COVER PAGE

Title of Design: Mobile Gate Design for Congested Airports

Design Challenge Addressed: Airport Management and Planning

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Executive Summary

It is projected that 53% of priority-group-one airports in the U.S. will be gate-constrained by year 2025 – a 22% increase since 2007. However, the lack of available gates is not the only problem airports are facing today. Aircraft-gate physical compatibility also poses a serious problem for many airport authorities and airlines as well.

According to recent research results by Boeing, there is a growing trend of increasing aircraft wingspan with new-generation aircraft. Based on reviewed literature and practices, it is found that the aviation industry lacks any effective method to (1) accommodate the severe shortage of gate capacity, (2) address the aircraft mix diversity at busy airports, or (3) resolve problems of aircraft-gate size incompatibilities. All the proposed solutions are either too costly (and time-consuming as they require building new infrastructure), or lack long-term sustainability. For this reason, we propose a more **elastic** option to resolve the airside congestion challenge by using *Mobile Gates* – an innovative way to address the gate-capacity and aircraft-gate compatibility problems.

The idea behind *Mobile Gates* is to increase gate maneuverability and gate physical mobility to dynamically meet different demands of aircraft-mixes. The proposed idea enables the parking spacing to change according to the mix of different aircraft-sizes and demand. In order to implement such a concept we propose a number of changes to parking orientation and boarding entrance orientation, too. In addition, we propose to use next generation technology for maneuvering and managing parking spaces, jet bridges and gate locations. We believe that the proposed design will revolutionize traditional gate capacity management, while preserving passenger safety and jet bridge security. Mobile Gates will become an integral part of Smart Airports where integration of real-time information and data, and collaboration between airports, airlines and ATC becomes a part of the System that goes beyond the Airport Collaborative Decision Making (A-CDM) concept.

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I. Problem Statement and Background

Airport surface congestion is a significant challenge faced by stakeholders in the aviation industry. As a result, considerable amounts of fuel and emissions are consumed and dispersed prior to departures and arrivals. Revenues are lost due to the scarce capacity available at the gate as the revenue-generating loads are commonly transferred at the gate. The lack of available gates poses not only congestion problems on the airside in airports in the United States, but also revenue loss for airlines and airport authorities. The number of airports that are gate-constrained in the United States are anticipating rapid growth in the decade ahead. By the year 2025 it is estimated that 53% of priority-group-one-airports will be gate-constrained, an increase of 22% since 2007, as indicated in Figure 1-1 (Hasan, Hart, Oseguera-Lohr 2009).

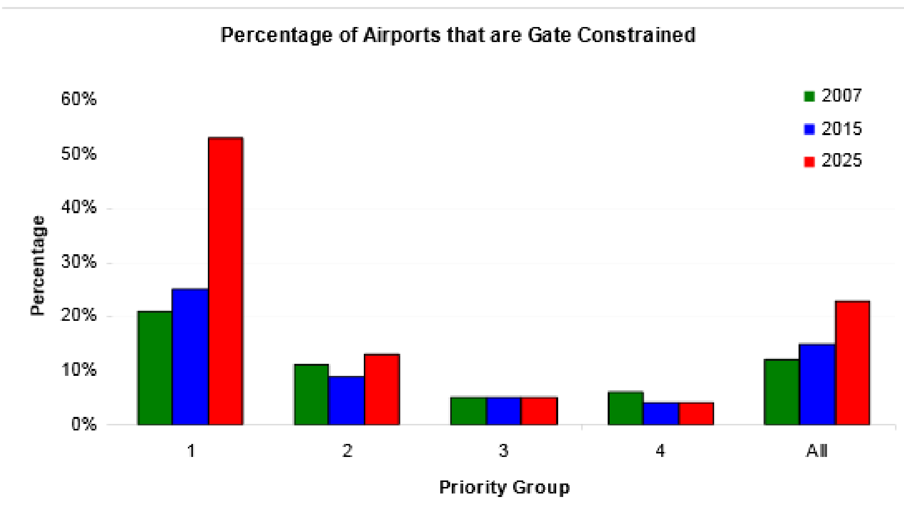

Figure 1-1: Percentage of Airports that are Gate Constrained (Ref: Hasan, Hart, Oseguera-Lohr, 2009)

A substantial number of airports in the U.S. have had to deal with extensive terminal improvements to increase their gate capacity in the past decade. For example, San Diego International Airport (SAN) has experienced a 4.9% passenger enplanement growth internationally and a 3.4% growth domestically between 1980 and 2003 (SAN Improvement

Plan 2001). It was also estimated that SAN will experience a continual annual growth between 2.2%-2.6% in the next three decades (SH&E International Air Transport Consultancy 2004). To cope with the continual growth, and to enhance the level of service to passengers, the San Diego airport authority has expanded its Terminal Two to include 10 additional gates. Airport such as Denver International (DEN), Austin-Bergstrom International (AUS), Orlando International (MCO), and John F. Kennedy International (JFK) airports are all following the same path, adding new gates to meet the increased demand.

It is widely accepted that the "lack of prompt remedial actions to increase the capacity (or control the demand) at busy major airports could lead to an eventual functional breakdown of the airport system" (Hamzawi 1992). Knowing that limited gate capacity could cause such a severe issue, how can current airport authorities and airlines work together to resolve the limited capacity problem and minimize the congestion and delays on the airside of the airports? Past researchers and consultants have explored different alternative solutions to limited gate capacity, and most of the proposed solutions are either too costly or time-consuming. For example, increasing gate capacity by conducting terminal improvements may take many years, such as in the case of the Tom Bradley International Terminal at Los Angeles International Airport. Currently, airports around the world lack the flexibility to increase gate capacity with respect to the aircraft fleet present at aprons at any given time. Therefore, when the gate-capacity is reached and flight-delays exceed the acceptable levels, airlines are often forced to de-peak their schedules as a part of long-term planning, or try to increase gate capacity by reducing the aircraft turn-around time in order to get a higher utilization of existing gates. Alternatively, airports try to resolve a gate-capacity problem by investing into various airport infrastructure improvement projects and building additional gates. New types of jet bridges are often deployed to address aircraft-gate compatibility issues, trying to maximize the utilization of apron areas for both small and large aircraft. One newer system used at large international airports such as JFK, Calgary Int’l (YYC) and Pearson Int’l (YYZ) airports is Multiple-Apron Ramp Systems (MARS). MARS is a concept used for better utilization of parking spaces on the tarmac in two distinct configurations: (1) one-wide body aircraft and (2) two-narrow body aircraft. However, such a system does not have the ability to dynamically accommodate a range of aircraft sizes.

The lack of gates is not the sole problem for gate-capacity today. Aircraft-gate physical compatibility also poses a serious impact for many airport authorities and airlines as well. The Federal Aviation Administration has established a long-standing methodology in classifying different aircraft types. Currently, there are only four gate-type categories, and the airport authorities determine the type of gate needed for the different aircraft mix based on the description as shown in Figure 1-2.

Gate Type	**Airplane Design Group**	**Wingspan (ft.)**
A	III	79-118
B	IV	118-171 (Fuselage < 160’)
C	IV	118-171 (Fuselage > 160’)
D	V	171-213

Figure 1-2: FAA Gate Type Determining Methodology (US Department of Transportation-FAA)

Based on aircraft-gate physical compatibility requirements determined by the FAA, wing span and fuselage length are two significant determining factors in choosing the gate size and dimension that are deemed fit for a particular aircraft. The main reason behind this is to conform to the wingtip clearance and frontage space safety requirements as specified by the Federal Aviation Administration. In lieu of this, the implication for airport design is that once the gate design is established for terminal construction based on current and expected future aircraft fleet mix, the ability to change apron and gate areas is limited. There are minimal actions that can be taken to remedy the need to change the gate areas, such as carrying out a new terminal modernization program or using remote aircraft gating, though both of these are either costly or inefficient respectively.

The major issue associated with the current FAA aircraft gate guideline is that airport authorities and airlines both lack the ability to accommodate a variety of aircraft fleet mix. According to the results of a research study carried out by the International Industry Working Group (2007) as shown from Figure 1-3, there is a trend of increasing wingspans with newer generation aircraft. The current airport gates are fixed to serve certain types of aircraft fleet mix in order to fulfill the FAA wingtip clearance compliance. The increasing wingspan growth trend therefore creates a problem for airports. As wingspans continue to increase, it becomes apparent that the only way to accommodate the larger size aircraft is by performing gate reconfiguration and modernization, which is both costly and inefficient. This limitation once again emphasizes the need for a gate design that has the flexibility to accommodate a variety of aircraft fleet mix.

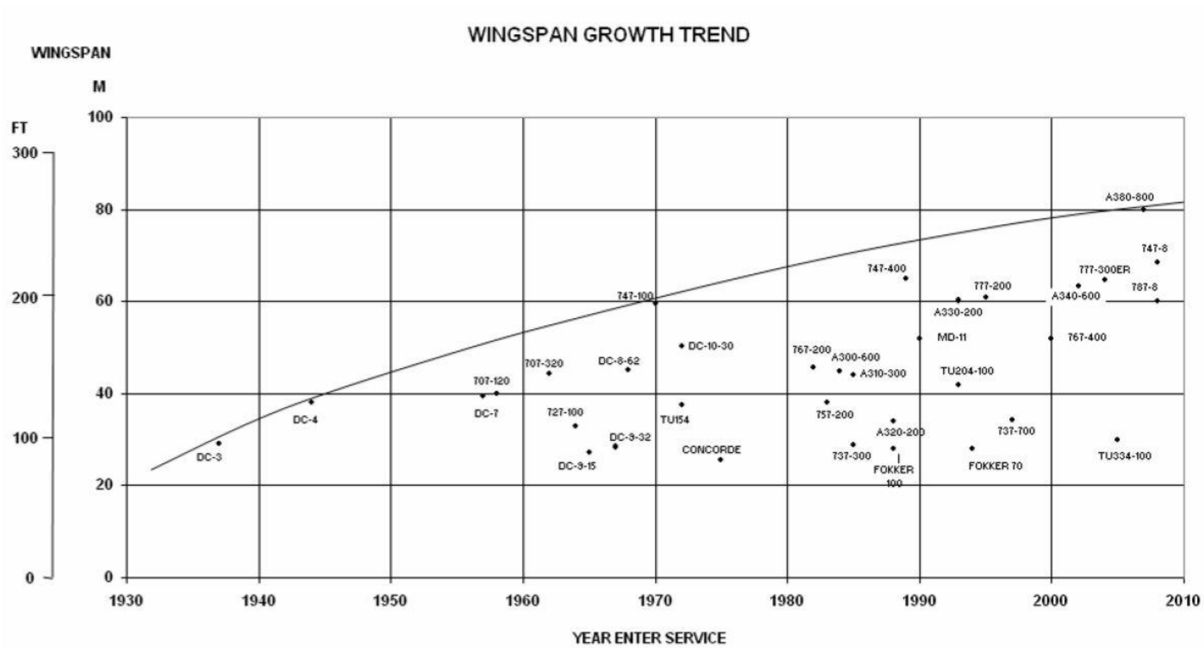

Figure 1-3: Trend of Increasing Wingspan (International Industry Working Group, 2007)

As the current solutions to resolving the limited gate capacity problem in a timely manner are infeasible in terms of their flexibility, we propose a more *elastic* option to resolve the airside congestion challenge. We believe that the increasing wingspan trend can be addressed by creating a new gate design, and more specifically a new jet bridge design, that can have the mobility to *adjust* and *move* in the apron area in order to accommodate newer generation aircraft. The introduction of new gate and jet-bridge designs should reduce the amount of traditional reconstruction required to accommodate new aircraft models produced by aircraft manufacturers. Taking into account the need to increase gate capacity and the need to accommodate a variable aircraft fleet, our team has proposed an innovative idea called *Mobile Gate Design*. The idea behind *Mobile Gates* is to increase gate maneuverability and gate physical mobility to meet different demands of aircraft-mixes. The proposed idea enables the parking spacing to change according to the mix of different aircraft-sizes with regard to demand. In order to implement such a concept we propose a number of changes to parking orientation and boarding entrance orientation. To preserve current passenger safety and the jet bridge security required by the Federal Aviation Administration's regulations, minimal transformation of the existing jet bridge is required in implementing this design.

