Project Title: "Innovative Revenue Generation Strategies for GA Airports"

ACRP Design Challenge: Airport Management and Planning: Creative approaches to airport revenue generation for general aviation airports

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2017 Spring Semester Project

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1. Executive Summary

The ACRP University Design Competition has identified that creative approaches to airport revenue generation for general aviation airports are needed to maximize airport capabilities (Airport Cooperative Research Program, 2016-2017). This design project team investigated six innovative strategies for revenue generation and developed a decision making process for airport operators to use to select the best revenue generation strategy for their airport. The process features a Pugh matrix, safety assessment, and cost benefit analysis. An example scenario is presented to demonstrate the use of the process for a fictitious general aviation airport.

The background experience of the design team includes private and commercial pilots, airframe and powerplant (A&P) mechanics, and regional airport management. Industry input from a current airport manager and an aviation fuel company provided insight and direction for our design. This project began in January 2017 and completed in April 2017.

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3. Problem Statement

The Federal Aviation Administration (2012) reports that the United States (U.S.) and its territories contain over 19,000 airports, heliports, seaplane bases, and other landing facilities. The FAA's National Plan of Integrated Airport Systems (NPIAS) includes 3,330 that are open to the public and are eligible for Federal funding through the Airport Improvement Program (AIP). Of these airports, 378 have scheduled commercial air service where U.S. and foreign airlines operate. The remaining 2,952 landing facilities are primarily used by general aviation (GA), and are therefore referred to as GA airports (Federal Aviation Administration, 2012).

These GA airports are very important to the national transportation system and serve other societal needs as well. GA airports connect communities, businesses, and people to provide critical support functions and many specialized services that scheduled airline service cannot provide. The FAA reported that in 2009, operators at GA airports spent over $12 billion. This included an estimated 27 million flights for emergency medical services, aerial firefighting, law enforcement and border control, agricultural functions, flight training, time-sensitive air cargo services, and business travel (Federal Aviation Administration, 2012).

Despite the importance of GA airports, some are struggling to stay open. In 2010, FAA statistics show there had been about 170 closures since 2000. Two famous losses were Chicago's Meigs Field in 2003 and Atlantic City New Jersey's Bader Field in 2006. The highest number of GA airport closures occurred in 2006, when 27 facilities closed (Epstein, 2012). Some airports struggle due to money, while others face different challenges. Santa Monica in California is facing closure. It is set to close on 31 December 2028, but will have to shorten its runway to limit jet traffic before then (Chiland, 2017). While increased revenue alone would not have saved this particular airport, it would have provided more resources for fighting legal battles while continuing to operate.

The ACRP University Design Competition has identified that creative approaches to airport revenue generation for general aviation airports are needed to maximize airport capabilities (Airport Cooperative Research Program, 2016-2017). GA airports are affected by increasing construction costs, decreases in available funding, and periodic downturns in the aviation industry. Airport operators must continually look for additional revenue sources to fund projects and sustain operations (Briggs, 2012).

4. Background

The current, traditional ways airports raise revenue are primarily through fuel sales, hangar leases, agricultural leases, and grants (Briggs, 2012). An airport operating authority can make money from fuel sales by charging flowage fees or uplift fees, which are fees imposed on any fuel that is pumped at the airport. The Central Illinois Regional Airport flowed about 3.2 million gallons of aviation a fuel a year, so even a small fee on flowage can earn an airport a significant amount of money (Baxmeyer, 2017).

With traditional forms of revenue generation at airports, however, revenue amounts will fluctuate significantly with changes in the economy. The Purdue University Airport, for example, has only half of the available hangars currently rented to customers. Fuel sales and hangar rentals do not encompass all the airport's potential assets. Therefore, there may be missed opportunities for revenue generation. For example, the Central Illinois Regional Airport owns about 700 acres of land, while the Purdue University Airport owns about 500 acres. There are many opportunities for compatible land use at GA airports (Baxmeyer, 2017). In this design project, the team proposes suggestions for alternative strategies for revenue generation and a process for airport operators to use to analyze and select potential revenue generation strategies.

