analytical analysis than traditional optimization methods.

V.2. Event Graph Model – Sigma

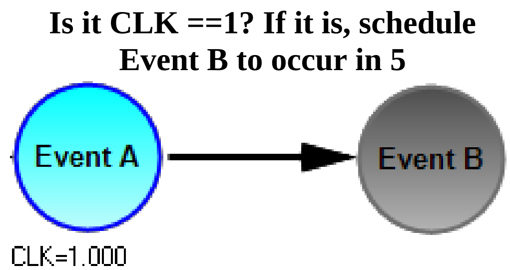
For our simulation model, we chose to use the SIGMA modeling software; it is an event graph model program, which resembles a flow chart that depicts the simulation process. Event graph models are simple to read because they consist of only two components: nodes and edges.

Nodes are the circles in the event graph model; they represent events that happen during a simulation. In an event node, there are state changes that occur to variables that are tracked while running the model. These variables are the inputs and the outputs of the simulation model.

Edges are the arrows pointing from one node to another; they represent a ‘trigger’ for the event node that it is pointing to. Edges have two properties: delay (i.e. time) and a condition. Delay is defined by how long the simulation has to wait until the next event is scheduled. Delay is used as the delay in the events that we are trying to simulate, such as the time difference between arrivals and the time it takes for a plane to occupy a gate. A condition is defined by the model checking the edge before scheduling the next event: if it is true, it schedules the event; if it is not, it does not schedule the event.

A sample is given below in Figure 4: Event A has occurred. There is an edge pointing from an Event A to Event B, and it has both a time delay and a condition associated with it. When the edge is executed, the edge asks “if the current time in the simulation, defined by the variable Clock (CLK), is 1.00, wait for 5.00 units of simulation time, and then execute Event B”

Before:



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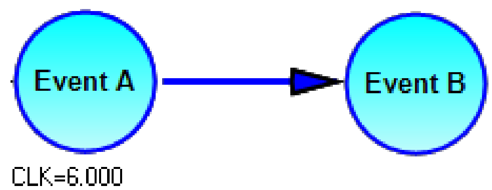

Figure 4 - Event Nodes

V.3 Application to Boston Logan Airport

As mentioned earlier, our simulation model can be used to model any airport as long as the required airport-specific data inputs are used. Our team chose to model Boston Logan Airport to demonstrate our SIGMA model because, after analyzing a number of airports, we concluded that Boston Logan is a good representation of a large metropolitan city that serves as a destination airport for major airlines that includes some of the following: AirTran, US Airways, JetBlue, and American Airlines. Thus, with these characteristics of the city of Boston and its airport, we concluded that if our CGA policy shows statistically significant benefits in delay reduction at Boston Logan, it will allow for similar benefits to other airports. We also assume that larger, busier hub airports will experience even greater results when implementing CGA under certain constraints.

V.3.1 Data Collection and Input Parameters

For this simulation model, we have three inputs: (1) the number of gates that each airline/alliance owns, (2) the arrival schedule of planes to the airport, and (3) the gate occupancy time of those planes in their respective gates. It is notable to mention that this model is not a trace driven simulation, which means that this simulation does not read data directly from a file and inputs into the model. The primary reason we did not build a trace given simulation is because the data gathered may be dated, since the data was from past results. Also, if we were to perform sensitivity analysis, we would have had to manually manipulate the data in order to get new results.

We decided to use parametric inputs for our simulation model. The data that was collected was analyzed and the distributions were created from this analysis; these distributions allowed us to generate random variables, which then became the numerical values that were inputted into the model. Thus every time we run our simulation, different outputs are expected since the inputs vary with each run. However, over a large number of iterations, the output values should converge into an expected value.

We assumed that the gates among alliances/airlines only serve planes that fall under certain alliances/airlines. For example, Airplane A would be gated at an Airline-A-owned-gate and never at an Airline-B-owned-gate. Aircraft sizes were extracted from the database and split into three categories: large/heavy, medium, and small. However, the number of gates and the size of the gates were not listed in the data given to us by Leigh|Fisher. So, in order to obtain this data, a cross-reference study between Google Maps and an academic research paper was conducted. The academic research paper included a schematic of the layout of Boston Logan with the airline owned gates listed as shown in Figure 5 (Skaltas, 2009).

