

Airport Research Design Challenge

Airport Management and Planning
Innovative Strategies for Reducing Airline Fuel
Consumption

Perimeter Taxiway System

Pennsylvania State University

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ACRP

AIRPORT
COOPERATIVE
RESEARCH
PROGRAM

Executive Summary (1 page)

Through the ACRP Challenge, this report focused on improving airport management and planning by exploring innovative strategies for reducing airline fuel consumption. Airlines consume billions of gallons of fuel every year, creating a great need for efficiency improvements. After initial research, the team decided to focus on reducing idling time. It was discovered through conversing with industry contacts that airlines can spend up to \$1,000 per minute on fuel while idling. The team looked at how airplanes spend ground time and where they spend the most time idling. By looking at portions of the airport navigation process and talking to industry professionals we developed an array of solutions in order to reduce idling time from gate to gate.

The team developed many solutions and chose to further expand upon one that would hopefully reduce time spent taxiing to and from the runways, because this is where the majority of idling takes place. The innovation that we chose to develop for this purpose was the use of a perimeter taxiway design that would decrease runway crossovers and traffic.

While similar designs could benefit many airports, we wanted to create our model based upon an existing airport in order to acquire meaningful results. After considering several of the busiest airports in the United States, we chose to base it on Chicago O'Hare airport. Chicago O'Hare is one of the busiest airports in the country and seems as though it would have an easier time than most acquiring the extra land required for such a design.

After further development of our solution we performed a cost benefit analysis based upon costs such as construction and maintenance over the course of 25 years and the benefit of

fuel savings based on our estimation of idling time reduction. This analysis yielded incredible savings for the airlines operating out of Chicago O’Hare.

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Problem Statement and Background

The two biggest inefficiencies at airports are when airplanes are taxiing from terminal to runway and when they are idling at gates waiting either to take off or cross the runway. We learned that a big reason for these long wait times in airports that were designed 50 plus years ago for two to three different airlines are having a hard time balancing the needs of all the different airlines that now fly out of the airports. We decided to find an innovative way to increase fuel efficiency as well as reduce the gate-to-gate time airlines currently face.

Narrowing down the problem, we saw that crossing active runways and covering the large distances between some of the runways at the edges of the airport is one of the main causes of wasting time on the runway. This was the issue that our team ultimately decided to resolve in airports, as we saw it as a cost efficient way to create real money and time saving measures at an airport, while maintaining safety and reliability.

Summary of Literature Review

Our main piece of literature was an article we found in the *Chinese Journal of Aeronautics* called, “Methods for Determining Unimpeded Aircraft Taxiing Time and Evaluating Airport Taxiing Performance[2].” This article was proof to us that taxiing delays is a very big problem in the Aerospace industry, and people want solutions. They state that taxi times are affected by the length of aircraft queues in the current taxiway system and that something must change. Their solution is a different approach than ours, but their research gave us a good base of

knowledge. We learned that a few key “bottleneck” areas at airports include, gates, taxiways, and runways. This gave us some areas to focus on for our solution. An important term we found was Unimpeded taxi-out time, “Unimpeded taxi-out time is defined as the travel time of an aircraft from pushback from the gate to takeoff on the runway without any interference of other traffic.” Another quote that stuck out to was this, “From an airlines’ point of view, once an aircraft has left the gate, any excess time from an optimum unimpeded time that occurs before takeoff shall be considered as inefficient, regardless of its occurrence in the ramp or movement area.” This showed us airlines were fed up with the current system and ready for change. Further reading of this article confirmed our initial thoughts and gave us quality information from which to officially develop our problem statement and begin research.

Once we determined that we would be working on a taxiway improvement, we looked into potential issues and information that we would need to know by exploring some of the outcomes of other runway/taxiway construction project such as one at Dallas Fort Worth airport[3]. From here, we decided that we would have to get a better idea of construction costs. It was important to get an idea of what these costs might be to see if it was worth further developing this solutions. While the potential fuel savings are extremely valuable, they would not be worth it if we discovered that the construction and maintenance costs were inhibitive high. These costs and benefits are much further analyzed later in the paper. We gathered values from places such as the Ohio Airports Focus Study [4] and used them to help determine the value and final design of our ideas.

Lastly, we wanted to look into what some of the primary causes were for planes wasting time taxiing, so we read an article done about MIT [5] that discussed what the main culprits were

for causing planes to spend excessive amounts of time on the airfield. Among other issues that have to do with air traffic control, it identified runway configurations and delays in crossing active runways as large time wasters for taxiing planes. This stuck out to us as aspects of the airport that could benefit from the perimeter taxiway design. This was proof to us that avoiding active runways entirely could have a significant impact on the amount of time planes waste on the runway and the amount of fuel they subsequently waste.