In addition, we propose to use next generation technology for maneuvering and managing parking spaces, jet bridges and gate locations. We believe that the proposed design will revolutionize traditional gate capacity management, while preserving passenger safety and jet bridge security.

II. Summary of Literature Review

II. a. Introduction

Amazon, Google, Tesla and many other technology companies have recently set out to change the realm of transportation by bringing about Unmanned Aircraft Systems (UAS) delivery, self-driving cars and people-moving tubes. Although some of the proposed technologies may never move beyond the idea stage and be fully implemented, they all show the unlimited modes and potentials of transportation. It is crucial for the aviation industry to keep up with today's rapidly changing technology and to use it for upgrading and modernizing airport infrastructure. Because we are proposing a design that might solve gate capacity shortage using innovative approaches, it is crucial to consider a paradigm shift that moves the focus of increasing gate capacity from the airside (i.e. runways and taxiways) towards the ramp area and the terminal building. The objective of this literature review is to identify the current gate capacity problems and to analyze the problems and attempted solutions. Thus, we investigate the problem of gate capacity shortage and the practices of increasing gate capacity, and potential solutions to the problem.

II. b. Gate Capacity Crisis

As the demand for air transportation has increased, so has the demand for terminal gate capacity. By 2025, 95 of 310 critical airports, which collectively account for more than 99 percent of domestic air traffic volume, will face gate constraints. By 2015, LAS and LAX will experience significant reduction in the number of operations due to gate constraints; 13% and 22% respectively. In 2025, LAX and ORD will only be able to maintain 69% and 80% of operations using the limited number of gates (NASA 2010). Lack of airport capacity could lead to low customer satisfaction, unrecoverable losses in profit of multiple stakeholders, and even huge impact on economic growth. Lack of capacity at Heathrow Airport is costing the UK economy 14 billion pounds a year in lost trade, and this number could grow up to 26 billion pounds a year by 2030 (Heathrow Airport 2012).

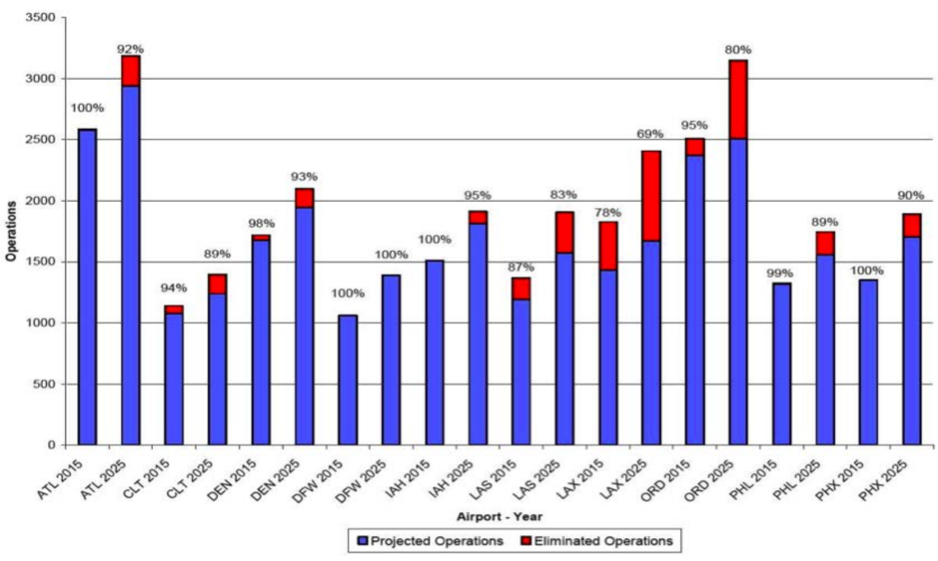

Figure 2-1: 2015 and 2025 Gate-constrained Operations at 10 of the busiest airports in the US (LMI Government Consulting, Metron Aviation, JPL Performance Consulting, 2010)

Another relevant subject to the implementation of the mobile gate concept is the use of a common use or collaborative gate allocation system in airports. Although not commonly found in US airports, common use terminals have been utilized in various airports around the world. In this system, airlines share gates at terminals based on instantaneous availability and demand in order to improve efficiency and maximize the number of operations per time. Collaborative gate allocation requires that airlines and airport operators, as well as the FAA, communicate and share data effectively. Today, most common use terminals are found at airports that serve primarily international flights such as those found in Europe. Many domestic carriers in the US are opposed to the implementation of common use terminals, especially at their hubs, due to the nature of exclusive leasing agreements and branding standards. The predominant gate-sharing policy in US airports is an exclusive model in which airports lease specific gates to certain airlines who have signed long-term leases for these facilities. In most cases, these airlines have also invested in the construction and maintenance of the gates. Traditionally, these airlines are given responsibility to control and operate in the designated parts of the terminal. One drawback of this system is the associated gate arrival delays that result from the unavailability of certain gates, causing significant inconvenience to passengers. In addition, it limits the runway capacity of airports since there is a finite number of aircraft that can wait on the tarmac to park. Furthermore, this becomes an extra burden on the airlines that have not leased enough gates who, as a result, must consider the opportunity cost of serving certain airports. The current system necessitates scheduling of flights around the gate capacity of an airport, which can be maximized using a common use terminal scheme.

If implemented, however, the mobile gate system will almost certainly require airlines and airports to adopt a collaborative gate allocation system, regardless of whether the majority of flights are international or domestic. This means that airports and airlines must work together with mutual trust to ensure adequate consultation and correspondence. A mobile gate system working in tandem with common use terminals will enhance many of the acknowledged, existing benefits of collaborative gate allocation. One of these benefits is operational efficiency. Under the mobile gate system, coordination of flights and gate management will be centralized and controlled by airport operators in conjunction with airlines. An increase in uniformity will also be seen in terminal maintenance and control as this responsibility will be placed on the airport. Common use terminals also minimize the number of unused and unoccupied gates. The mobile gate system will further enhance this benefit by making terminals more versatile, allowing them to respond quickly to delays caused by mechanical and weather-related issues, as well as variations in flight schedules. Collaborative gate allocation seeks to increase the amount of flights that can be accommodated, and the mobile gate network guarantees this increase. Airlines will also benefit from a common use system as their growth will not be limited by the long term leases. Demand fluctuates over time and airlines will be allowed to adjust accordingly under the common use system. For this reason, it will also be easier and less costly for airlines to grow and respond to new and emerging markets. Airports will also benefit from a mobile gate network that is integrated with collaborative gate allocation because they will be able to accommodate more aircraft without increasing their size, which may be more costly and/or geographically unfeasible.

Ultimately, the mobile gate system requires that airlines and airports work collectively in a cooperative manner to serve a mutual client. While the transition to a mobile gate system may be challenging due to organizational reasons, it can be improved if airlines and airports work openly and with transparency to reduce suspicions of hidden interests. Traditional competition by airlines can be replaced with a more advanced concept where airlines operate in a collaborative, yet competitive, environment. This concept is known as co-opetition (Brandenburger & Nalebuff 1996). It is also important to note that the implementation of a mobile gate system with common use terminals will not be as effective if it occurs only in unique instances. Uniformity in the common use of technology will be key to the mobile gate system's effectiveness in improving overall efficiency of airports across the US. Airlines should not be burdened with having to support multiple systems.

II. c. Current Practice of Increasing Gate Capacity

In terms of increasing gate capacity, the most common solution is to expand the required infrastructure by building new airports or expanding existing terminal buildings and piers and thus directly increasing system capacity. However, new construction and expansion usually require large capital expenditures and extensive amounts of time. They are also limited by growing community resistance, ever-increasing environmental concerns, limited use of land, and many other restrictions (Hamzawi 1992; Reynolds-Feighan and Button, 1999).

The other widely used way to increase gate capacity is remote aircraft gating, which transports passengers using transporters between the terminal building and aircraft parked at remote locations to compensate for the shortage of terminal gates. The idea of the mobile lounge was popular before the 1990s, but was outmoded due to high operation and maintenance cost, congestion in the apron area, and low efficiency (Hamzawi 1992).

Another option is peak-spreading, which reduces the extensive amount of operations at peak hours through peak period pricing, gate auctioning, traffic quotas and slot allocation, traffic flow control, and restrictions on general aviation. The augmentation of airport capacity through peak-spreading is either too costly or infeasible in long run, and or does not increase the gate capacity fundamentally (Hamzawi 1992; Caves, R. 1994)

Reducing demand by shifting a portion of demand to other locations is another alternative to increase capacity, but it could not solve terminal congestion efficiently and would lead to additional costs due to duplication of services and accommodation of facilities, and the security of baggage transfer from such location to the terminal (Hamzawi 1992, Pels at al 2000; Barett 2000).

II. d. Conclusion

Upon reviewing literature, we found that aviation industry lacks an effective method to accommodate the severe shortage of gate capacity. All the proposed solutions are either very expensive, or lack long-term sustainability. Without significantly changing the current terminal building infrastructure, the mobile gate design is beneficial as it increases the current gate capacity in a timely manner and provides more flexibility in terms of gate capacity during seasonal changes of flight schedules.

III. Problem Solving Approach

III. a. Introduction

As flexibility and cost efficiency are two of our main goals in resolving the airport gate congestion problems, a new airport gate design concept is proposed that can address the existing challenges and limitations.

The *Mobile Gate* design is created through a continuous and comprehensive review, as shown in Figure 1-5. After we identified the problem, our team drafted several design proposals trying to address and resolve the problem at hand. Once the jet-bridge design has been selected and developed, five large US airports (DTW, IED, LAX, JFK, and SFO) were analyzed in detail, in order to determine gate capacity issues, aircraft fleet mix, airport layout, and the nature of operations at each airport. In the following step, based on analyses results, LAX airport was identified as the most representative case study. Cost-benefit and safety analyses were performed afterward to prove the practicality and feasibility of the *Mobile Gate* design.

Figure 3-1: Comprehensive Review Process in Creating the Mobile Gate Design

III. b. Mobile Gate Design Description

We transformed the standard jet bridge and created an innovative design that will revolutionize the typical gate capacity, while preserving passenger safety and jet bridge security.

The new jet bridges are fashioned to maneuver along a network of rails running around the airside perimeter of the terminal building. There will be multiple "attachment/detachment points", or circular openings in the rails, that will allow the wheels on the jet bridge to connect and disconnect from the rails, which will prevent vertical and perpendicular movement of the jet bridges.