5. Literature Review

Airports must be financially, socially, operationally, and economically sustainable. The airport community uses a definition of sustainability with the acronym EONS, which includes Economic viability, Operational excellence, Natural resource conservation and preservation, and Social responsibility (Transportation Research Board, 2015). There are many ways for a GA airport to generate revenue using strategies and technologies that benefit the community and have little to no harmful impact on the planet. These ideas are becoming more popular across all airports in the U.S. Airport operators must choose the best fit for their airport. This section discusses six areas of opportunity for revenue generation found during this project and include:

- Solar energy
- Wind energy
- Electric ground support vehicles
- Commercial leasing
- Alternative fuel sales
- Education in science, technology, engineering, and math (STEM).

5.1 Solar Energy

Solar energy is radiation from the sun that is converted into an energy source that can be used by consumers. Solar energy is most commonly used for electricity generation, water heating, and heating and cooling. These examples, however, are of solar energy being used on a small scale, such as in one home or a business building. Utility companies are now beginning to build large scale areas that can be used to power entire cities and small towns (National Renewable Energy Laboratory).

Solar energy has immense potential. According to the World Energy Assessment in 2000, the amount of solar energy that hits the Earth every year is more than three times what is needed to power the world. Researchers believe that at minimum solar energy can produce 1,575 exajoules of energy every year globally, and could be as high as 49,837 exajoules annually. It is believed that even at minimum energy production, solar energy alone could power the entire world until the year 2100, when researchers believe that humans will be using between 880 and 1900 exajoules of energy globally (United Nations Development Programme, 2000).

Indianapolis International Airport, KIND, is one of the leading airports in the use of solar energy on the property in the world. The solar farm began in October 2013. The entire solar farm is 183 acres and positioned on the east and west side of the terminal. The system consists of 87,488 panels which produce 280-305 watts at peak production. The entire solar farm produces about 36.1 million kilowatt hours every year, which is enough to power more than 3,600 home annually (Greening the skies over INDy, n.d.).

5.2 Wind Energy

Wind is a result of solar energy hitting the Earth, and is caused by the uneven heating of the atmosphere by the sun. Air moves from cold, high-pressure areas to warm, low-pressure areas. Wind turbines can convert this natural air movement into electrical energy. According to the U.S. Energy Information Administration (EIA), in 2015, 4.7% of net U.S. electric power generation (190,927-gigawatt hours), came from wind energy. In 11 states in U.S., wind facilities produced at least 10% of each state’s total electricity (U.S. Energy Information Administration, 2016).

Wind is a renewable and non-polluting resource for creating electricity. Wind is a free resource, so it is competitive with other power generating technologies even though wind energy generation plants require a high initial investment. The wind facilities, however, have some adverse effects on the surrounding environment. Wind energy plants create noise when producing electricity. Birds and bats can be killed if they fly into the rotors (Wind Energy Development Programmatic EIS, n.d.).

Not every location is good for installing wind energy plants. In the U.S., wind resources are ranked from class 1 to class 7 (lowest to highest) by wind-power density (Wind Energy Development Programmatic EIS, n.d.). Good locations should have a class 3 or higher wind resource. Most of these places in the U.S. are in the Central High Plains and the Rocky Mountains. There are many U.S. airports with good wind resources that airport operators can leverage. For example, the Honolulu International Airport and the Boston Logan Airport generate the electricity supplied to the airport administrative buildings using wind energy (Harris Miller Miller & Hanson Inc., 2012).

Wind energy equipment has potentially adverse effects on airport safety. The “impacts of wind turbines on aviation include physical penetrations of airspace, communication system interference, and rotor blade-induced turbulence” (Barrett & Devita, 2011, p. 20). The FAA also provides guidance to help airport operators to determine if a new wind energy structure has adverse effects on the safety of airports. (Barrett & Devita, 2011)

5.3 Electric Ground Support

Electric vehicles (EVs) are becoming more popular in the world today. EVs run on electricity instead of fossil fuels. They are propelled using one or two electric motors powered by batteries. According to the U.S. Department of Energy, EVs convert about 60% of their energy into power that is transferred to the wheels while a standard internal combustion engine only converts 20% of the energy in gasoline to the wheels. EVs also have no air pollutants expelled from them during use so they do very little damage to the environment. Also, if the energy the EV receives is from a nuclear, hydro, solar, or wind-powered plant, there are no exhaust pollutants from the vehicles operation. EVs are also very quiet. The electric motors emit very little noise. The electric motors also require less maintenance than the standard combustion engine (US Department of Energy, n.d.).