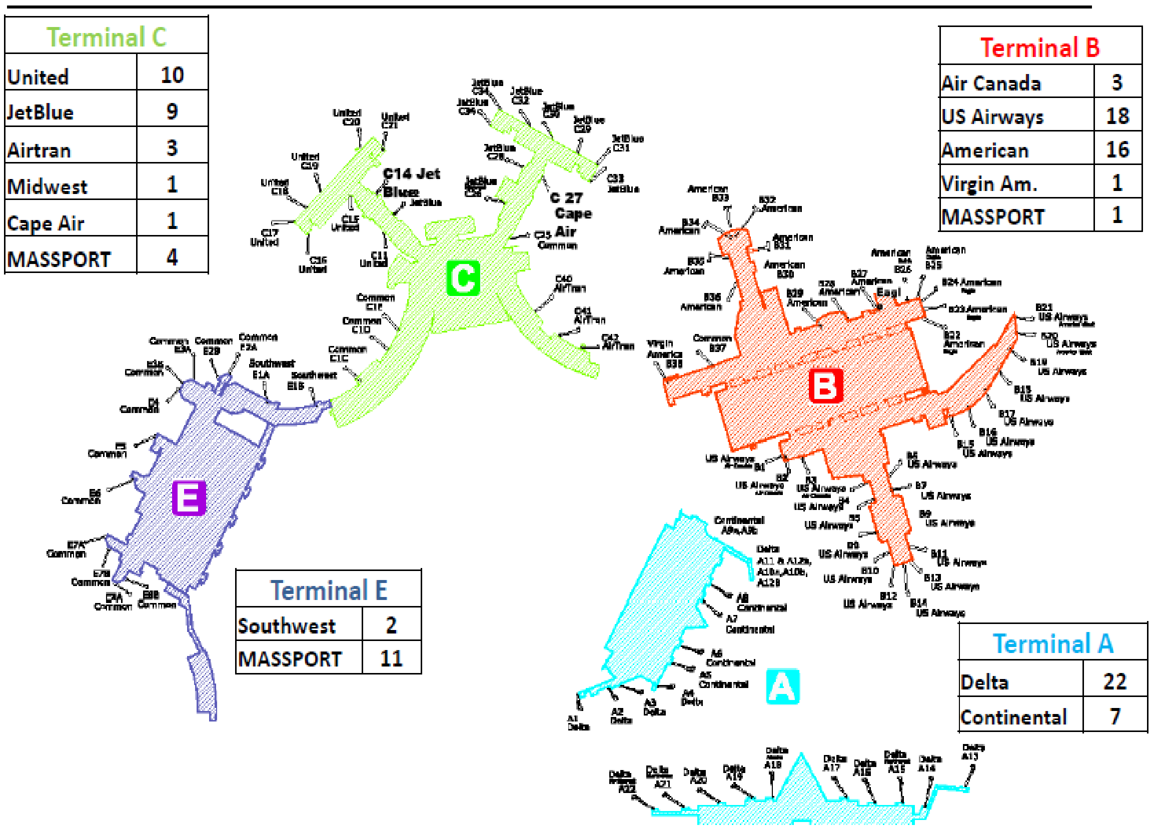

Figure 5 – Boston Logan Airport

Figure 5 does not display the gate sizes, thus to obtain the size of each gate, our team looked at the Google Maps image of Boston Logan and measured the gate sizes. We concluded that a gate that was able to accommodate a plane with a wingspan over 160 feet would be considered as a large gate, 110 to 160 feet would be considered a medium gate, and under 110 feet would be considered a small gate.

The gate occupancy time was an input required that we did not explicitly have from the arrival/departure data provided by Leigh|Fisher. Flight identification tags were also lacking in the data. Thus, in order to obtain this data, engineering judgment was used in tracing an incoming aircraft until it left the gate. For example, if a United Airways A310 aircraft arrived at a given time, and a United Airways A310 left within a reasonable range of time later, it was assumed that it was the same aircraft, meaning that it remained at the gate for that period of time. For aircraft that arrived and departed later than a reasonable range of time, it was assumed that the aircraft did not remain at the gate but rather returned to the airline's hanger. The gate occupancy time, in this scenario, was omitted. After tracing the aircraft for the given day, we grouped the various gate-occupancy times by the size of the aircraft with their corresponding airline and arrival time. In other words, each of the small, medium, and large aircraft groups had their own pool of occupancy times.

Once this data was sorted, all present airlines were grouped into eleven major airlines (including an "Others" category that includes very small and/or private airlines); these groups were then further split into three size groupings (small, medium, and large). Note that international flights were not considered in this model due to additional logistical obstacles. After these major categorizations were defined and set, the data, given to us by Tim Dulac, was then organized and arranged to show how the gate occupancy times were split between the size groupings and airline groupings. With additional help from our statistics consultant, Bernard Niu, we were able to take our sorted data and fit it into different distributions with estimated parameters. Each airline would have three probability distributions that would correspond to small, medium, and large sized planes. These distributions generated a corresponding numerical random variable, which was one of the three inputs for our model. For example, the gate occupancy time for a small plane from Airline A is a random variable that is generated from a Normal Distribution with a mean of ten and a standard deviation of two.

The data chosen for our simulation is from the 31st of August of 2010 because this day (Tuesday) was the Average Day in a Peak Month (ADPM), a common day used for designing airport facilities. For each data entry, the arrival and departure time, the size of the aircraft, the airline operating the aircraft and its destination or origin is given. For example; if an aircraft arrived at 6:00AM, it is assumed that it is at the gate at 6:00AM and if an aircraft has a departure time at 7:10AM, it is assumed that it leaves the gate at 7:10AM.

In looking at the arrival data, we split the data into hour block time intervals. The time blocks serve as a method to calculate the probability that a certain sized airplane from a certain airline would arrive during that specific time block. For example, in the Boston data, there was only ones small AA airplane arriving between 10:00 and 11:00 AM, while there were 25 airplanes in total arriving in that time block. Thus, the probability that a small AA plane arrived from 10:00 to 11:00 AM is 1/25 or 4%.

We assume that the arrivals of aircraft follow a Poisson process because it posses the following properties:

- $N(0) = 0$: No planes have arrived before time 0.
- Independent increments: The time differences between aircraft arrival are independent from each other.
- No counted occurrences are simultaneous: no two planes ever arrive at the same time.

In other words, we assumed that planes arrive according to a Poisson Process. We generated aggregate and individual airline arrival schedules by looking at the gathered data distributions and created probabilities that a certain sized aircraft of an airline would arrive in a certain time period.

V.4. Types of Policy Modeling

In our SIGMA simulation model, the system begins when the airplane first gets detected by the airport and the airspace operators, and ends when the plane physically leaves the gate. The metric that we are interested in is the gate assignment time, which is the time when the plane first enters the system and the time it gets *assigned* a gate. We defined this system and this performance metric because the gate assignment time is the one variable that an airport operator would have any control over. Aircraft taxi, park, and get serviced for a determined amount of time, however since breakdowns are random, such events are not controllable. The simulation model's objective is to see if our Collaborative Gate Allocation Policy will in fact lower the gate assignment times compared to the current exclusive/preferred use policy.

Our model has two major assumptions. First, we assumed that the gates service planes on a first-come, first-serve policy. This logic is based on the fact that gates can only service planes that have entered the system. Second, we assumed that airplanes go to gates of its largest accommodating size. For example, if a large gate is available, and there are both large and medium planes queued and waiting to be gated, the large gate gives priority to the large planes. However, if a medium plane comes into the system before a large plane, the first plane gets priority in gate allocation.