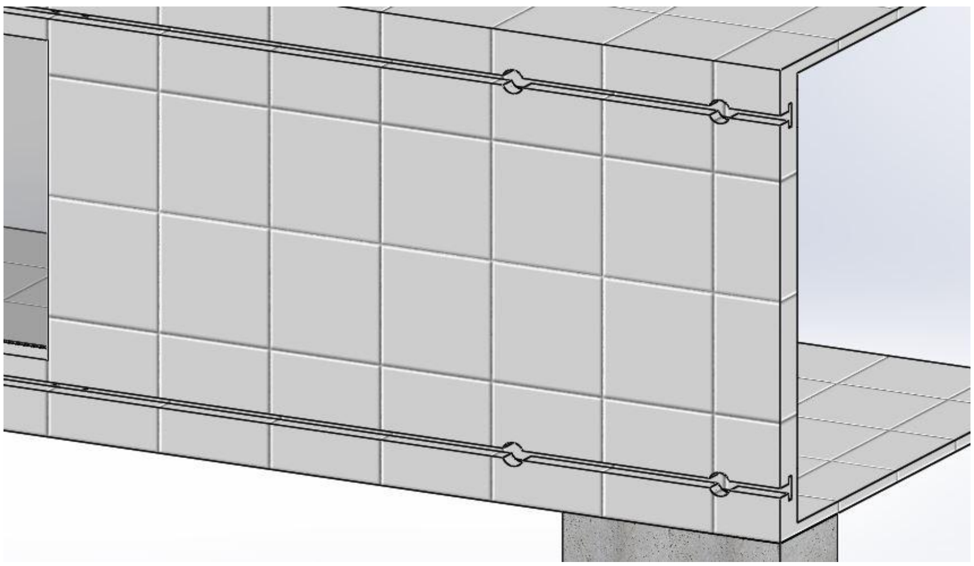

Figure 3-2: An Attachment/Detachment Point on the Terminal Building. Created in SolidWorks© by Steven Van Leeuwen.

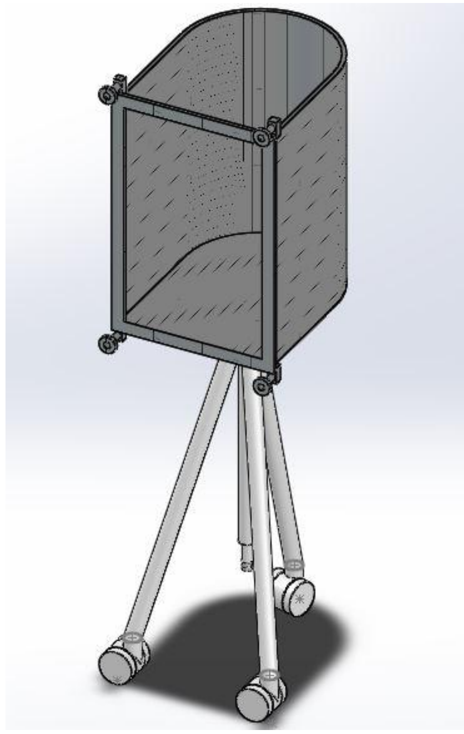

Figure 3-3: Visual Representation of a Rotunda. The four wheels around the opening will attach to the terminal building at the Attachment/Detachment Points.
Created in SolidWorks© by Steven Van Leeuwen.

Once the jet bridge is secured to the rail system, the bridge will move automatically using the four wheels that are attached to the jet bridge itself. In order to achieve a more sustainable design, the jet bridges will be powered using alternative energy sources, such as solar energy, or energy produced from hydrogen fuel cells. Solar photovoltaic modules may be installed on top of the jet bridges in order to supply them directly with power to operate and mobilize along the rails. Another way to power the jet bridges is by using hydrogen fuel cells. Although the cost of hydrogen fuel cells are currently expensive, they may become progressively inexpensive in the future, allowing for a green, zero-emission form of energy to power the jet bridges completely.

Upon moving left or right, the jet bridge will be prevented from detaching from the rail network because the rail openings are structured to converge on either side of the attachment point.

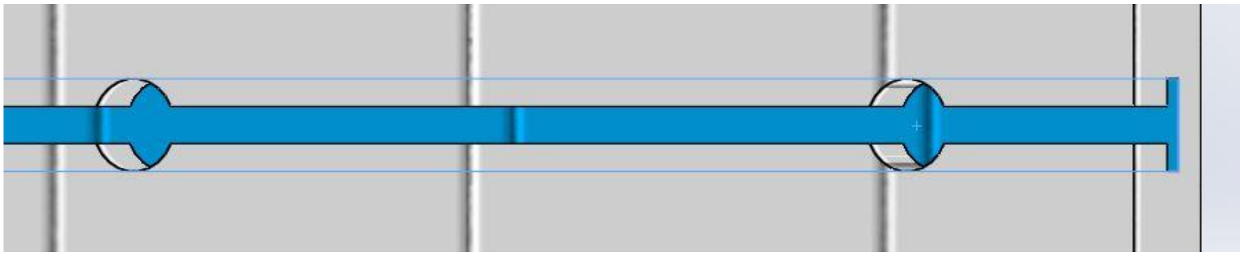

Figure 3-4: The Converging Rails at a Attachment/Detachment Point.
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Attachment/detachment points will be located in strategic locations equidistantly apart along the rails, specifically at the two ends of the building, and a few in between which should only be used if necessary. Attaching and detaching jet bridges at the ends of the terminal building is intended to avert interference with traffic operations around the terminal, which will also increase safety because there will likely be less traffic on the edges of the terminal compared to the middle of the terminal. If the storage area for the jet bridges is located closer to one side of the terminal building, then it would be optimal to attach or detach the jet bridges from that attachment/detachment point. This will interfere less with traffic operations and lessen the amount of time and energy used to transport the jet bridges. Ideally, the attachment points would not be positioned directly at gates in order to make sure that they are fully locked and secured to the terminal building while passengers are loading and unloading onto the jet bridge.

Once a jet bridge reaches the gate it will serve via the rail track, the four wheels connecting the jet bridge to the terminal building will be prevented from moving by metal bars penetrating the back of the rails from the terminal building. The diameter of the metal bars will be small enough to fit in the gap created by the converging rails. These safety measures will prevent horizontal movement of the jet bridge during earthquakes, for example.

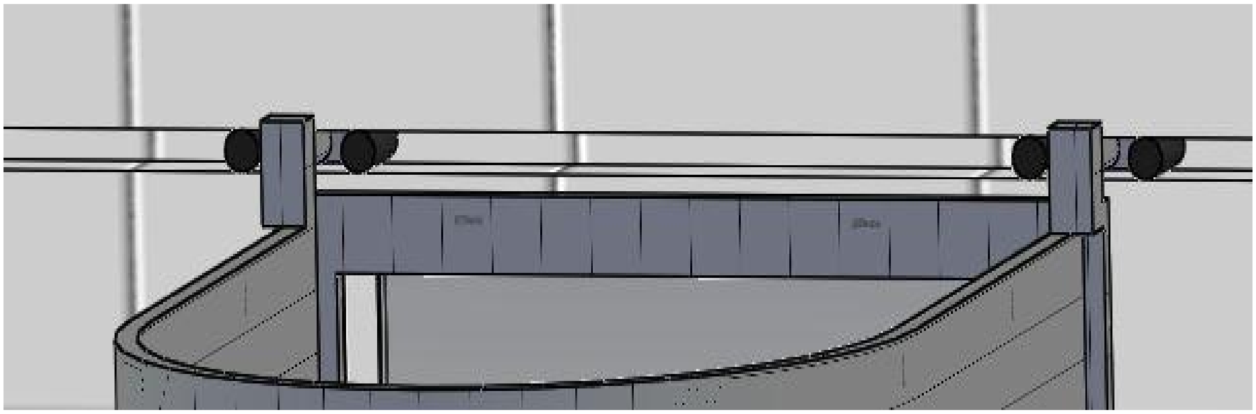

Figure 3-5: The Metal Bar Braking System.
Created in SolidWorks© by Steven Van Leeuwen.

Another inventive safety measure implemented into our design of the jet bridge is the support under the rotunda. For accessible movement, three roller wheels will allow the jet bridge to either move along the ground or stay in place if put in park.

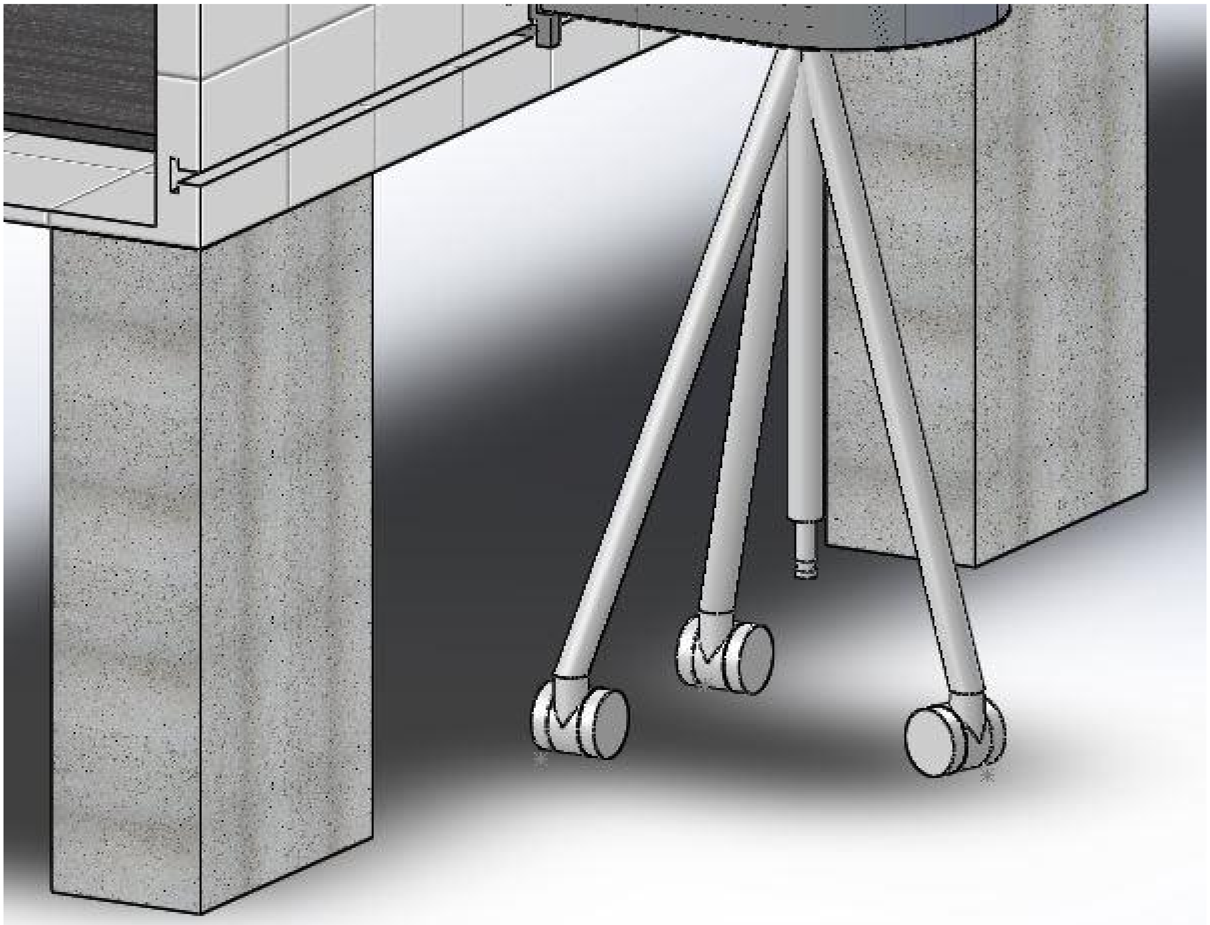

Figure 3-6: The Roller Wheel Support of the Rotunda.
Created in SolidWorks© by Steven Van Leeuwen.