Problem Solving Approach

After we finished our initial research it was clear we had found a relevant problem in attempting to reduce the fuel consumption due to time spent idling and were on track to finding a potential solution. We began to develop an array of potential solutions that may be able to reduce idling time throughout different legs of the planes journey from gate to gate. Through brainstorming processes the team developed a series of different solutions ranging from completely re-organized airport layouts to simply increased use of generator use to decrease consumption of the more valuable jet fuel by the auxiliary power unit.

The list of ideas was narrowed down to a much smaller list of the ones that were most feasible and beneficial by the use of a pugh matrix. The ideas that made it past this step were then researched with slightly

more depth in order to gain a better understanding of each one's benefits and potential

		Perimeter Taxiway		Open Gate Area		Generators	
METRICS	Weight	Score	Weighted	Score	Weighted	Score	Weighted
Efficiency	0.352	4.000	1.408	3.000	1.056	2.000	0.704
Feasibility	0.244	4.000	0.978	3.000	0.733	4.000	0.978
Reliability	0.203	5.000	1.017	4.000	0.813	4.000	0.813
Affordability	0.2	3.000	0.601	3.000	0.601	5.000	1.002
Safety	0.351	4.000	1.404	4.000	1.404	5.000	1.755
Total	1	Total:	5.407	Total:	4.607	Total:	5.252
		Rank:	1	Rank:	3	Rank:	2

barriers. With this knowledge in mind, the team created a weighted AHP matrix, as seen in Figure 1, in order to assist us in narrowing down our scope to one solution. Based on the results of this matrix and a further discussion within the team, the perimeter taxiway design was set to be further developed. The reasoning behind this decision was largely based on the fact that the time spent taxiing to and from the runway is the largest portion of the time spent idling and where even a small difference could go a long way towards saving fuel and money throughout the industry.

Figure 1: Weighted AHP Matrix

Our plan was to design a more time efficient taxiway system for planes. This was meant to provide a faster, safer, and easier transit route for planes to get from terminal to runway. While designs similar to this could be beneficial for a large range of airports, we wanted to create our model based off of an existing airport in order to acquire meaningful results and have a more concrete display of the solution's potential. After talking with multiple industry professionals and researching the most problematic airports, we considered several of the busiest airports in the United States to base our initial model on. Our conclusion was that the airport it could most easily be implemented at with a lasting effect would be Chicago O'Hare airport. O'hare is one of the three busiest airports in the country and is often associated with some of the longest runway wait times in the country. In addition, O'Hare seems as though it would have an easier time than most acquiring the extra land required for such a design. There are also currently runway remodeling plans underway at the airport, which would set it up in such a layout as would be ideal for such a perimeter taxiway addition.

Safety Risk Assessment

After completing the testing and design aspects of the prototype, we began to consider the safety implications of our design and its impact on the airport industry as a whole. One of the biggest considerations with our design was how it would impact traffic flow around the airport. From looking at data from multiple large airports, we were able to determine that airplanes follow very similar and established paths from terminal to runway. This means there are less unknowns for air traffic controllers to watch for and prevent. As we were looking at the design and how airplanes moved, along with real data from Chicago O’hare airport, we were able to develop a risk assessment matrix following the FAA safety management system.

Risk Assessment					
	Impact (1- least impactful, 5 most impactful)				
Likelihood	1	2	3	4	5
5	Green	Yellow	Yellow	Red	Red
4	Green	Yellow	Yellow	Red	Red
3	Green	Unexpected Construction Cost	Yellow	Red	Red
2	Green	Plane to Vehicle Incursion	Plane to Plane Incursions	Yellow	Red
1	Green	Pilot Confusion	Green	Green	Yellow

Figure 2: Risk Assessment Table

The three main risks associated with the perimeter taxiway design is nothing different than a standard taxiway system. The risks associated with these are mainly runway incursions, from planes or vehicles, and unclear directions to pilots landing or taking off from the airport immediately after implementation. From our contact with real commercial pilots, we learned

instructions for taxiing are generally very clear and the appropriate signage on and around the taxiway is enough for pilots to navigate a maze of taxiways. Incursions occur because of human error either from the air traffic controllers, or pilots. When a plane enters a active runway, whether or not the plane ends up colliding with the other airplane, this is an incursion. At O'hare airport, in 2015 there were 42 incursions. In 2016, this dropped to 25 and in 2017 it dropped again to 15. Chicago services over 1.3 million airplanes each year meaning these incursions account for much less than .01% of all flights in and out of Chicago O'Hare [7]. Our design has the benefit of allowing planes to pass the end of a runway as opposed to the center of a live runway, an area where on a normal flight won't be. The likelihood that a plane overshoots a take off or landing at the same time another airplane is taxiing across the same section is so low that it is a risk we will accept and transfer to the pilots to stay aware of their surroundings and take action as necessary.