One opportunity for GA airports to use electric vehicles is the electric tug. There are several electric tugs on the market today. For example, SMARTech Industries, LLC sells an electric tug called the SMARTug. The SMARTug is controlled via remote control so a person can walk beside the aircraft, or not even be with the aircraft, as it is moved. There are three versions of the tug, each being able to move and handle a different size aircraft. The smallest tug can handle up to a 10,000-pound aircraft, while the largest tug can handle a 20,000-pound aircraft. There are also add-ons available for extra lights, chains for snow use, and ground power units (GPU) which allow the operator to start an aircraft using the tug as well. The SMARTug can also be used to move other things such as boats and trailers that are often stored in hangars (SMARTug, 2014).

5.4 Commercial Leasing

Airports are important economic engines for surrounding communities (Crider, et al., 2011). The unique roles and characteristics of airports require airports to have large amounts of land and facilities to operate. The land and facilities, such as offices and hangars, are valuable resources that can be used to increase the revenue of airports. There is no explicit FAA approval required for leasing airport property, however, every airport sponsor who wants to lease airport land or facilities must be in compliance with any grant obligations (Federal Aviation Administration, 2009).

Based on the types of the tenant and anticipated use of the land or facility, the airport commercial lease can be divided into eight broad categories:

- Aeronautical versus non-aeronautical leases
- Land leases
- Fixed-base operator (FBO) leases
- Specialized aeronautical service operator (SASO) leases
- Hangar rental leases
- Agricultural leases
- Sublease
- Airline leases (Crider, et al., 2011)

The potential tenants for airports are varied and are not limited to the aviation industry. For instance, the Lost Nation Municipal Airport (LNN), in Willoughby, OH, is a reliever airport for the Cleveland Hopkins International Airport. LNN repurposed an unused 75,000-square-foot hangar and rented it to a local business for developing a sports park. Now this facility generates $83,000 per year in rent for the airport (Schwanz, 2016).

5.5 Education

Science, technology, engineering, and math (STEM) education is an increasing need in the U.S. In 2006, the President announced the *American Competitiveness Initiative* to address shortfalls in federal government support of educational development and progress in STEM fields. The goals include improving K-12 science and mathematics education, strengthening the skills of teachers through additional STEM training, and enlarging the pipeline of students prepared to enter college and graduate with STEM degrees. The America COMPETES Act (P.L. 110-69) became law in 2007 (Blaine Airport Promotion Group, 2011).

Many school systems have realized the need for increased STEM education, and are implementing requirements for hands-on laboratory learning activities. This is a tremendous opportunity for GA airports. Project Lead the Way (PLTW) is a provider of STEM education curricular programs that have been endorsed by the President and the U.S. Secretary of Education (Blaine Airport Promotion Group, 2011). GA airports can engage business on the airport and support the community by inviting schools to use the airport as a resource for STEM activities. In 2014, the Anoka County Blaine Airport in Minnesota has provided over 3,500 K-12 student visits to the airport (Blain Airport Promotion Group, 2014).

Getting students and families involved at local airports is very important to GA airport survival. In the case of Santa Monica airport, if the community "valued the airport more than a park or business option," the airport might not be facing closure (Sclair, 2017, p. 10). STEM education can provide revenue generation as well as social sustainability. Alexendria Field in NJ was funded by $100,000 grant to develop a 12-month STEM-based case study (Sclair, 2017).