A bar in between the rollers supports will extend down from the bottom of the rotunda and connect to the ground while parked at a gate or off-site for storage to fix the jet bridge to the ground for added structural safety. The retractable bar will temporarily lock into the ground using a simple, yet efficient "snap-fit buckle" until the jet bridge has to be moved.

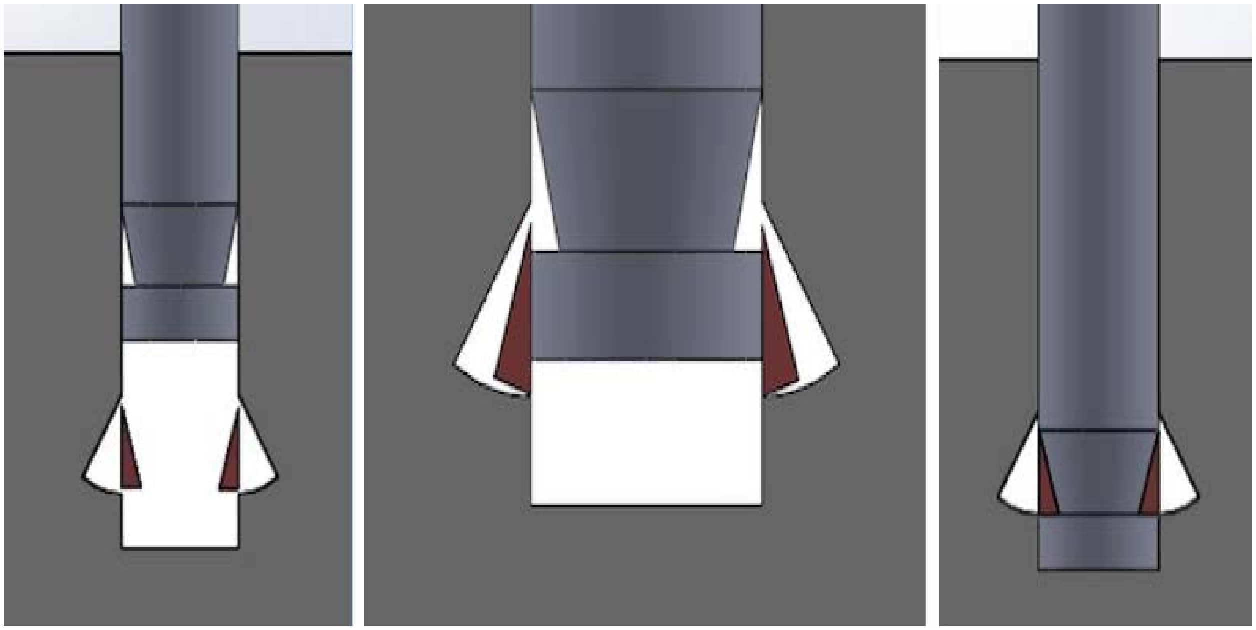

Figure 3-7: "Snap-Fit Buckle" Mechanism in its three stages (from left to right): Entering the ground, pushing the locks into the void space temporarily, and locking the bar into place. Created in SolidWorks© by Steven Van Leeuwen.

To prevent issues with jet bridge incline grades and height differences in aircraft, the shorter mix of aircraft should park further away from the terminal building. This will mitigate issues of percent grade of the jet bridge from the terminal building to the aircraft. Smaller aircraft should be able to fit inside the designated parking area by parking further away from the terminal. As an added benefit of this mitigation technique, the aircraft capacity of round or edged terminals could increase because of the enlarged radius of the parked airplane.

Storing the jet bridges will involve compressing them to their smallest configuration and towing them to their storage location on airport grounds. The jet bridges should be towed by attaching the towing vehicle to the end of the jet bridge that connects to the terminal building. The end of the jet bridge that connects to the aircraft should be lowered as much as possible in order to increase stability of the jet bridge while towing. Upon reaching storage, the jet bridge should be fixed to the ground in the same way it is while parked at gates for added support.

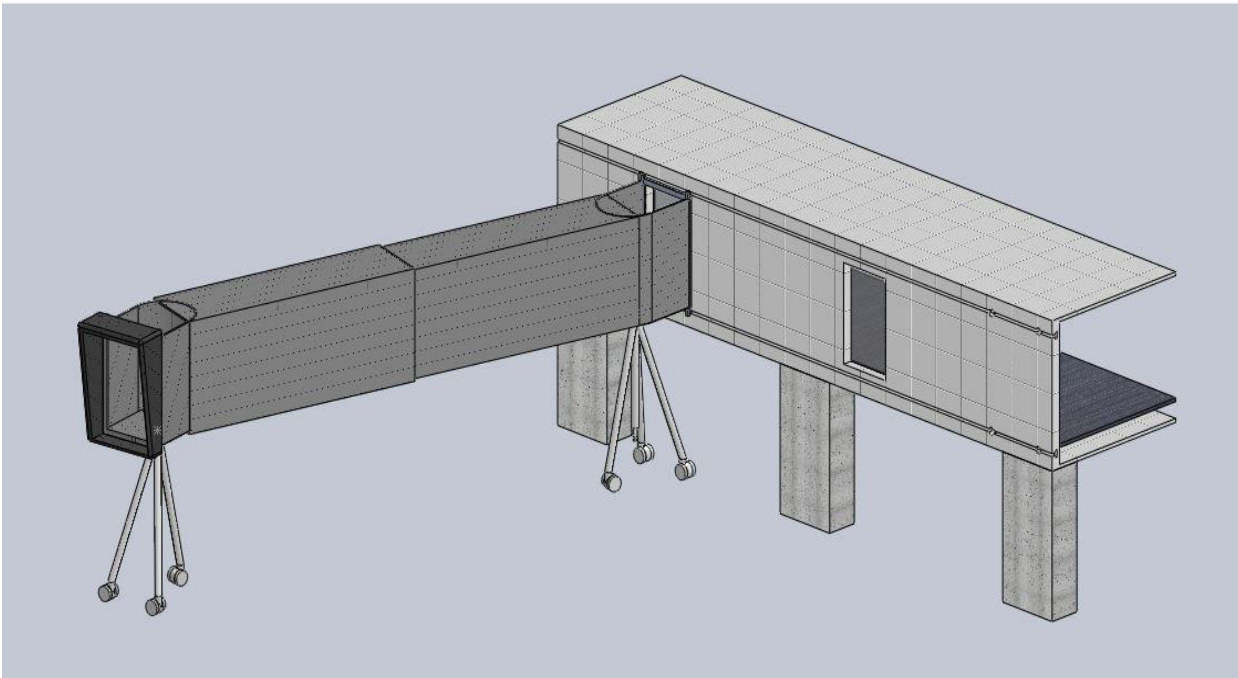

Figure 3-8: Mobile Jet Bridge System.
Created in SolidWorks© by Steven Van Leeuwen.

IV. Safety and Risk Assessment

Mobile Gate requires changes in the airport's physical structure and thus most of the safety concerns are directly related to construction and physical alterations of the airport. Although the *Mobile Gate* design can be interpreted as a simple transformation of the standard jet bridge, it also involves physical alterations of the existing exterior of the terminal building, the markings and signage on the frontage space and the terminal apron. Therefore, safety concerns on the *Mobile Gate* design are assessed based on the assumption that this innovative design will be implemented on SMART airports. We define SMART airports as airports that (1) integrate real-time information using data analytics among airports, airlines and ATC, (2) utilize Airport Collaborative Gate Allocation (A-CDM) and (3) incentivize airlines to collaboratively share airport infrastructure, especially gates.

This is the risk assessment of the proposed *Mobile Gate* design from the FAA Advisory Circular 150/5200-37 Introduction to Safety Management Systems for Airport Operations Safety Risk Assessment (SRA) points of view. The FAA Advisory Circular 150/5200-37 lists these steps below as phases for safety risk management:

Phase 1. Describe the system

Phase 2. Identify the hazards

Phase 3. Determine the risk

Phase 4. Assess and analyze the risk

Phase 5. Treat the risk

IV. a. Safety Concerns - Wingtip Clearance (FAA)

The foremost safety concerns that would need to be addressed with *Mobile Gate* are the wingtip clearance and frontage space safety requirements specified by the Federal Aviation Administration. According to existing FAA requirements, the wingtip clearance should be between 20’ to 25’, depending on the existing airport condition. The *Mobile Gate* design will conform to existing FAA wingtip clearance requirements. However, noting that newer generation aircraft may be installed with folding wingtips (Boeing 2013), this adds to the benefit of the *Mobile Gate* since the wingtip clearance will decrease with the implementation of folding wingtips. From this perspective, the *Mobile Gate* has the flexibility to accommodate a variety of aircraft fleet mix, but it is performed in accordance with the safety requirements as specified by the FAA.

IV. b. Safety Concerns - Designed Structure

According to the FAA Advisory Circular 150/5200-35, the safety risk assessment must follow the phases specified from above. Since *Mobile Gate* mainly involves physical alterations of the airport, there are multiple hazards and risks that have to be identified and analyzed by performing different types of structural modeling and analysis. Based on the result obtained from the analyses, our team revised the design until it is adequate to perform under the risks and hazards identified from the start.

The transformed jet bridge proves to be the principal safety concern for the *Mobile Gate* design because it is prone to different types of incidents, due to unexpected weather conditions or collision with aircraft. These incidents can in turn be impactful since the jet bridge remains the primary source of passenger transport between the parked aircraft and the terminal building. Therefore, the transformed jet bridge must be structurally sound and can withstand any unexpected impact. Our design addressed different types of movement that the jet bridge may encounter and a final structural modeling and analysis was performed to prove that the new support system added to the transformed jet bridge can perform under different loadings and movements.

Any unexpected horizontal and perpendicular movements of the jet bridge that may have been caused by an earthquake or strong wind conditions were addressed first with the *Mobile Gate* design. To prevent the jet bridge from performing any unanticipated vertical and perpendicular movement, multiple attachment and detaching points will be installed along a network of rails running around the airside perimeter of the terminal bridging. The new jet bridge will move by the wheels that are attached and detached through the circular openings in the rail and in this manner, vertical movement will be prevented. Horizontal movements are prevented by using an effective metal bar braking system; the four wheels connecting the jet bridge to the terminal building will be prevented from moving by metal bars penetrating the back of the rails from the terminal building.

The concern with heavy loading and inadequate support of the transformed jet bridge were assessed and resolved with the improved support under the rotunda. The three roller wheels are installed for accessible movement while the bar in between the rollers can be extended down from the bottom of the rotunda and connected to the ground for added structural safety. A structural analysis was performed with the redesigned rotunda. From the model, it is assumed that the three supporting legs are fixed at the bottom since it will be restrained in all directions through the insertion into the ground. The top of the model is conservatively modeled as a cube with the top open, and the steel material is assumed to be A7 09 Grade 50 Steel. From figure 4-1 and 4-2, it displays the undeformed and the deformed shape of model. The result of the analysis from figure 4-3 clearly shows that the axial, shear, and moment capacities all passed and thus the design passes the failure case. This in turn proves the soundness of the redesigned rotunda and transformed jet bridge. Our design should require no further safety analysis on the designed structure since the change has proven to not introduce additional safety risks. For that reason, there is no need to follow through Phase 5 in the FAA Advisory Circular 150/5200-35 SRM process.