Technical Design Aspects

Throughout the project the team has created representations and models of various different potential solutions. In considering our final solution, we have settled on creating perimeter taxiways at Chicago O'Hare airport as we have mentioned. The first thing that we did was look at the airport as it exists currently and as it will exist in a couple of years when construction is complete on the demolition of existing runways and paving of the new ones at the airport. Our decision was to focus on creating the perimeter taxiways based upon the future runway layout. Once we turned out focus to the future runway layout we were able to turn our attention to which sections would benefit from adding these taxiway designs.

There were three key places that we felt could benefit from such a design at the new Chicago O'Hare airport. The first was in the bottom right where we could incorporate a basic design joining the two bottom runways that ran parallel to each other. The second and third key places that we felt this design was necessary were just above that on the left and right bookends of the parallel runways north of the terminals.

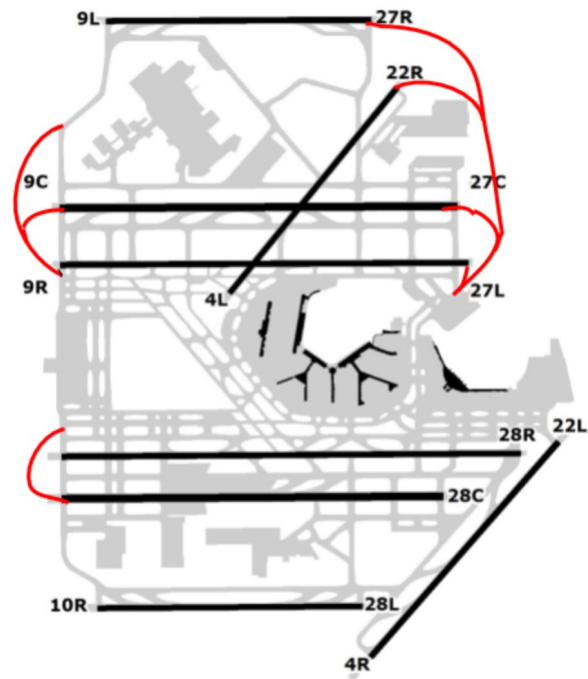
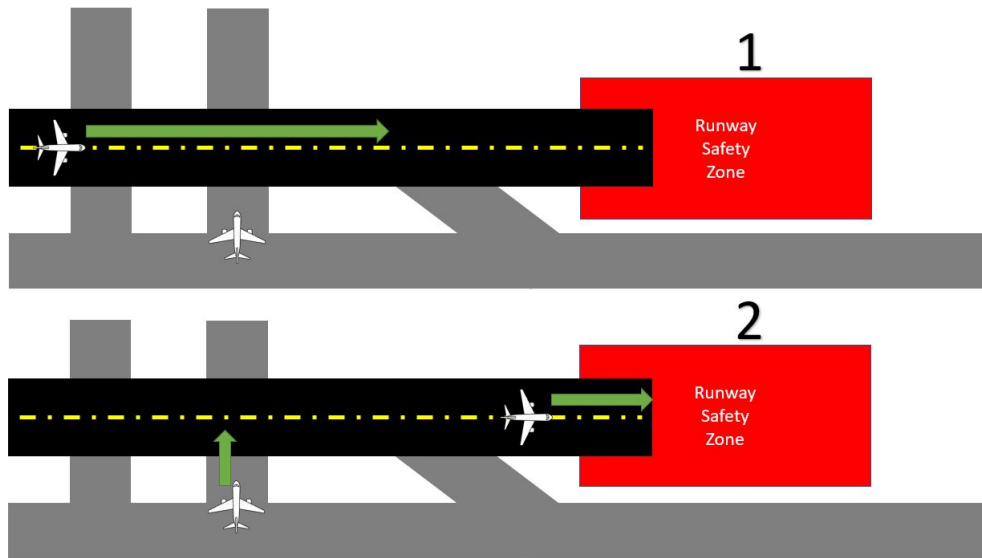
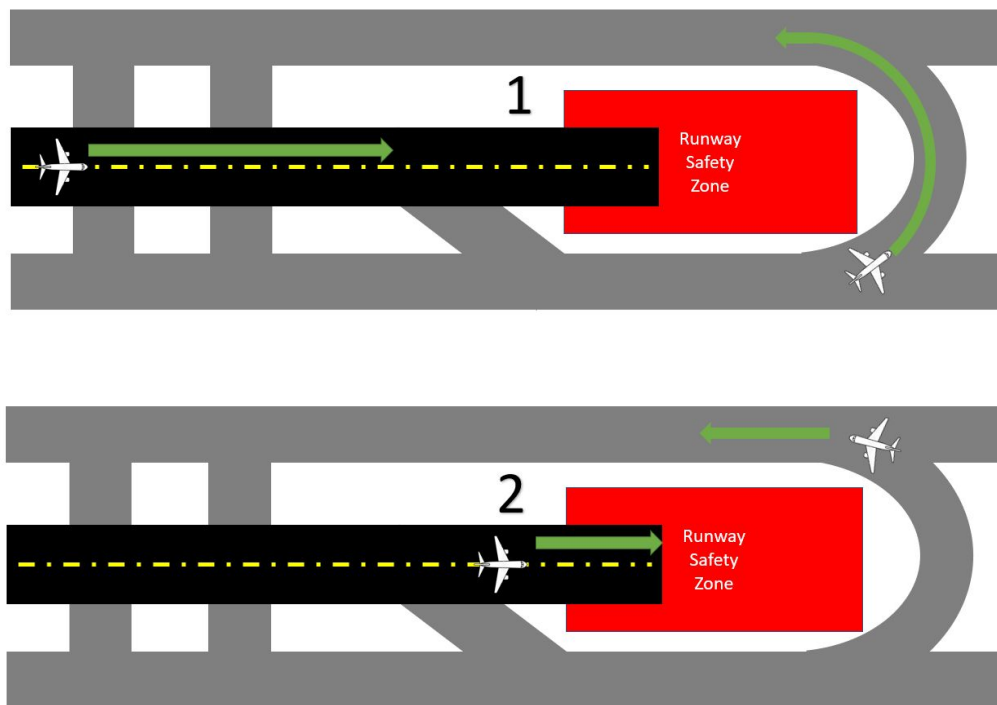