5.5 Fuel

There are opportunities for GA airports to increase revenue through expanding their fuel sales. One way to accomplish this is to install a self-fueling station. A self-fueling station helps increase fuel sales because an airport can offer lower fuel prices by lowering the cost of providing fuel service. If the pilots purchasing the fuel are pumping it themselves, the airport does not have to pay line personnel to perform the service. Also, fuel trucks are commonly used and are expensive to maintain, so a self-fueling station can decrease overhead costs for an airport and help lower fuel costs to attract customers (Baxmeyer, 2017).

A GA airport could also offer a new, more environmentally sustainable fuel to its customers. Swift Fuels now sells UL94, an unleaded aviation gasoline. There are many environmentally friendly pilots who would fly out of their way for access to unleaded fuel. Unleaded avgas can also be sold to customers outside of the aviation. Racecars and boats use high octane unleaded fuel, and UL94 is higher quality and can be stored longer than regular gasoline (Zuilkowski, 2017).

Another important benefit of selling UL94 instead of automobile gasoline is that Swift Fuel has product liability insurance coverage. If an airport sells automobile gasoline the owner, operator, board, or municipality would be liability for any damages, not the distributor. “Mo-Gas” is sold with restrictions that it is not to be used for military or aviation. Swift Fuels is properly insured so the airport would not be exposed to liability for misfueling (Zuilkowski, 2017).

6. Decision Making Process for GA Airport Operators

The research team developed a decision making process, shown in figure 1, for airport management teams to use to analyze and select new revenue generating strategies. This research paper identifies several potential areas for revenue generation, but the decision making process can be used for any revenue generating strategy.

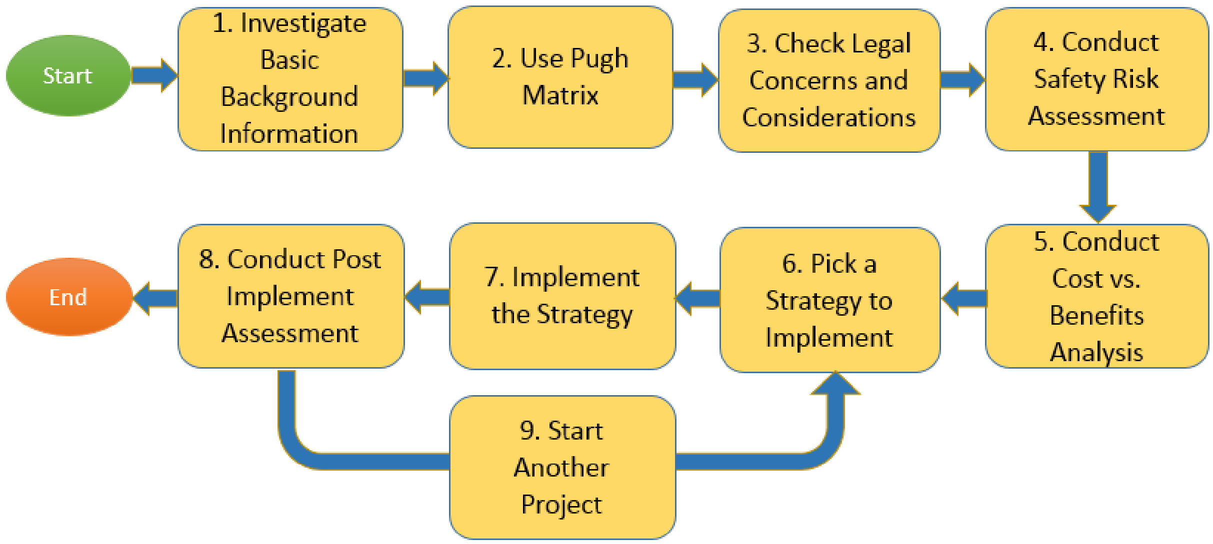

Figure 1. Decision making process for analyzing new revenue generation strategies

Step 1. Investigate Basic Background Information

A basic background investigation is an important step for assessing each possible strategy. For example, if the airport has a grant that prohibits the use of airport property for non-aviation uses, then several of the revenue generating strategies would be eliminated immediately. This step takes into account the operating environment to determine the general boundaries and constraints for each airport. A more in-depth examination of each issue will be performed during later steps; this initial decision is to save time by removing options that have known problems before spending time doing further investigations.