V.4.1. Common-Use Policy Modeling

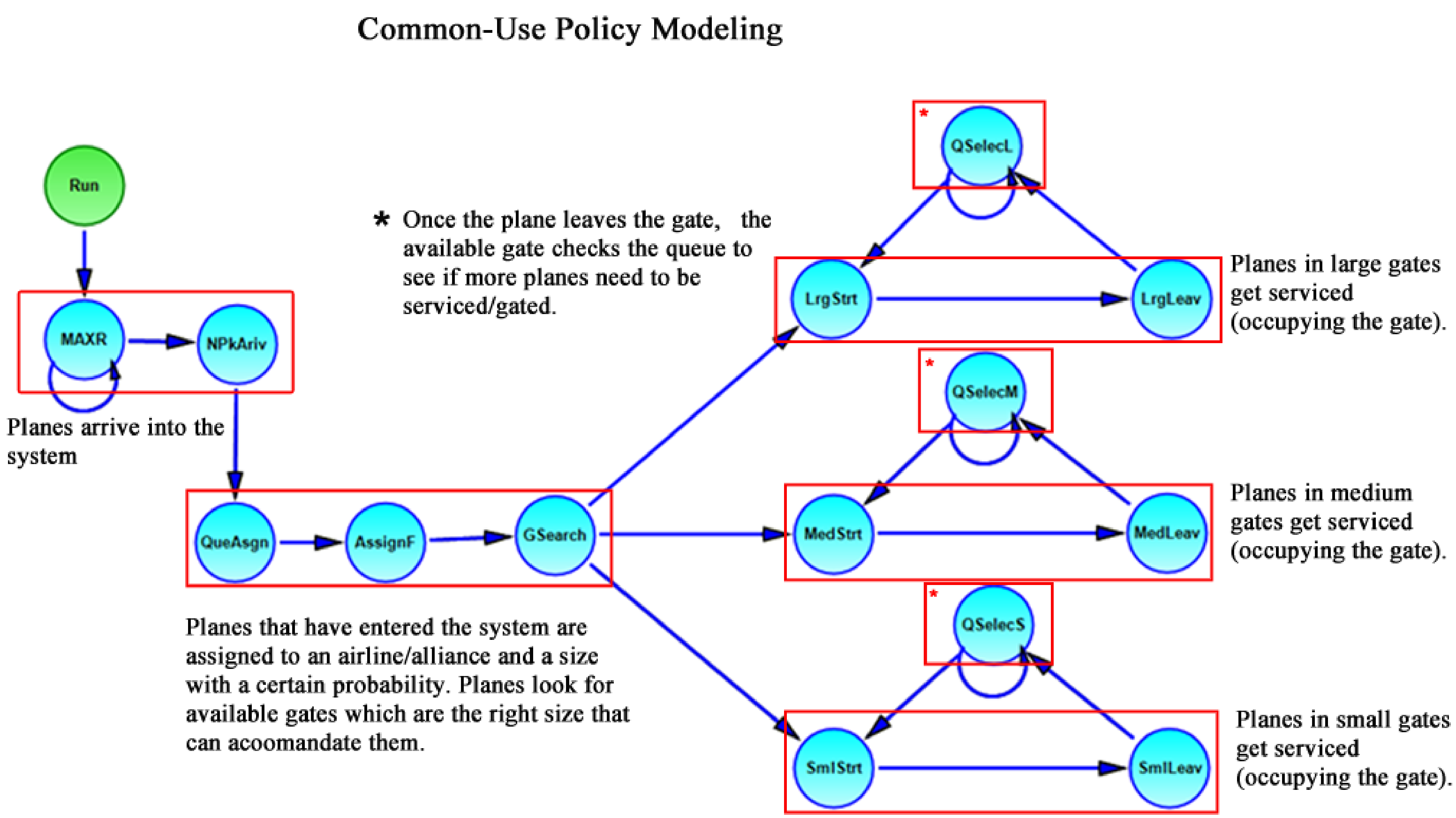

Figure 6 – Common-Use Model

V.4.2. Exclusive-Use/Preferred-Use Policy Modeling

Note: The model is the same as the common use model except that in the queue allocation, planes only look for gates that are of their alliance/airline and their size.