Figure 3: Chicago O'Hare layout with additions [1]

These three places are where our design would have the greatest impact. We then considered whether or not it was beneficial to expand upon the idea beyond there. Ultimately, we decided that extending these taxiways in order to reach the further runways more efficiently, while requiring a larger scale of construction and maintenance costs, would still prove to be beneficial to the operations of the airport. All of these taxiways would be designed to standard taxiway standards and would match the dimensions of the other common pathways throughout the airport system.



Current method of airplane crossing active runways.



Proposed method of perimeter taxiway system

Interactions with Industry Experts

In order to help determine which of the three solutions was most viable, we conducted a series of interviews with professionals in the aerospace industry. Our panel of professionals consisted of a pilot, a safety officer, and a vice president of operations at Memphis airport. Interviewees were asked about their background, involvement at key institutions, and the groups and people in their professional networks. Questions also focused on aspects and designs which the contacts believed were necessary for reduced fuel consumption and idling time, based on industry knowledge.

John Greaud: Airfield Operations Planning Design

Through this interview, the biggest take away from this interview was that every airport is different. John Greaud stated to our team “once you have been to one airport, you have been to one airport.” This interview was highly productive and informative, Mr. Greaud spoke about communication within an airport, the specific rules and regulations which the team should further research, and specific airports which were currently running most efficiently. This interview guided our research towards finding an innovative solution which focuses specifically on a singular airport, but could eventually become universal.

Frank Farmer: Design Standard and Safety Inspections

Our interview with Frank was mainly focused on the safety aspects of the project. He emphasized to us that throughout our design process, we need to continually hold safety as our highest priority. Beyond this, he also stressed that human error must be factored into any decisions that we make with the design, being that they are never perfect, and in high stress situations such as an airfield, prone to make errors that wouldn't normally be made. It was useful

to hear his experience on the industry, especially the human aspect of it, as we had not taken that into consideration as much before the interview.

Descriptions of the projected impacts of the design

The goals of the ACRP project is to develop innovative solutions to benefit the airline industry. With this innovative design, we have been able to increase the efficiency of airports and reduce costs. The ACRP project guidelines gave our team a direction to put forth creative effort to help bring awareness about the need for improvements in the infrastructure of airports and the FAA's attempts to develop the new technologies. The installation of a perimeter taxiway has multiple benefits. Primarily, there is the decreased chance of accidents and incursions on runways as mentioned before. This comes from the absence of active runway crossings where a majority of plane on plane collisions occur. Secondly, for passengers, they will see a decrease in runway taxi times by about a minute based on our simulations. While the actual reduction in time will vary based on management, demand and current conditions. This will result in an overall better experience for consumers at that specific airport. Finally, the cost savings in fuel alone will help offset the costs of construction. The model developed[Figure 4] for the cost assumes a 25 year life span, and accounts for the increasing amount of traffic through the Chicago O'Hare airport.