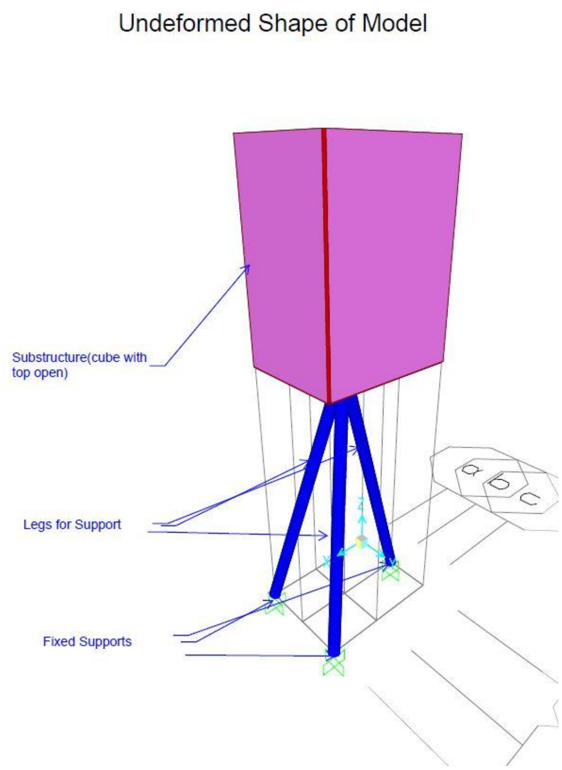

Figure 4-1: Undeformed Shape of Model

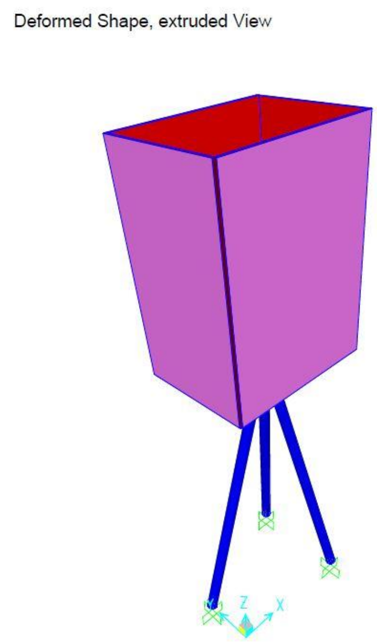

Figure 4-2: Deformed Shape

SAP2000 Analysis Results

TABLE: Element Forces - Frames

Frame	Station	OutputCase	CaseType	P	V2	V3	M2	M3
Text	in	Text	Text	Kip	Kip	Kip	Kip-in	Kip-in
1	0	DEAD	LinStatic	-12.804	-0.346	3.175E-13	2.5E-11	-19.869
1	91.642	DEAD	LinStatic	-12.745	-0.33	3.175E-13	-4.1E-12	11.082
1	183.285	DEAD	LinStatic	-12.685	-0.313	3.175E-13	-3.3E-11	40.541
2	0	DEAD	LinStatic	-5.924	0.223	0.202	11.781	13.341
2	91.924	DEAD	LinStatic	-5.865	0.24	0.202	-6.798	-7.904
2	183.849	DEAD	LinStatic	-5.805	0.257	0.202	-25.377	-30.711
3	0	DEAD	LinStatic	-5.924	0.223	-0.202	-11.781	13.341
3	91.924	DEAD	LinStatic	-5.865	0.24	-0.202	6.798	-7.904
3	183.849	DEAD	LinStatic	-5.805	0.257	-0.202	25.377	-30.711

Governing Cases for Each Leg

Elemnt ID	Max Axial(kip)	Max Shear(kip)	Max Moment(kip-in)
1	-12.804	-0.346	40.541
2	-5.924	0.257	-30.711
3	-5.924	0.257	-30.711
Max	-12.804	-0.346	40.541

Capacity and Results

Element ID	Axial Capacity(kip)	Shear Capacity(kip)	Moment Capacity(kip-in)
All Legs	37.1	71.1	180
Test	OK	OK	OK

All 3 Capacities passed, design is adequate

Figure 4-3: SAP2000 Analysis Results displaying the Mobile Gate design is adequate

IV. c. Safety Concerns - Pavement Marking and Signage

Current airport structures mostly depend on painted markings to guide both aircraft and ground support equipment to their places at the gate. These markings include lead-in lines and markings to ensure the safety of ground personnel and to maintain the minimum wingtip distance. Some airports even have automated Stand Entry Guidance systems to assist the pilots in parking their aircraft.

However, all these components are intended for aircraft parked at the specific location of the gate. A mobile gate system will require a differently designed set of markings and positioning aids. Rather than marking the parking spot according to one location of the bridge, parking spots will need to be marked with respect to all installed possible bridge locations. In addition, because the gates may be expected to accept multiple sizes of aircraft, different safety lines around the wingtips and engines will need to be marked.

Stand Entry Guidance systems also assist the pilots as they park their aircraft. Current systems include marshalling, as well as azimuth and stop guidance. The automated systems can be integrated with mobile gates, either by installation at each location or by mounting them on the bridges.

In addition to markings, ground support equipment will also need to serve aircraft at all of the bridge locations. As airlines are trending towards outsourcing their GSE, they may be able to simply specify the service in their contract. This practice is not only more efficient on a management level, but also helps to reduce the carbon footprint of the airline and the operation.

New technology, such as Airport Surface Detection Equipment, Model X (ASD-X), or the Aeronautical Mobile Airport Communications System (AMACS) may be used to help improve the accuracy of these existing systems. ASDE-X will be able to detect the positions of the aircraft and the GSE, while AeroMACS can inform pilots and ground crew of their own and each other's positions. The better flow of information allowed by these devices will generate a more cohesive unit that will complete its task more efficiently.

V. Practicality and Feasibility

V.a. Scheduling of Mobile Gates - Introduction

For the concept of mobile gates to be successful, moving and reconfiguring gates will have to be efficient. To accommodate the dynamically changing parking sizes and locations, it is important to design a safe and secure scheduling system in moving the gates so that operations are performed safely and possible collisions between gates (i.e. jet bridges) and aircraft are avoided. Therefore, data analysis of the arrivals and departures of a specific airport is done and a scheduling system is created for Wed, August 21st, 2013. LAX is used as a representative case-study, which is one the busiest airports in the United States and the sixth largest in the world (Los Angeles World Airport 2012).

V. b. Scheduling of Mobile Gates - Method of Analysis

For the purpose of this study the Official Airline Guide (OAG) data is used for the analysis of all departures and arrivals at the LAX airport in a 24-hour period. This way, a schedule can be created for off-peak times of the airport where no aircraft are departing and arriving, and give the airport an opportunity to put its mobile gates to work. This analysis is based on four types of aircraft for the mobile gate system; as shown in Figure 1-2, the different types of aircraft are consolidated into four specific groups of airplanes. These groups are: Group A, wingspan of 78-118 ft, Group B, wing span of 118-171 (Fuselage < 160'), Group C, wing span of 118-171 (Fuselage > 160'), Group D, wing span of 171-213. After looking at the data for these groups of aircraft, we are able to assess the different off-peak scheduling periods where the airport can be changed to accommodate the new fleet combinations. The increments of time of the raw data for this analysis will be 1 hour, therefore the count of arriving and departing flights for a specific group of aircraft will be shown and an off-peak schedule will also be determined within that increment.

Departure and Arrival Count Analysis in 1 hour increments								
Time	Arrivals A	Departures A	Arrivals B	Departures B	Arrivals C	Departures C	Arrivals D	Departures D
0000-0100	3	3			2	1		1
0101-0200		2				1		1
0201-0300								
0301-0400								
0401-0500					1			
0501-0600	1	1				4		
0601-0700	4	5				6		
0701-0800	5	18				5	1	
0801-0900	6	12				6		3
0901-1000	15	13			2	5		
1001-1100	9	12			9	2		1
1101-1200	8	9			6	9	3	
1201-1300	11	10			4	2	1	
1301-1400	5	15			6	5	1	2
1401-1500	8	7			6	4	1	
1501-1600	4	8			4	3		2
1601-1700	7	5			4	5	2	2
1701-1800	9	8			4	1		1
1801-1900	10	9			4	1	2	3
1901-2000	10	6			5	1		
2001-2100	10	6			8			
2101-2200	15	4			8	3	1	
2201-2300	11	11			2	6	1	2
2301-2400	5	8			2	6		3

Figure 5-1: Table displaying the Departure and Arrival Count Analysis in 1-hr increments