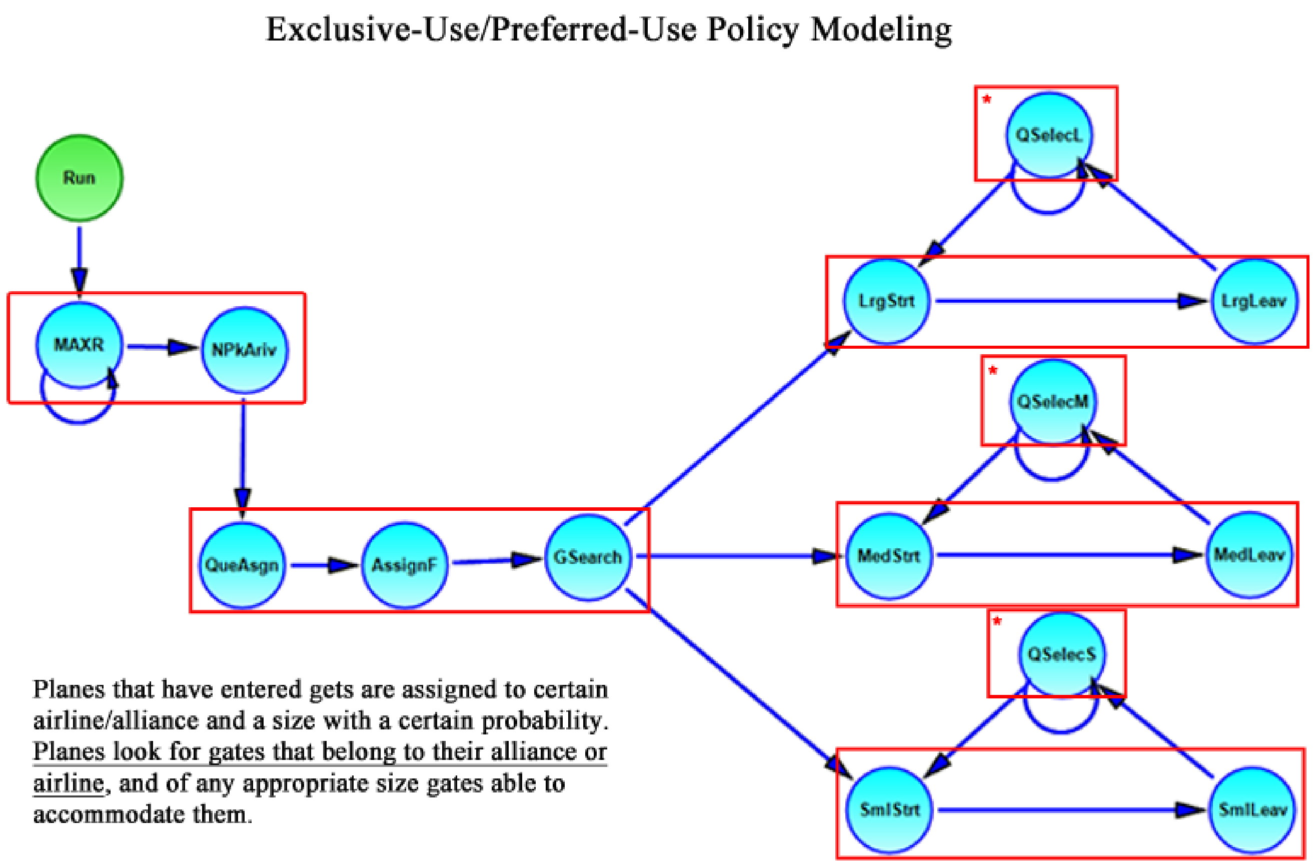

Figure 7 – Exclusive-Use Model

V.4.3. Collaborative Gate Allocation Policy Modeling

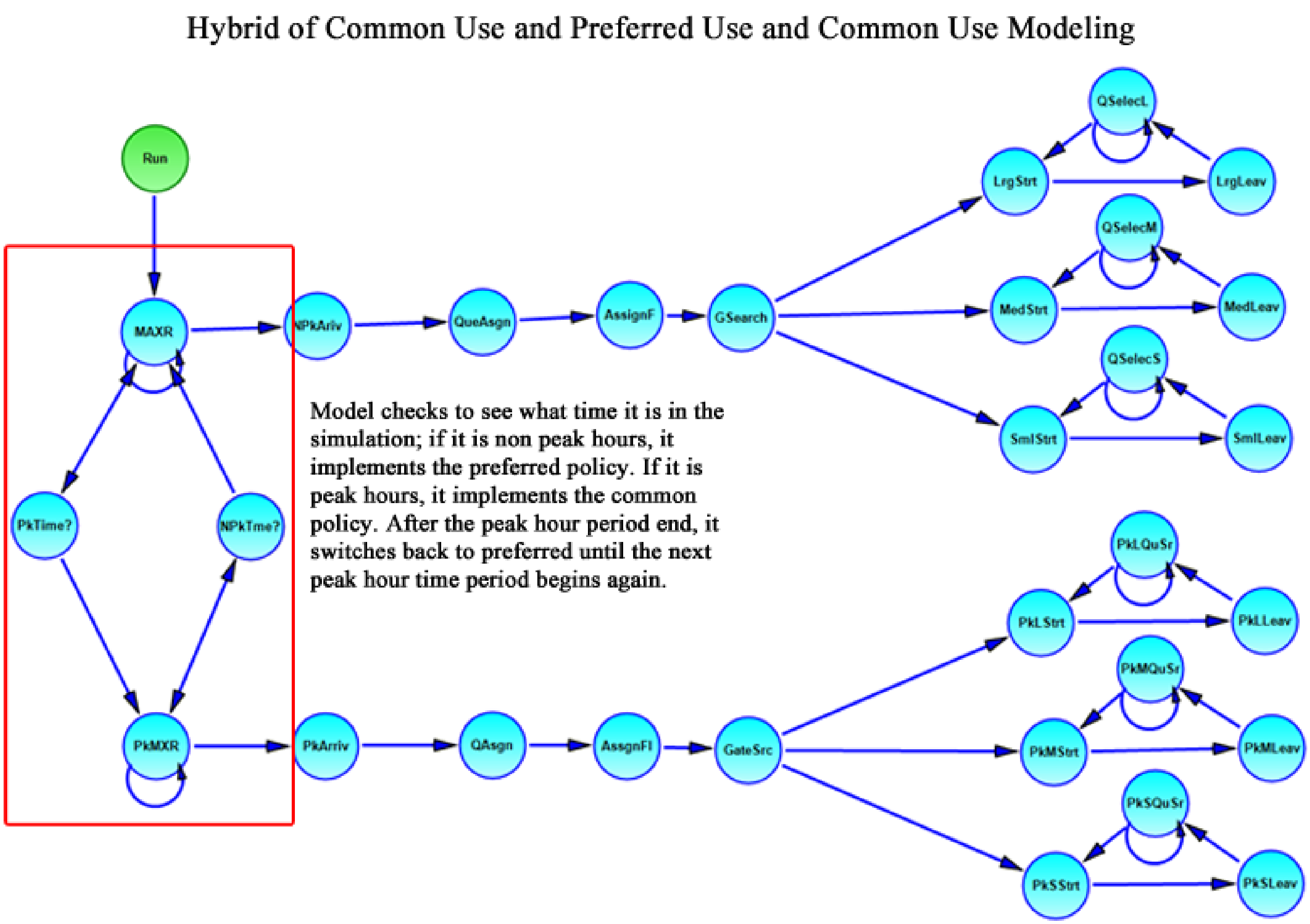

Figure 8 – CGA Model

V.5. Outputs

The outputs of this model are: (1) the gate assignment time, (2) the queue length of planes that have not been assigned a gate, (3) arrival time in the system, (4) type of airline/alliance they belong to and (5) aircraft size.

From these outputs, we are able to gather meaningful statistics and make conclusions which can be found in our results and conclusions section below.

VI. Interactions with Industry Professionals and Airport Operators

During the development of our model, we were in contact with Tim Dulac, a consultant with Leigh|Fischer. Tim Dulac is an expert aviation analyst in the field of airport operations and currently utilizes the Gate Model, common software used for analysis of airport gate operations for airport gating analysis. Tim Dulac supplied us with Logan Airport's flight data as well as advice regarding how to approach our problem, such as how to obtain data we required for our simulation model. Upon completion of our common-use and exclusive/preferred-use simulation models, we presented our two simulation models and our future plans of investigating CGA to a panel of industry professionals, UC Berkeley professors, UC Berkeley graduate students, and the public. Some of those in the audience included a pilot with Delta Airlines, Frank Ketcham, a director at Leigh|Fischer, Linda Perry, a senior research analyst from Sensis Corporation, and aviation research expert/professor, Mark Hansen.

In developing the model, the team consulted an Industrial Engineering and Operations Research (IEOR) professor, Professor Lee Schruben frequently to assure the accuracy of our model to our logic. As we developed the model, we determined that the model would be more useful if it provided a cost amount for the gate-delay observed. This cost amount is used as an evaluation tool to determine whether or not the new concept yields enough benefit to implement at an airport. The model was created such that it would output a certain time amount of gate-delay for each airline and each category of size of plane (small, medium, large). This time value was then used to calculate associated costs due to fuel burn, crew operating cost and passenger cost.