Step 2. Use Pugh Matrix

The next step in the decision making process is to fill out the Pugh matrix (Pyzdek & Keller, 2009). The Pugh matrix the team developed can be seen in figure 2. The Pugh matrix is used to analyze potential revenue strategies that could work at the airport. The revenue generation strategies are based on EONS sustainability criteria (Transportation Research Board, 2015). The research team developed an initial set of criteria listed in fugure 2. Airport operators should review the criteria, and develop criteria that apply to their airport. Across the top, the

Pugh matrix shown has four potential strategies listed in columns. If the airport wishes to investigate more strategies, then more columns can be added.

To start the Pugh matrix, the airport operator is to go through the criteria and give them a weight from 1 to 5, depending on how important each of these criteria are to the airport. A weight of 1 would mean that the criterion is less important to the airport, while a 5 means that the criterion is more important to the airport.

Next, the airport operator is to use the first column as the baseline of their current revenue generation strategies. The baseline would receive a rating of all zero's in the rating column, giving it a final score of zero, which represents no changes.

Next, label the top of each column with a revenue generation strategy the airport is considering, based on the background investigation done in step 1. Each criterion is then rated by how it compares to the baseline (current revenue generation), using a value of -3 to 3. A rating of -3 means the new strategy would be much worse than the current strategies and a score of 3 is much better than current strategies. If the new strategy would not improve or worsen the criterion compared to the current revenue generating strategy, then it would receive a rating of zero.

Once each column has been completed, the airport operator then multiplies the rating by the weight for each criteria, while making sure to carry any negatives through the process. After the airport operator has multiplied across each of the rows, then they would add up the resulting scores of each column. A positive number in the final score means that the strategy would theoretically be a positive addition to current revenue generating techniques. If the final score is a negative number, then the strategy would have a detrimental impact on the airport and should not be used.

Revenue Generation Pugh Matrix for ____________ Airport

	EONS Criteria	Wt (1-3)	Baseline (Current Strategies) Rating (-3 to 3)	Baseline (Current Strategies) Score	Solar Energy Rating (-3 to 3)	Solar Energy Score	Wind Energy Rating (-3 to 3)	Wind Energy Score	**Other Alternatives can be Included**	Alternative Fuel Sales Rating (-3 to 3)	Alternative Fuel Sales Score
Economic	**Revenue Generation** (Amount of additional revenue to be generated by the new strategy)										
	Start-up Costs (purchase and installation of equipment and facilities)										
	Maintenance Costs (Any cost to maintain, repair or upgrade facilities, tools or equipment)										
	Operating Costs (cost to operate day to day including labor, taxes, and energy costs)										
	Grant Availability (Is there a grant avaiable to assist with costs)										
	Facilites/Land Available (Is there space that can be used for the strategy including offices, hangars, and land)										
Operational	**Improve Infrastructure and Operations** (Does the strategy help the airport operate more efficiently)										
	Encourage Alternative Fuel or Energy Usage (Does the strategy improve the use of alternative power sources on the airport)										
Natural Resource	**Air Quality** (Does the stategy increase or decrease the air pollution in the surrounding area)										
	Land Pollution (Does the stragtegy create additional pollution to surrounding land)										
	Reduce Energy Usage (Reduce the amount of power that must be purchased from the power compnaies in the area)										
Social	**Legally permitted** (Is it legilation that prevents you from using the strategy for any reason)										
	Safety (Does the technology increase or decrease safety of all operation occuring at and around the airport)										
	Community Service Opportunity (Is there a benefit for the surrounding community)										
	Noise Pollution (Does the stragtegy create additional noise or reduce the noise in the surrounding area)										
Total				**0**		**0**		**0**			**0**

Suggested criteria. Please customize to meet the specific situation

Four columns shown. Add as many columns as needed.

Figure 2. Pugh Matrix

The criterion in this Pugh matrix are divided into four major sections based on the ACRP EONS definition of sustainability. The areas include Economic, Operational, Natural Resource and Social impacts (Sustainable Aviation Guidance Alliance, n.d.). The team put each criterion into one of these four sections based on which area it affected the most. The criteria in the Pugh matrix are recommendations, so the airport operator may add or delete anything based on their specific needs.