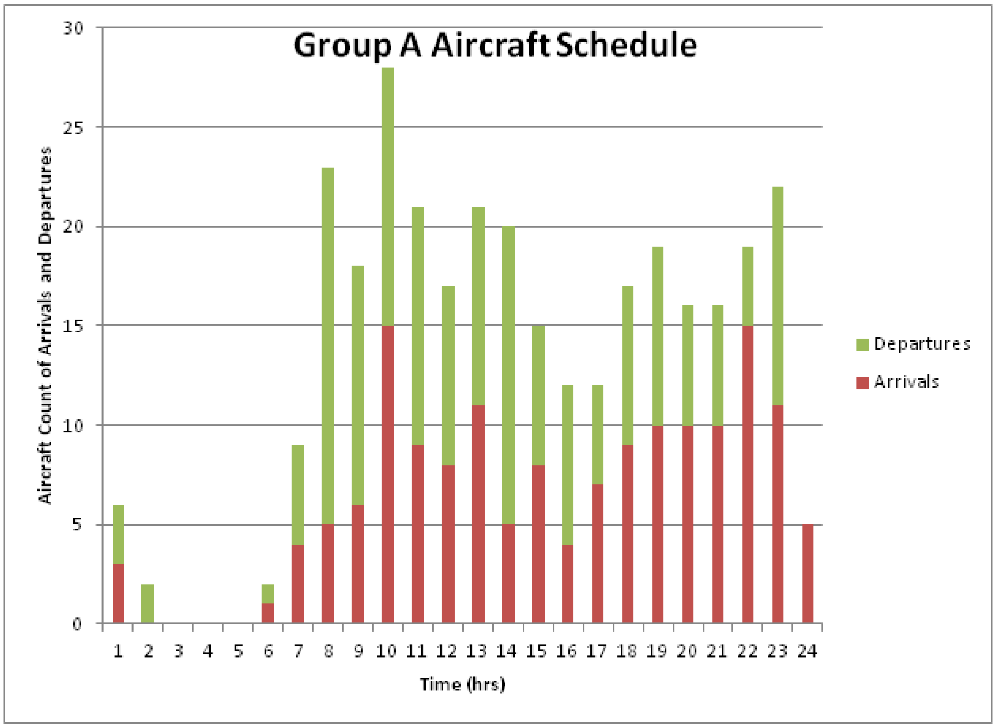

Figure 5-2: Graph displaying the Group A Aircraft Arrival and Departure Schedule

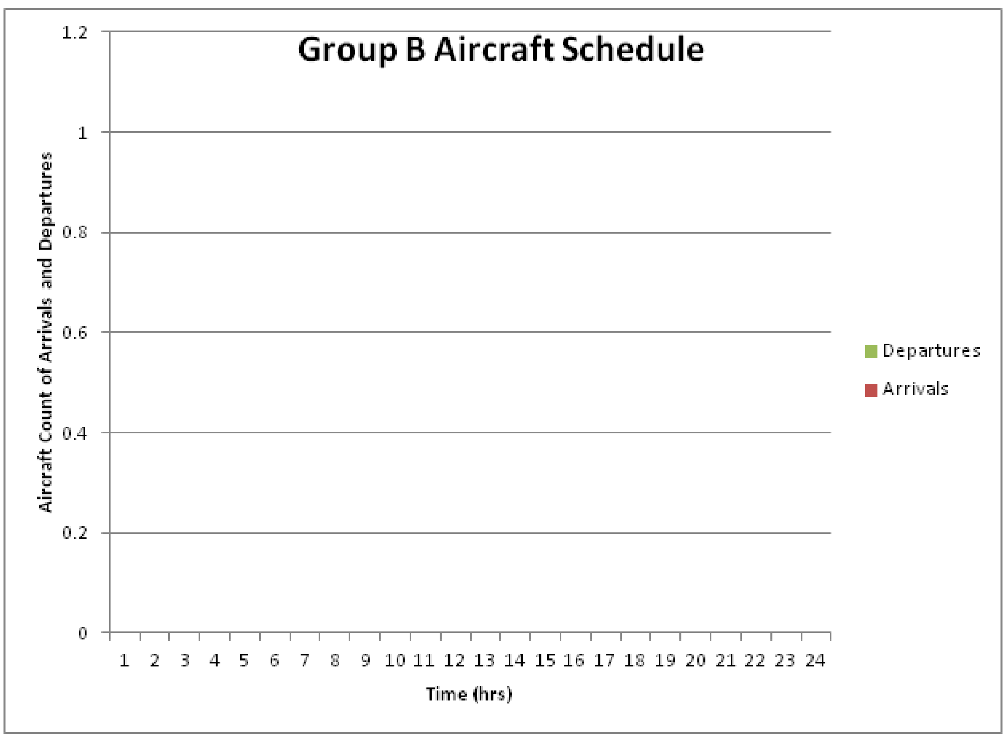

Figure 5-3: Graph displaying the Group B Aircraft Arrival and Departure Schedule

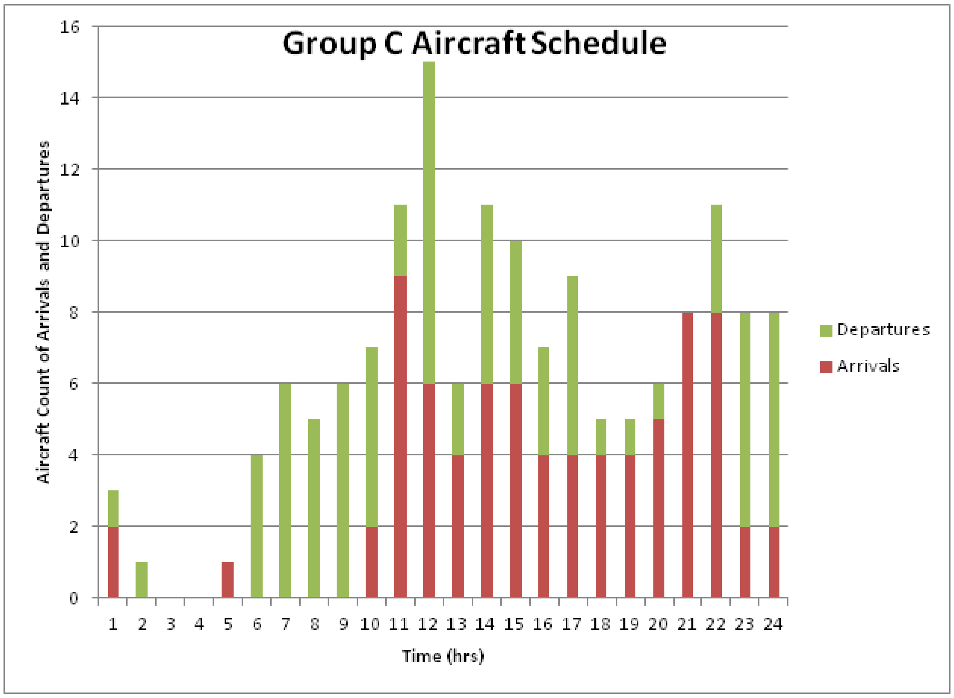

Figure 5-4: Graph displaying the Group C Aircraft Arrival and Departure Schedule

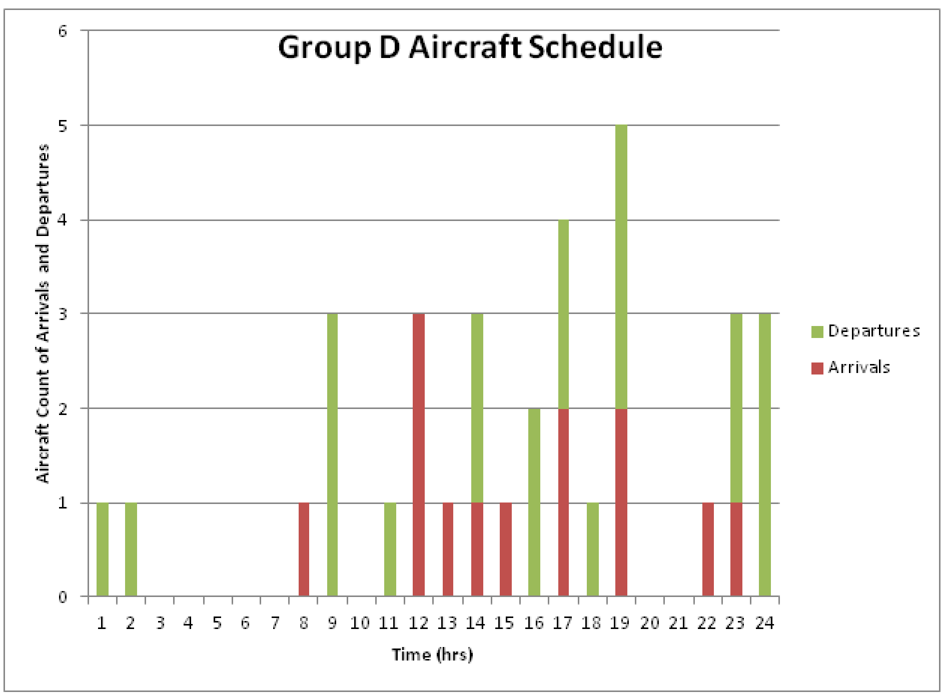

Figure 5-5: Graph displaying the Group D Aircraft Arrival and Departure Schedule

V. c. Scheduling of Mobile Gates - Results of Analysis

Group A:

As seen in the graph, the off-peak scheduling time for Group A is from 2 AM to 5 AM. At this time, there are very few aircraft arriving and departing from the airport. Group A, being the type in highest demand at LAX, is the most important group for this study. To accommodate for the most demanded type of aircraft in this airport, the prime time in moving the mobile gates will prioritize the schedule of Group A. After having only 2 aircraft departing at 2 AM, the rest of the time until 5 AM is free at the LAX airport. Therefore, during this time, the airport can change the locations and sizing of its parking spaces.

Group B:

As shown in the graphs, there is no demand for the group B aircraft at LAX.

Group C:

Being the second most demanded type of aircraft at LAX, Group C should also be taken into consideration. As shown in the graphs, Group C has an off-peak schedule also from 2 AM to 5 AM. This time slot will also serve as an opportunity for parking spaces and gates accommodated for Group C to be mobile.

Group D:

Lastly, the off-peak schedule slots for Group D are 2 AM to 7 AM, and 8 PM to 10 PM. Besides Group B this is the least demanded type of aircraft at LAX and while it should still be put into consideration, it should not be prioritized over Group A and C. Therefore, the main time slot for the mobility of the gates will still be set to accommodate groups A and C.

V. d. Scheduling Optimization

To make a significant impact on the efficiency of the terminal apron areas, the gate schedule will need to reflect the demand set by the number of flights made by the airlines. However, there are still several approaches to the scheduling of mobile gates because the airlines' needs change on different time scales. Overall aircraft size is trending upwards, as shown in figure 1-3, so gate schedules must change as airlines update their fleet mixes. On a shorter time scale, passenger demand changes over the course of the year, for example around holiday season. There are also day to day changes and, on the smallest scale, changes in schedule due to circumstances such as flight delays or ad hoc situations. We choose to analyze LAX as a case study further, and to determine the total demand and the percentage of the total demand due to flights from each aircraft group over the course of the day.

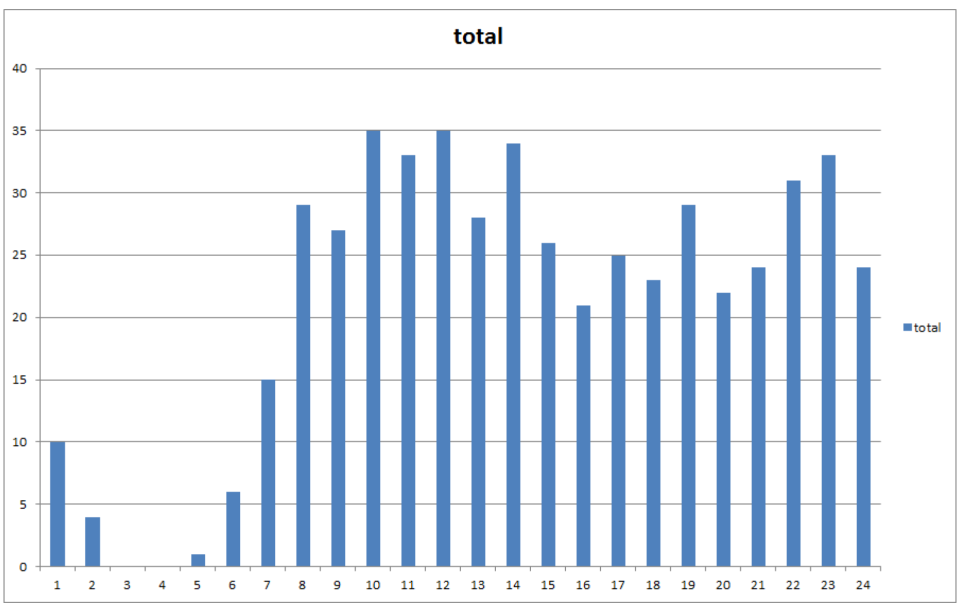

Figure 5-6: Graph displaying the hourly number of operations

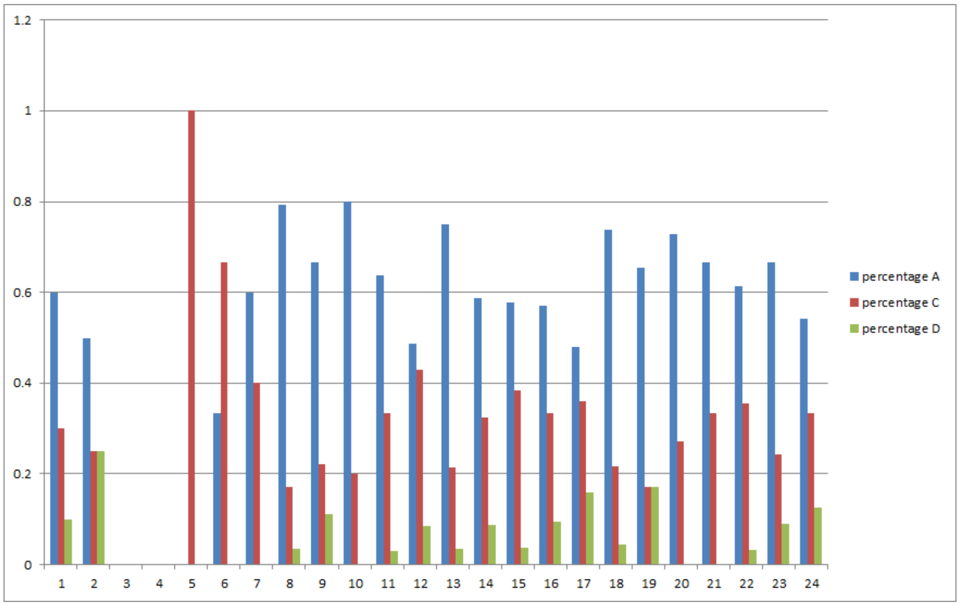

Figure 5-7: Graph displaying the percentage of total demand for each group for one day

Figures 5-6 and 5-7 display the demand shifts over the course of the day. While Group A generally has the highest demand, followed by Group C, then Group D, the proportions of demand are not constant. As a result, the airlines' need for gates may not match the constant supply provided by airport facilities.