Our team also met with a Delta Airlines pilot, Frank Ketcham, who gave us a pilot's perspective. The discussion with Frank Ketcham consisted of addressing operational issues that our concept would likely encounter. These issues mainly consisted of the necessary equipment and crew mobility for our proposal to work. After speaking with Mr. Ketcham, the required equipment for gating aircraft was deemed mobile. If there is ever an incident where an aircraft cannot be serviced by external equipment due to the gate-switch, the auxiliary power unit (APU) can serve as a last resort. On another note, since the act of "gate-loaning" of our CGA concept is to be made at least 45 minutes prior to arrival, passengers will be notified in time of the gate-switch that has been made.

In addition, our team approached Flavio Leo, Deputy Director of Aviation Planning and Strategy at Massport, and Robert Pyrka, business analyst for JFK International Air Terminal LCC, to receive feedback about the feasibility of implementing CGA at Boston Logan Airport. In our interview with the two airport operators, we discussed the feasibility of implementing the CGA policy. Overall, our concept was well received by both operators as something definitely worth investigating for implementation.

Flavio Leo mentioned that Boston Logan Airport currently has limited space for gates and the challenges are multifold. Logan Airport is gate constrained in the summer month during the peak afternoon timeframe. It was also mentioned that gate utilization is likely to be an issue in the future. The obstacles that Mr. Leo addressed included operational tasks such as how passengers will know where to go. However, this problem is addressed in our concept implementation that notice will be given 45 minutes prior to arrival to the destination airport.

Rob Pyrka mentioned that gate-delay is observed on a daily basis and there are actually gate-holds pre-planned into gate planning because the schedule is so tight. Mr. Pyrka mentioned that this policy would be a good tool for airlines especially under irregular operations and airport that are extremely busy, running close to capacity, or delay prone. Mr. Pyrka encouraged our project stating that the implementation of CGA is a win-win situation for all parties. In our interview, Mr. Pyrka mentioned the benefits that the team predicted such as minimizing the amount of traffic sitting on the taxi areas and the amount of time an aircraft sitting on the ground. Issues that Mr. Pyrka addressed are similar to those addressed by Mr. Leo. The forecasted problems are the operational obstacles that airports would encounter if CGA is implemented right now. His concerns included the logistics behind moving employees, passengers, and related equipment from one set of gates to another. These concerns are 100 percent operational and the cost of addressing these problems can be calculated by the airports and used to offset the savings we determine from using our simulation model.

VII. Results

The main objective of our modeling is to compare the proposed policy with the current Preferred-Use Policy. Through cost analysis, we show that by implementing Collaborative Gate Allocation, the total airport operation cost is reduced.

Aircraft gate-delays from the two policies were translated into monetary values for comparison. Our simulation outputs are average gate-delay under the Preferred-Use Policy and the CGA Policy. For each minute of gate-delay, the airport incurs the following cost (Table 1):

		Preferred-Use Policy	**CGA Policy**
	Unit Cost Per Minute ($/min)	Total Cost per flight ($)	Total Cost per flight ($)
Total Fuel	24.9	747.6	722.0
Idling Fuel	0.7	22.4	21.7
Crew	14.6	438.4	423.4
Maintenance	10.8	324.9	313.8
Aircraft Ownership	8.2	247.1	238.6
Passenger Cost	54.9	1,647.9	1,591.5
Other	2.4	73.3	70.8
Total Cost per flight	91.7	2,753.9	2,659.7

Table 1 – Itemized Costs (Air Transport Association)

The first column shows the breakdown of each item cost for each minute an airplane is idle. The next two columns are the total cost calculated by multiplying the unit cost with the average gate-delay incurred by an aircraft under the two policies. It is important to point out how we derived the average passenger cost for each incoming plane because only the individual passenger cost per minute was available. To better represent the expected number of passengers on a randomly sized plane, we had to first determine the probability of each size aircraft arriving at Boston Logan. We then took these probabilities and used them to weight the average number of passengers per size of aircraft to get the expected number of passengers per plane. Thus, the unit passenger cost can be obtained by multiplying the individual passenger cost with the expected number of passengers.

Figure 9 demonstrates the item cost comparisons between the two policies for an aircraft experiencing average delay. In the results shown, it is evident that costs are higher in every category under a Preferred Gate Policy.

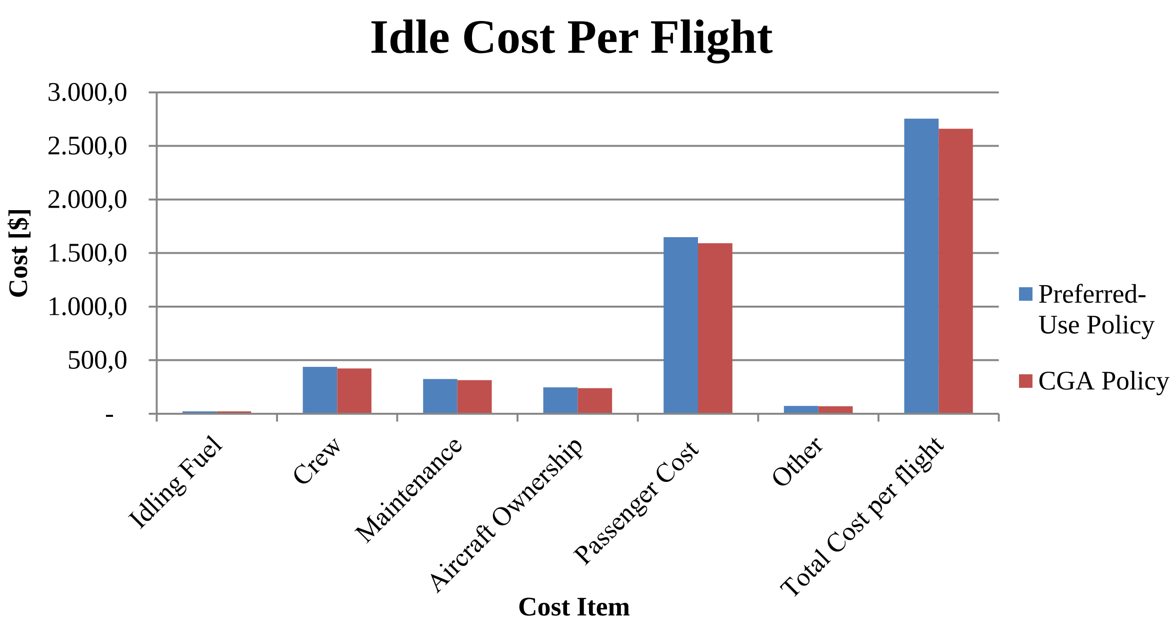

Figure 9 Idle Cost Per Flight

By taking the difference in assignment time, we see that the airport is able to save one minute of gate delay per incoming flight under the proposed CGA policy. To understand the impact of this one minute saved per flight, it is important to scale it to a full-day of operation. There are approximately 350,000 movements annually at Boston Logan, where arrivals and departures each account for roughly half of these movements (Leo, 2011). In other words, there are around 500 arrivals on an average day and by implementing the CGA policy, Boston Logan decreases its gate-delay by 500 minutes per day. The monetary impact of the decrease in daily delay can be seen in the following table and graph.