Economic Impacts include the criteria that address the financial costs and benefits of the implementation of the new strategy. The strategy's ability to generate revenue is the first criterion in this section. This is the amount of additional revenue that the strategy would generate once fully operating. It could include direct additional revenue or existing costs that are offset. The next criterion this team uses is the start-up costs. A start-up cost is anything that must be purchased for to get the new strategy running. This includes all parts, labor and facilities, or any other cost that may arise to get the strategy operational.

Maintenance costs are also included in the economic impacts section. These costs include anything to fix any problems with the strategy or to upgrade it for any reason. This includes costs such as labor, parts, tools, and equipment or upgrade materials as well as any other costs associated with maintaining or upgrading the equipment. The next criterion is the operating costs. Operating costs are anything to keep the strategy running from day to day. These are things such as labor if someone has to operate the technology, taxes, or the energy cost to operate the equipment.

The economic criteria also includes the availability of grants for implementing the strategy. These grants can be from any source, such as federal, state, or even local agencies. The final criterion for the economic section is the whether there is land or facility space available to implement the strategy. Some strategies would need land that would be rendered unusable for aviation purposes, and others would need office or classroom space in a building. The airport would need to make sure there is space for the strategy to use.

Operational Impacts assess how efficiently the airport is run and whether the new revenue generating strategy would improve the operation of the airport. A criterion this team recommends for operational impact is the improvement of infrastructure and operations. These improvements could decrease downtimes or reduce the need for future investments.

The other criterion used for operational impact is the encouragement of alternative fuel or energy. The airport management is going to assess whether implanting the new strategy would encourage the airport and its customers to use an alternative source of power that is sustainable. The airport operator should also assess whether the strategy would encourage customers to use alternative fuels with lower or no lead and ozone depleting compounds.

Natural Resource Impact criteria address how implementing the strategy is going to affect the earth and its natural resources. The first criterion is this section is air quality, which considers the air pollution created at the airport. When assessing the air quality, the airport operator would want to consider whether implementing the strategy would increase or decrease the pollution put in the air by the airport equipment.

The next natural resource criterion would be land pollution. This criterion is looking at how implementing the strategy would affect the land on and around the airport. This is to assess whether implementing the strategy would increase or decrease the amount of pollution put into the ground in the area around the airport.

The last natural resource criterion is reduction energy consumption. This criterion is assessing whether implementing the strategy would decrease the amount of energy that the airport has to purchase. In addition, the airport operator would want to investigate whether the airport can sell the unused energy back to the city, which would generate more revenue.

Social Impacts are the final section of the EONS criteria in the Pugh matrix. Social impacts evaluate the affects that implementing the strategy would have on the community and the perception of the airport. A criterion in the social section is legality concerns. This could be things such as liability if someone were to be injured, killed, or sustain damage to property as a result of implementing the strategy. Also with legal concerns, the airport operator or board would want to make sure there are no federal, state, or local laws or regulations that would prohibit or lessen the effectiveness of the implementation of the strategy.

The next criterion for social impact is safety. When looking at safety the individual completing this matrix is going to assess if the safety of any person is positively or negatively affected by the revenue generating strategy. The researchers put safety in the social impacts section because a high concern for safety relates to an organization valuing people, communities, and society (Giudice, 2015).

Another criterion for social impact is the community service opportunities. Being able to involve the community in airport operations is going to benefit the airport's perception. With the improved perception of the airport, people are more likely to be involved and wanting to be at the airport, which would generate additional revenue. By interacting with the local community, the airport operator could assess if implementing the new strategy would be perceived as beneficial to their community.

The final criterion for social impacts is the noise pollution. This could include added noise pollution or reduction of noise pollution depending on the strategy that is implemented. Some strategies would increase the amount of noise in the air. While it not always a significant amount by itself, when added to the noise already produced by an airport it can have a negative impact. The opposite is also true, however, in that a small reduction in the noise can add up if utilized correctly.