Not including the international terminal, LAX currently has 107 gates available across 8 terminals, each capable of serving up to a maximum size of aircraft. These gates are distributed to serve a mix of 70% Group A, 25% Group C, and 5% Group D aircraft. At peak demand, particularly between 10 AM to 2 PM, this distribution is inefficient.

The implementation of mobile gates would allow the distribution to change. By repositioning gates in between peak hours, the airport could meet demand more efficiently, handling more flights in the same amount of time.

In this case, the gate schedule might involve 75% Group A, 20% Group C, and 5% Group D gates from 8 AM to 11 AM, but changing to provide 55% Group A, 40% Group C, and 5% Group D gates between 12 PM and 3 PM. This redistribution of gates greatly reduces the strain on the system, allowing the airport to process more flights when necessary.

V. e. Scheduling of Mobile Gates - Discussions of Results

The time slots for the mobility of gates were chosen at a time when there were very few departures and arrivals. The reason for this is because at this time, there will not be any aircraft coming in looking for a space to park, making it a down time for the mobile gates to move to the desired locations. However, a problem may arise where there are still aircraft parked at the gates during this time slot for down time. To solve this issue, we propose to consolidate to one area aircraft assigned to parking spaces before the downtime occurs. In turn, there will be an area where there will be no aircraft at all during the downtime of the airport, and the parking spaces and gates in this area will be able to freely move and resize to the needs of the airport. Following this type of scheduling, the mobile gate system will have both a safe and secure method for its dynamic characteristics, creating a more efficient and safe environment for the airport. It is important to keep in mind that optimizing passenger walking distance for transfer passengers is beyond the scope of this study as it relates to the movement of passengers inside the terminal building (Terminal building design is outside the scope of this competition). Therefore, it is recommended that future research be undertaken in the area of passenger walking distance and to include it as one of the objective functions in a more comprehensive, multi-objective mathematical formulation for optimal scheduling of mobile gates.

Airports can use mobile gates to adapt to changing demands over time, such as when fleet mixes grow or in between seasons. On this time scale, the airport can analyze the mix of incoming aircraft and decide on appropriate gate configurations. Even under daily operating conditions, airports can still utilize gate mobility. However, because this time scale is much shorter, the reconfiguration process must be streamlined, as in Figure 5-8.

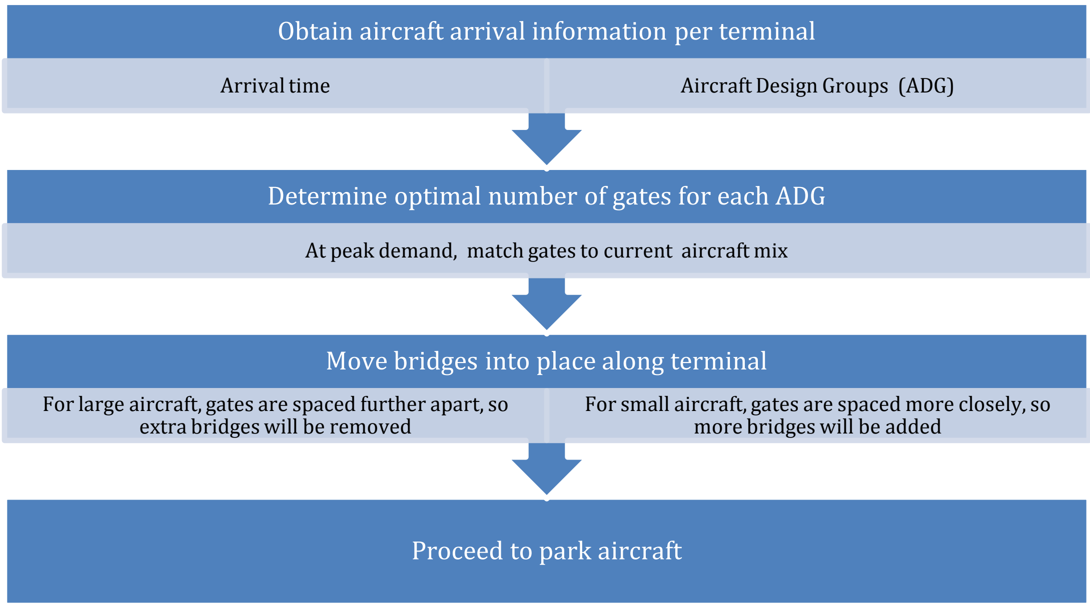

Figure 5-8: Process for scheduling and configuring mobile gates

The process begins with the real-time schedule of flights coming into the terminal, which the airlines will provide. Required information includes the time the aircraft will be at the terminal and the aircraft design group (ADG) of the aircraft. This information will be used to determine the optimal number of gates for each ADG during peak hours through analysis as shown in Figure 5-6 and Figure 5-7. The bridges will then be moved into the peak configuration during off-peak hours, allowing the airport to handle demand as needed and reach higher efficiency than otherwise possible.

V. f. Mobile Gates - Current Jet Bridge Cost and Maintenance

There are a number of variables that factor into the cost of passenger boarding bridges with the current fixed jet-bridge configuration. Factors such as foundations, local codes, aircraft mix, and terminal layout can significantly impact the price. Other customer options such as ancillary equipment (ground power, preconditioned air, etc.) also influence the pricing of each bridge, depending on customer specification.

Our preliminary budget estimation for a three tunnel passenger boarding bridge, including freight and installation, would be around $425,000, plus or minus 15%. This assumes a steel, corrugated boarding bridge, and options such as glass walls will increase the cost as well.

Cost of maintenance is a real challenge to forecast as variables related to frequency of use, geographic location (coastal or non-coastal) and ownership (municipality or airline) determine many of the costs related to upkeep. Maintenance cost can vary from very low for many years, to costs over $10,000 per gate per year. Again, much of the options and the locale of the bridge impact the gate's yearly maintenance cost.

V. g. Mobile Gates – Discussion on Preliminary Cost – Benefit Findings

At LAX it was estimated that in 2007 at least 30% of flights were gate-delayed for 15 days (Figure 5-9), and that the estimated average daily gate-hold-delay (in min) during these days was 1500 min (i.e. 25 hours) (Shortle at al, 2009). This implies the following Direct Aircraft Operating Costs (DOCs) per Block Minute for these 15 days only (Table 5-1):

Table 5-1: Direct Aircraft Operating Costs per block minute for 15 days only

Items:	**2012 Direct Aircraft Operating Cost per Block Minute (Ref. Airlines for America website)**	**Delay Costs**
Fuel	$39.26	$58,890
Crew - Pilots/Flight Attendants	16.26	$24,390
Maintenance	12.02	$18,030
Aircraft Ownership	7.92	$11,880
Other	2.71	$4,065
Total DOCs in 15 Days only	$78.17	$117,255

Based on the FAA-recommended values as adjusted using U.S. Bureau of Labor Statistics employment cost index, the average value of a passenger's time is assumed to be $39.74 per hour, implying the additional $101,971,615 of cost of delay to air travelers in 15 days (as depicted in Table 5-2 below). Hence, the total DOCs and cost of delays to air travelers is estimated to be $102,088,870.

Table 5-2: Estimated total cost of delays to air travelers in 15 days (30% or more flights experiencing gate-hold)

LAX Total Number of Passengers in 2007 (Ref. LAWA)	**LAX Average Daily Number of Passengers**	**LAX Number of Passengers in 15 Days**	**Average Value of a Passenger's Time per Hour (Ref. FAA)**	**Estimated Total Cost of Delays to Air Travelers in 15 Days**
62,438,583	174,488	2,617,320	$39.74	$101, 971,615

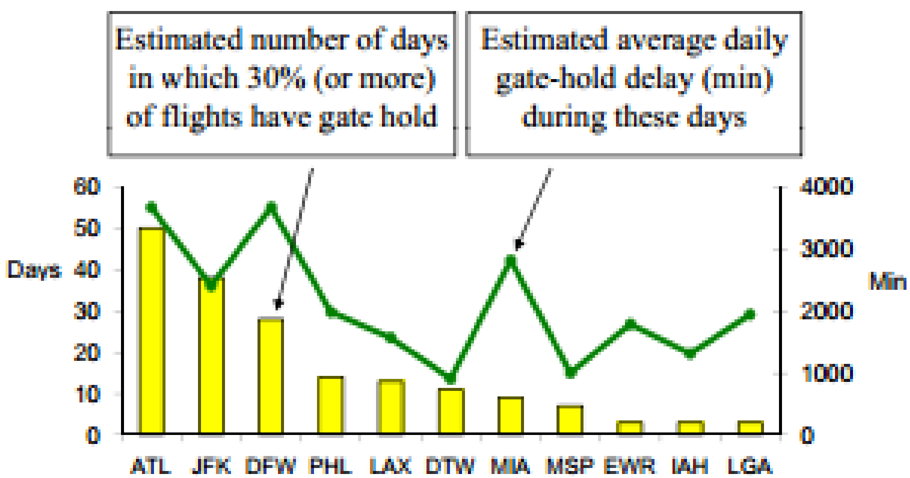

Figure 5-9: OEP Airports Gate Delays (Ref: Shortle et al, 2009)

Rakas and Porier (2009) estimated that 32.7% of the terminal frontage space can be additionally utilized if sharing of aprons is done between one wide-body and two narrow-body aircraft considering a linear terminal building layout. This significant saving was found without taking into consideration benefits of utilizing mobile gates and redistributing them among a range of aircraft types.

Hence, the installation ($425,000) and annual maintenance ($0-10,000) of proposed jet bridges are marginal in comparison to the costs caused by gate-delays. If we assume that the proposed jet bridges are installed in the apron areas that are the most impacted by gate-delays and aircraft-gate incompatibility problems, based on a model by Rakas and Poirier (2009), we estimate that the total delay cost savings exceed installation costs as indicated in Table 5-3.