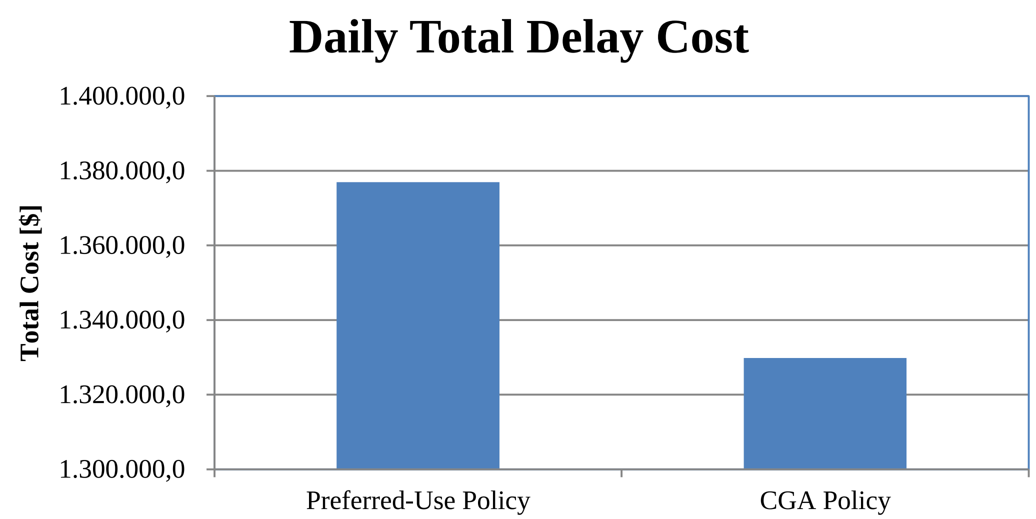

Figure 10 – Total Cost

	Savings by All Airlines ($)
Daily Operation	47,121.70
Annual Operation	17,199,423.00

Table 2 – Savings from Policy Switch

Figure 10 illustrates the daily total cost comparison between the two policies incurred by all participating airlines; it is evident that by implementing CGA policy we significantly reduce the total cost derived from gate-delay. The results in Table 2 further show a saving of nearly $50,000 per day which represents an annual saving of over $17 million. In addition to the monetary saving, we also found that there is a significant decrease in pollutant emission from idling planes shown in Table 3. A low power setting is used for the following calculations which can only be a lower bound representation of the amount emitted (Kim, 2011).

Policy	Fuel Flow (kg/s)	THC (g/kg)	CO (g/kg)	NOx (g/kg)
Preferred-Use Policy	99,000	225,720	3,405,600	386,100
CGA Policy	95,700	218,196	3,292,080	373,230
Difference	3,300	7,524	113,520	12,870

Table 3 – Release of Daily Pollutants by Idling Aircraft

There is a significant decrease in carbon monoxide (CO) and nitrogen oxide (NOx) while there is a less-than-significant decrease in hydrocarbons. All three pollutants contribute to urban pollution as well as human health hazards, especially carbon monoxide which is poisonous and all workplaces were prohibited to expose its employees to more than a certain limit by Occupational Safety and Health Administration. (US Department of Labor, 2002). Such effort in reducing pollution emission by implementing CGA policy will definitely take the aviation industry closer to achieving a greener environment.

VIII. Summary, Conclusions and Recommendations

With ever growing traffic in airports and constrained land for expansion, airports must look inwards at its own system efficiency to increase capacity. Building more runways or constructing more gates is a costly and time consuming endeavor without a certain monetary return. So with these things in mind, we looked to improve the system by increasing the efficiency of the gating policy. Understanding the success and procedures of Collaborative Decision Making (especially its voluntary and negotiating nature) we developed our own gating policy called Collaborative Gate Allocation that aims to utilize underused gates during peak hours or other unforeseen scenarios to decrease aircraft delay.

Intuitively, it is expected that the CGA policy is more efficient in comparison to the current Preferred-Use policy. However, in our study, this is the first time that this concept was proposed, fully analyzed, and quantified. While approaching the problem of analysis, we decided to develop a large scale simulation model using Boston Logan as a good representative real world case study. Boston Logan is located in a large metropolitan city and is itself a busy airport (although not a hub airport). Our given data was from a Tuesday in August 2010, a day generally used for airport design. Because this day was during a year of economic downturn, the air traffic flow given in the data was quite moderate. Even with such modest demand, the switch to CGA from Preferred-Use policy allowed Boston Logan to save roughly $50,000 per day, which scales to over $17 million in savings per year. When looking at our current economic upswing and the implementation of CGA in busier hub airports, we can expect much greater savings than our current results indicate. Subsequently, due to the decreased idle delay time, CGA policy allowed Boston Logan to significantly lower its Air Pollutants, especially Carbon Monoxide and Nitrogen Oxide.

The current Preferred-Use policy and some Common Gate policies are all static systems that do not adapt to the varying demands that the airport will encounter, but CGA is a dynamic system that will allow airports to adapt according to their current demand or other unforeseen circumstances and minimize their delay costs accordingly. Due to the significant benefits that an airport will receive from implementing CGA policy, it is our strong recommendation to other airports to implement CGA policy, not only for the monetary benefits, but also for the environmental benefits.