Cost Benefit Analysis		
Item	Cost	
Construction Costs	\$268,000,000	
Research and Design	\$50,000	
Maintenance	\$1,516,500,000	
Benefits		
Fuel Savings from reduced taxi time	\$26,677,485,000	
Overview		
Costs	\$1,784,550,000	Ratio:
Benefits	\$26,677,485,000	14.6

Figure 4: Cost Benefit Analysis

With fuel consumption at \$1000/min of taxi time, even a 50 second decrease in the total time a plane spends taxing can mean large savings in the long term for airlines. The estimates for construction cost and maintenance come from other airports that have implemented simerly sized additions to a taxiway system based on distance. The benefits described in the chart represent the cost of fuel savings modeling the increase of the average daily capacity of Chicago O’Hare airport for the next 25 year and a reduction in total taxi time of 50 seconds. The effective application of our design could drastically change the way Chicago O’Hare and potentially more airports handle the expect increase in demands for flights.

Appendix A: Contact Information

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Appendix B: Description of the University

Penn State University is an institution of higher education in Pennsylvania. It houses the college of engineering which includes numerous engineering degrees at both the undergraduate and graduate levels. The college of engineering supports an undergraduate minor in engineering leadership in which undergraduate engineers can build the non-technical skills to support the great technical skills they are developing through their engineering curriculum. The engineering leadership development program offers students classes in project management, leadership education and development, business basics, and cross cultural teaming. Students in the minor are dedicated to building these skills in addition to the technical work load required of their discipline's curriculum. The engineering leadership program also offers a graduate program in the form of a master of engineering and an online graduate certificate in Engineering Leadership and Innovation Management.

Appendix C: Description of non-university partners involved in the project

There were no non-university partners involved in the creation of this project.

Appendix D:

**Airport Cooperative Research Program
University Design Competition for Addressing Airport Needs
Design Submission Form (Appendix D)**

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the design.

University Pennsylvania State University

List other partnering universities if appropriate: _____

Design Developed by:

Individual Student

Student Team

If individual student:

Name Drew Peirce

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If student team:

Student Team Lead: _____

Permanent Mailing Address _____

Permanent Phone Number _____ Email _____

Competition Design Challenge Addressed:

Airport Management and Planning: Innovative Strategies for Reducing
Airline Fuel Consumption

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 _____

Name _____

University/College _____

Department(s) _____

Street Address _____

City _____ State _____ ZIP code _____

Telephone _____ Fax _____

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

Students:

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airports Needs provide a meaningful learning experience for you? Why or why not?

The ACRP competition provided a lot of meaningful education for our team. We learned a lot about managing projects and what processes and strategies yield the best results. Along the same vein, we learned a lot about working in teams and team dynamics. In addition we learned about how specific different industries can be and how to gain information about them. Finally, we learned a bit about the airport industry which may someday be used by team members if they ever work in relation with that industry.

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

Our biggest challenge in this project was not having industry experience. The air travel industry is a very nuanced industry with a lot going on in it and it has been difficult to see the smaller details and issues that could create barriers to our project without first hand experience of its operation. We overcame this by doing research, thinking critically about everything that we did, and leaning on our industry contacts.

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

We selected a topic that we felt we could more easily relate to because it is similar to many more consumer focused industries. By focusing on fuel consumption we could lean on many of the concepts and struggles that we know about the automotive industry and other similar applications. Our process we used to develop our hypothesis was to think about the concepts that we were trying to apply and researching them to see how they were applicable specifically in the air transport industry and how we might be able to improve upon current operations.

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

Participation by industry throughout this project was a difficult task. While the ACRP gave us many contacts that we could reach out to, few were responsive and it was difficult to get the information that was desired for our class assignments and for the project. The people that we were able to talk to, however, were very friendly and helpful.

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 deal about working on a project team from this. We were forced to communicate well throughout the project and stay organized through a variety of project management methods such as weekly summary reports. These strategies and processes are things that we will be able to bring with us on all future school and work projects in the future and will help us to achieve success.

Faculty:

1. Describe the value of the educational experience for your student(s) participating in this competition submission.
2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?
3. What challenges did the students face and overcome?
4. Would you use this competition as an educational vehicle in the future? Why or why not?
5. Are there changes to the competition that you would suggest for future years?

Appendix F: Reference List (APA)

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