Table 5-3: Preliminary cost estimates and benefits

Number of Jet Bridges Installed	**Installation Cost ($)**	**Total Delay Cost Savings: DOCs + Cost to Air Travelers ($)**	**∆ Cost Savings ($)**
10	4,250,000	5308621.219	1,058,621
20	8,500,000	10310975.83	1,810,976
30	12,750,000	15415419.31	2,665,419

VI. Interaction with Industry Experts and Airport Operators

Throughout the development of the mobile gate concept, our team was in contact with numerous aviation professionals from airports, airlines, consulting firms, and the FAA. In order to understand airlines' perspectives on mobile gates, we first spoke to an experienced pilot at Delta Airlines, Frank Ketchum. He explained how the ramp area experiences most delays and how aprons (i.e. parking areas - gates) are among the most congested areas at an airport because of multiple types of movements: aircraft, passengers and cargo, ground support equipment and airline/supplier personnel. One important aspect discussed was the parking area marking and signage. We also focused on the safety of the jet bridge design in order to prevent any accidents in such a critical location. For example, a bar in between the rollers supports will extend down from the bottom of the rotunda and connect to the ground while parked at a gate or off-site for storage to fix the jet bridge to the ground for added structural safety.

Linda Perry, Director at Leigh|Fisher Consultancy, thought that the concept of mobile gates was very interesting and noted its potential to alleviate gate-constraints at airports. Because this concept is futuristic, however, she also pointed out that the concept raises a number of questions. For example, flight delays can cause operational challenges for the system. However, flight delays already cause problems for airports. Mobile gates would provide flexibility to help keep gates available even with airplanes behind schedule. Other issues included adequate parking area definitions, the effectiveness of mobile gates when interacting with the apron and terminal, and scheduling issues associated with reconfiguring the gates.

Christopher Oswald, Vice President of Safety & Regulatory Affairs, Airports Council International - North America (ACI-NA) thinks that the proposed concept of mobile jet bridges does offer possible increases in gate utilization/flexibility. He pointed out issues associated with GSE parking, apron marking, and the mechanical/structural challenges associated with mobile "head of boarding bridge" installations. Thanks to his comments, we made sure to thoroughly address the operational and safety challenges associated with flexible gate reconfiguration.

Prakash N. Dikshit, Senior Consultant | Airport Planning at Landrum & Brown, agreed that limited gate capacity will definitely become a major problem for airports in the future and that flexibility would always be valuable to their operation. To help develop our concept, he asked how GSEs, lead-in lines, and Stand Entry Guidance would interact with the mobile gates. Also, he brought up another solution, Multiple-Aircraft Ramp Systems (MARS). MARS addresses many of the same issues as mobile gates, but MARS is limited in that it provides two configurations, while mobile gates can provide any configuration, making it capable of satisfying anything from day-to-day changes in demand, up to long term fleet mix changes.

John Bergener, Airport Planning Manager at San Francisco International Airport, questioned the effectiveness of mobile gates as compared to MARS or just additional terminals and gates. However, he did note that the option of additional gates can be limited by a lack of available land. His other concerns included how the mobile gates would interact with the interior of the terminal, and how the GSE could serve the different gate configurations, and how to meet the vertical and moment load structural requirements. Because the FAA Airport Design Competition does not include terminal building design, we did not address any questions raised by Mr. Bergener in this report. However, we have solved structural and safety issues using rolling supports under the rotunda, making the system safe at all times.

VII. Summary, Conclusions and Recommendations

Current gate and ramp congestion and aircraft-gate physical incompatibility will continue to pose a serious problem for many airports and airlines in the U.S. and the world. Based on reviewed literature and practices, it is found that the aviation industry lacks any effective method to (1) accommodate the severe shortage of gate capacity, (2) address the aircraft mix diversity at busy airports, or (3) resolve problems of aircraft-gate size incompatibilities. All the proposed solutions are either too costly (and time-consuming as they require building new infrastructure), or lack long-term sustainability. For this reason, we propose a more elastic option to resolve the airside congestion challenge by using *Mobile Gates*.

The idea behind *Mobile Gates* is to increase gate maneuverability and gate physical mobility to meet different demands of aircraft-mixes. The proposed idea enables the parking spacing to change to meet the demanded mix of different aircraft-sizes by implementing a number of changes to parking orientation and boarding entrance orientation. In order to preserve the current passenger safety and jet bridge security requirements set by the Federal Aviation Administration, this design requires minimal transformation of the existing jet bridge.

In addition, we propose using next generation technology in order to maneuver and manage parking spaces, jet bridges, and gate locations. We believe that the proposed design will revolutionize traditional gate capacity management, while preserving passenger safety and jet bridge security. It is recommended to integrate this concept into the Airport Collaborative Gate Allocation (A-CDM) program, which will alleviate congestion and delays at airports of the future.

It is recommended that future work is extended in the following areas:

1) Using UC Berkeley’s Invention Lab, prototype a jet bridge and apply it to several terminal building configurations using robotics and simulated data. Special attention should be given to the estimation of time to reconfigure gate positions.
2) Because the FAA Airport Design Competition does not include topics related to the passenger terminal building, it is recommended to conduct a separate study on the following topics: impact of Mobile Gates on boarding doors in the terminal, hold rooms and gate ticket areas; and passenger walking distance for transfer passengers.

Appendix A: List of Complete Contact Information

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Appendix B: Description of the University

University of California, Berkeley is the world's number one 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 PhDs 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 five research libraries in 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 four 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: Non-University Partners Involved in the Project

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The Airport Consultants Council (ACC) is the global trade association that represents private businesses involved in the development and operations of airports and related facilities. ACC is the only association that focuses exclusively on the business interests of firms with airport-related technical expertise. ACC informs its members of new trends while promoting fair competition and procurement practices that protect the industry's bottom line.

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Leigh|Fisher

Leigh|Fisher is an international consultancy that has over 60 years of expertise within the aviation industry. According to its website, Leigh|Fisher specializes in business advisory, facility and operational planning, environmental and sustainability planning, management and strategy, and government advisory services. Leigh|Fisher's Bay Area office, located in Burlingame, serves west coast airports, including San Francisco International (SFO).

Byron Thurber
Senior Airport Planner
ARUP

Arup has the expertise to put forward-thinking strategy, design and technology into practice, whether advising clients on aviation planning, policy or finance, or delivering smarter airport operations and infrastructure. Arup's solutions deliver real business benefit by balancing the needs of people, operational processes, technology solutions and the facilities and environments in which solutions are implemented. Arup has 90 offices in 35 countries, with 10,000 planners, designers, engineers and consultants deliver innovative projects across the world with creativity and passion.

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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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Airports Council International - North America represents the interests of airport owners and operators in the United States and Canada. ACI - NA’s mission is to “advocate policies and provide services that strengthen the ability of commercial airports to serve their passengers, customers, and communities.” ACI - NA promotes airports’ interests through advocacy, research, education, and periodic industry conferences.

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San Francisco International Airport

San Francisco International Airport (SFO) is the busiest airport in the San Francisco Bay Area and the second busiest airport in California, following Los Angeles International (LAX). SFO serves as a hub for both United Airlines and Virgin America. Hosting a variety of legacy airlines, low cost carriers, and international flag carriers, SFO offers nonstop service to most states and many countries around the world. SFO is owned by the City and County of San Francisco.

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Appendix D: Design Submission Form

FAA Design Competition for Universities
Design Submission Form (Appendix D)

University ___University of California, Berkeley___

List other partnering universities if appropriate ___N/A___

Design Developed by: ☐ Individual Student ☐ Student Team

If Individual Student

Name _N/A___

Permanent Mailing Address _N/A___

Permanent Phone Number ___N/A___ Email ___N/A___

If Student Team:

Student Team Lead Patrick Poon

Permanent Mailing Address 869 Charmain Dr., Campbell, CA 95008

Permanent Phone Number 408-429-3925 Email patrick452@berkeley.edu

Competition Design Challenge Addressed:

___Management and Planning___

I certify that I served as the Faculty Advisor for the work presented in this Design submission and that the work was done by the student participant(s).

Signed ___ *Date* _4/14/2014___

Name _Jasenka Rakas___
University/College __University of California, Berkeley___
Department(s) ___Civil and Environmental Engineering Dept., and ITS/NEXTOR___
Street Address ___107BMcLaughlin Hall___
City __Berkeley___ State_ CA___ Zip Code ___94720-1720___
Telephone ___(510) 642-9064___ Fax __(510) 642-5687___

Appendix E: Evaluation of Educational Experience Provided by the Project

Students

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

The FAA Design Competition has been a rewarding experience for all of us. FAA student competition gave us an opportunity to create our original design and combine the theories we learnt in class with practice. Since our design covered a wide range of subjects in aviation, we were exposed to new challenges that we never experienced before and learnt how to overcome this challenges with multi-disciplined engineering skills. Furthermore, realizing that our design is able to have such tremendous impact on aviation industry gave us confidence and let us develop deep interest in aviation. Everything we learnt in the competition will definitely benefit us both academically and professionally.

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

Recruiting students for the competition is the first challenge we faced. Since our design covers a wide range of subjects, we need more people to accomplish our goal. We reached out to our classmates and Professor Rakas helped us a lot by publicizing our project in her other classes. Finally, we successfully recruited ten students working on the competition.

Being a group of 10 people, the greatest challenge is organizing the team and keeping everyone on track. Due to the large size of the group, we divided the group into four teams by their tasks, including design, data analysis, safety and risk analysis and literature review. In addition to the individual team meetings, we also assembled the leaders from each team and discussed the project for better cooperation between teams.

Another challenge we met was lack of data for the case study. Since our case study requires a large amount of flight data from a specific airport with large variety of aircraft mix, we reached out to professionals in aviation field and Professor Rakas also contributed a lot in this process.

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

After literature review, our team realized that lack of gate capacity has been an universal phenomenon and no effective resolution has been developed. We studied the current terminal building infrastructure and decided to provide larger gate capacity without modify the current structure in a large scale. In order to increase gate capacity and provide more flexibility, we agreed to design dynamic terminal gates to minimize wasted parking area. Dynamic terminal gate is able to accommodate gate capacity with seasonal demand change and minimize the area between parked aircraft. With the cost benefit analysis, we are able to see the profit our design can generate.

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

Participation by industry in the project has been highly meaningful and useful in all aspects. Like mentioned before, professionals in aviation industry provided us valuable data for our case study. The opinions and advices provided by the associated industries allowed us to more deeply tackle the problem and to broaden the scope of our project. In addition, participation by industry also provided credibility to our project and added confidence to our team. We gained insight of the certain specific operations otherwise unavailable to us. They are not only the experts in their own field, but also the educators in the industry. We highly appreciate their help for our project.

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?

For those of us who are planning to pursue a master degree in the future, the competition enables us to develop a better understanding of overall structure of a group research project. Moreover, the experience of designing the research structure and conducting literature review gave us a valuable lesson before going into graduate school study. For those of us who are planning to enter aviation or other fields, the FAA student competition provided us with an unique opportunity to interact with professionals and academics. Many of us also had fun while doing research since we were finally able to use our own creativity, knowledge and experience to create our own product.

Faculty

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 concept of mobile gates from the initial stages to the end by designing a mobile-gate concept, applying it to a busy airport and testing its feasibility. 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. Although the research group was relatively large (10 students), this Competition also allowed students collaborate in small teams of two-three 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, operations research, political science, and business/management background, and had little previous knowledge or understanding of aviation or airport systems. Many of the student-team members never took any formal aviation classes. The Airport Design class that some of the students 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 concept of surface management, apron design and gate capacity limitations. Another challenge the students faced was the initial resistance of their proposed mobile-gate concept by airport operators and industry experts, and the industry's initial "suspicion" about the proposed design. Whenever the experts commented on their design from a more tactical, today's 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 definitely 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, as well as on aviation sustainability.

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