If CGA policy is accepted, our team would recommend further research in several areas. The first area would focus on developing a forum in which the exchange of information between aircraft operators and airlines would be easily and efficiently deposited and used in day-to-day operations through CGA program. Another area of research would focus on allowing for a balancing mechanism to allow for equitable usage of leased gates. Thirdly, we would focus research efforts on cultivating a CGA culture among different airlines which would in turn stimulate CGA growth in many more areas of airport operations. By having different airline employees accepting and utilizing CGA, this permeating culture of gating efficiency can lead to standardized equipment among airlines, which would allow CGA to affect otherwise non-sharing gates. For example, the voluntary airline members of CGA would be able to share gates without worrying about incompatible proprietary equipment; this fact would allow for a much easier transition from the current Preferred-Use policy to CGA.

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Appendix B: Description of the University

University of California, Berkeley is the world's number 1 public university in the Academic Ranking of World Universities for 2010. It serves as a home for higher education for 36,000 students, including 25,700 undergraduates and 10,300 graduate students. UC Berkeley holds 1,455 permanent faculty and 7,059 permanent staff serving among 14 colleges and schools with 130 academic departments and more than 100 research units. More than half of all UC Berkeley seniors have assisted faculty with research or creative projects and more UC Berkeley undergraduates go on to earn Ph.D.s than any other U.S. university.

The Civil and Environmental Engineering department consistently ranks at the top of the best civil engineering programs in the country by U.S. News and World Report. The Department of civil and Environmental Engineering has fifty full-time faculty members and twenty-two staff dedicated to the education of more than 400 undergraduate students and 360 graduate students. The education in the department prepares students for leadership in the profession of civil and environmental engineering and sends approximately one-quarter of its undergraduates into a graduate education. Our CEE laboratories for teaching and research are among the best in the nation, providing opportunities for hands-on experience for all students. There is no other location with comparable resources in the San Francisco Bay Area that can provide students with ground-breaking local civil and environmental engineering projects and participate in professional activities.

UC Berkeley was chartered in 1868 as the first University of California in the multi-campus UC system. The school houses a library system that contains more than 10 million volumes and is among the top 5 research libraries n North America. Throughout its full history, Berkeley has had 21 Nobel Laureates, 234 American Academy of Arts and Sciences Fellows, 213 American Association for the Advancement of Science Fellows, 363 Guggenheim Fellows, 32 MacArthur “genius” Fellows and 4 Pulitzer Prize winners. Just as important as academic excellence, UC Berkeley has held a respectable active history of public service. More than 7,000 UC Berkeley students every year do volunteer work in 240 service-oriented programs while there are more Peace Corps volunteers from UC Berkeley than from any other university. Clearly, UC Berkeley is not solely focused on academia as countless research and outreach initiatives focused on public benefits to the community, nation and world.

Appendix C: Description of Non-University Partners Involved in the Project

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LeighFisher (formerly, Jacobs Consultancy) provides a broad range of strategic management consultancy services, with an emphasis on policy, economic regulation, business strategy and planning, economic and financial modelling, and public-private-partnership (PPP) and related transaction support. Consulting work performed by Leigh|Fischer include enterprise risk management, strategic government services, surface transport and aviation.

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Los Angeles International Airport (LAX) is owned by the city of Los Angeles operated by the Los Angeles World Airports. LAX was considered the sixth business airport in 2009 and serves as a hub for Alaska Airlines, American Airlines, Great Lakes Airlines, Horizon Air and

United Airlines. LAX has an annual economic impact of $60 billion and creates, attracts and supports economic activity through Southern California (www.lawa.org).

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Massport is a port district created in 1956 in the state of Massachusetts. Massport operates the airports and seaports in the eastern and central regions of Massachusetts but focuses mainly on the Port of Boston. Airports operated by Massport include Logan International Airport, L.G. Hanscom Field, and Worcester Regional Airport. “Over the past decade, Massport and our transportation partners have invested more than $4 billion to improve and modernize our facilities and equip them with the latest time-saving and customer service amenities to give you a safe, comfortable and convenient travel experience whatever your transportation needs” (www.massport.com).

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John F. Kennedy International Airport is an international airport located in Queens County on Long Island in New York City. In 2010, JFK Airport handled over 46 million passengers, making it the 14th busiest airport in the world in terms of passenger traffic.

“Terminal 4 at JFK International Airport is one of the most modern, efficient, spacious and unique terminals in the New York area serving nearly 40 international and domestic airlines carrying over 9 million passengers per year” (www.jfkiat.com). JFK operates over 90 airlines and is the base operations for JetBlue Airways.

Appendix E: Evaluation of the educational experience provided by the project

For the Students

1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

The greatest benefit for our project was the development of a research that was of our own interest. Unlike ordinary school assignments, this project provided us the freedom to explore the different topics of aviation and choose an issue we believed we could improve. Through the course of this project, we learned how to address a current, real issue and develop a research topic about it that is meaningful and potentially practice-changing. Another great learning experience was the exposure to writing a technical report similar to that of a graduate studies thesis. As undergraduate students, we have never written a research report such as this before. The experience of conducting literature review was a good preparation as some of us continue our academic pursuit in graduate school.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

While the faculty was completely receptive to our efforts, it was difficult to recruit more students, whether undergraduate or graduate. This issue mostly caused an obstacle in our computer model development. We overcame this challenge by self-teaching the programs and consulting our professors frequently with questions.

Being only a group of 4, it was difficult to cover such a large project. Nonetheless, we began our research early in fall, which allowed us a lot of time to cover most of our literature review and focus on perfecting the model in the spring. We assigned leaders of different tasks, i.e. literature review researcher, data analyzer, computer-model designer, and collectively assisted each other in accomplishing each task.

Another challenge that we encountered was obtaining the data we required for the different airports to input into our computer model. To solve this issue, we contacted numerous professionals in industry and reformatted the data they provided into data we could input.

3. Describe the process you or your team used for developing your hypothesis.

After filtering our own potential research topics proposed by the competition, we spoke with Dr. Rakas and developed the concept of implementing the concept of gate sharing on peak hours. Our drive was based on developing a method to increase efficiency without the construction of new infrastructure. This was to efficiently and effectively address the problems of gating aircraft under the current status of our economy and green movement.

In analyzing our concept, we found similarities in Collaborative Decision Making. Knowing the benefits of CDM, we knew that collaboration among airlines results in positive results. As a group, we furthered our scope with the idea of creating a simulation model to measure its benefits in terms of operation costs saved and the reduction of environmental impact. We wanted to develop a model that would determine if the CGA concept should be implemented at an airport.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Our collaboration with industry, specifically Leigh|Fisher, was particularly useful in aiding us obtain the data we required for our model that we otherwise would not have. Talking to Tim Dulac from Leigh|Fisher provided us a practicality aspect as well as an appropriate method to go about our model design. Also, our meetings with Frank Ketcham, a pilot with Delta Airlines, were very helpful in providing us the perspective from an airline point of view and how they will react to our policy. In both collaborations, industry provided us a feasibility mind that we otherwise would not have developed.

Furthermore, our contact with Flavio Leo, Deputy Director of Aviation Planning and Strategy at Massport, gave us a real picture of what our CGA concept would be like at Boston Logan Airport. The work with Flavio gave us realness to our concept as he encouraged our concept and provided additional issues we needed to address.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

We learned a great amount about the practice of gate-assignment and collaborative decision making. Also, it was a great experience collaborating with industry and meeting with our professors frequently to develop our model. This project definitely provided us the experience in working with a mentor similar to that of working under a senior engineer in the work force. During the project we also learned how to build a simulation model using Sigma as well as a little VBA. Furthermore, we learned to work in a group efficiently and effectively by peer-accountability/performance monitoring in completing our tasks.

Again, in writing the technical paper, we developed skills for writing a research paper in our graduate studies. This project was a good preparation in conducting literature review, developing a concept, and analyzing our proposal.

For Faculty Members:

l. Describe the value of the educational experience for your student(s) participating in this Competition submission.

My students gained tremendous educational value from this Competition. They went through the entire creative process of designing a policy for collaborative aircraft gate assignments from the initial stages to the end by creating a methodology and a model for testing their gate assignment policy. As some of the students are planning to apply to various graduate programs, this educational experience was a perfect way for them to learn about how to start creating new concepts and new knowledge. Once they start their graduate programs, the experience gained while participating in this Competition submission process will help them make a smoother transition towards conducting more advanced research that is expected in any graduate program.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

The learning experience was quite appropriate for the context in which the competition was undertaken. It tested the intellectual capability of the students at the right level, and offered challenging insight into practical, "real-world" problems. This Competition also allowed students collaborate in small teams of four students, which required them to co-operate, organize and designate tasks within a complex goal-oriented endeavor. .

3. What challenges did the students face and overcome?

There were many challenges the students faced and successfully overcame. First, these are undergraduate students with no prior experience in conducting research. Furthermore, they came from a civil engineering and operations research background, and had little previous knowledge or understanding of aviation or airport systems. The Airport Design class that they took the previous semester was their only formal education in aviation. Hence, the beginning of the research process included a long learning process about how to conduct research and how to understand more advanced aviation concepts, such as the Collaborative Decision Making (CDM) method. Another challenge the students faced was the initial misunderstanding of their proposed gate sharing policy by airport operators and industry experts, and their (who is they? The operators?) initial "suspicion" about the proposed policy design. Whenever the experts commented on their design from a more tactical, operational perspective, the students very professionally and patiently would explain their paradigms and strategic goals. Consequently, their communication with the airport operators and industry experts was a very positive and productive enterprise.

4. Would you use this Competition as an educational vehicle in the future? Why or why not?

I would definitively use this Competition as an educational vehicle in the future. In previous years I conducted a significant amount of undergraduate research through the UC Berkeley Undergraduate Research Opportunities (URO) program. This program was designed to assist undergraduate students in developing research skills early in their college education. On average, half of my students from the Airport Design Class would participate in aviation research projects in the following semester, and would formally be funded and sponsored by URO. However, due to recent budget cuts, this program had to be closed. By using this Competition as an educational vehicle, I am not only continuing research with undergraduate students, but also teaching them how to structure, organize and present their work to a large number of experts in the field.

5. Are there changes to the Competition that you would suggest for future years?

I would expand Challenge Areas by adding more emphasis on the Next Generation Air Transportation System (NextGen) requirements and expectations.

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Appendix G: Biographies

Andy Chou

- Andy Chou is currently a senior in Civil and Environmental Engineering who will graduate in May 2011. Andy has a degree emphasis in structural engineering with interest in seismic design and structural analysis. He will be interning at URS this summer and return to school at UC Davis or UC San Diego to obtain his Master Degree in Structural Engineering.

Kevin Leung

- Kevin Leung is currently a senior in Industrial Engineering and Operations Research who will graduate in May 2011. Kevin has an interest in operations, supply chain management with an emphasis in aviation. He will be interning at Disneyland in Anaheim this coming fall.

Edmund Tam

- Edmund Tam is currently a fourth year Civil Engineering student who will graduate in May 2011. Edmund is interested in transportation engineering with specific interests in transportation network optimization and public transit system efficiency. Edmund is currently working to optimize traffic signal timings and running traffic simulations using traffic optimization software.

Xia Xiao

- Xia Xiao is in his last semester at Cal, majoring in Civil and Environmental Engineering. He is interested in the area of construction management and transportation. Xia is currently working as a part-time junior cost estimator for Jacobs Engineering. After graduation, Xia intends to find a full-time position in the field of Construction Engineering.

Appendix H: Ethical Considerations

In the development and the implementation of a Collaborative Gate Allocation policy, there are important ethical considerations that should be recognized and addressed. First, we must first establish what constitutes an ethical issue. Ethics are moral codes that serve to guide human actions and determine whether an action is “right” or “wrong.” We deem our proposal an ethical issue because it has relation to morality with social, environmental, and legal implications.

In development of our model, our main drive was decreasing gate-delay. This led to a decrease in fuel burn, passenger waiting time and aircraft operation cost. This is both social and environmentally friendly as we were developing a policy that would reduce environmental impact and increase efficiency of airport operations while reducing operation costs. With the trend of sustainability on the rise, our policy coincides with the movement. In terms of environmental concerns, our policy is superior to the current practices of exclusive/preferred used gating policy.

Another social factor is our policy towards the airlines. Since Collaborative Gate Allocation participation is 100% voluntary, airport operators are not enforcing any airline to comply with the practices. This does not impede on any current airline practices should they decide to continue their current practices.

In the development of our project, the team researched on the current gating practices, gating problems, CDM and sharing facilities. Almost all information serving as a basis of our project is derived from the knowledge of others. When information gained by research is used, it is cited. The same applies for information gained from our interviews and interactions with our non-university partners.