After evaluating each criteria in the Pugh matrix and calculating a score, the airport operator should review the results and select which, if any, strategies should be further explored. The operator should continue using the decision making process on strategies with a positive score.

Step 3. Check Legal Concerns and Considerations

The third step of the decision making process is to conduct a thorough investigation into the laws, regulations and legal issues that would impact the implementation of the strategy. At this point, a strategy that would not be legal would be eliminated from the process. If the strategy has several laws or regulations that would make it difficult to implement, the airport may choose to eliminate it from consideration as well.

Step 4. Conduct Safety Risk Assessment

The fourth step of the decision making process is to conduct a safety risk assessment for each of the remaining strategies under consideration. The FAA advises airports to do a safety risk analysis before any new equipment or procedure is added to the airport.

Advisory Circular (AC) 150/5200-37 describes safety management systems (SMS) for an airport, and explains how to do a safety assessment. The FAA uses the predictive risk matrix chart shown in figure 3 to analyze how much risk is associated with a certain outcome and whether it is acceptable or not.

The matrix uses the assumption that likelihood multiplied by severity equals the potential risk. Severity of the outcome is determined by the worst possible case no matter how likely it is for that to happen. To manage the risk, an airport would want to eliminate anything in the red area. However, the airport would still need to make sure to manage risks in the yellow and green areas as well. (Federal Aviation Administration, 2007).

Severity / Likelihood	1. No Safety Effect	2. Minor	3. Major	4. Hazardous	5. Catastrophic
5. Frequent	5	10	15	20	25
4. Probable	4	8	12	16	20
3. Remote	3	6	9	12	15
2. Extremely Remote	2	4	6	8	10
1. Extremely Improbable	1	2	3	4	5

High Risk
Medium Risk
Low Risk

Figure 3. Predictive Risk Matrix (Federal Aviation Administration, 2007)

Step 5. Conduct Cost Benefit Analysis

The fifth step is to perform a cost benefit analysis as shown later in section 7. The cost benefit analysis will help the airport and the airport directors decide whether implementing the new strategy is truly worth the time, money and effort. If the benefits outweigh the costs, then the airport should move on to step 6. If the costs outweigh the benefits then that strategy should be eliminated. A return on investment of capital (ROIC) analysis is also necessary before the implantation of new strategy.

Step 6. Pick a Strategy to Implement

Once all the assessments are completed and the unfeasible options are discarded, a revenue generation strategy may be selected for implementation. The best choice is determined using the ratings from the Pugh Matrix and the results of the in-depth legal, safety, and cost-benefit analyses. There is a possibility that none of the strategies explored should be implemented. Then the airport operator should return to step 1 of the decision making process

Step 7. Implement the Strategy

During the implementation step of the process, the airport has continually assess the progress on implementation. If any issues arise the airport directors would want to reevaluate if the implementation of the strategy is still useful. If the airport directors deem the new strategy to be no longer be useful, then implementation should be stopped and the team move on to step 8. However, if the airport directors do see the new strategy as useful, then work should resume until the new strategy is installed and operational.

Step 8. Conduct Post Implementation Assessment

It is necessary to assess the effectiveness of the revenue generation strategy. If the implementation of the new strategy has generated revenue, the airport operator can continue the operations. If the new strategy was unsuccessful, the airport operator needs to assess why the strategy failed to generate revenue. The airport operator needs to identify the barriers to implementation and whether or not they can be overcome. If the airport operator can make adjustments to make the revenue generating strategy successful, they should do so. If not, the airport operator can return to the Pugh matrix to try again with a different strategy.

The post implementation assessment is not just limited in the economic viability of the project. The implementation of the new strategy will also have an impact on the natural resources, social responsibility, and operational efficiency of airports. These four aspects of effects are known as "EONS" approach to sustainability. The airport industry expands the concept of the Triple Bottom Line by adding operational efficiency. Therefore, the post implementation assessment should include determining if the new strategy stimulates economic growth, protects the environment and natural resources, benefits society, and efficiently operates the facilities of an airport (Sustainable Aviation Guidance Alliance, n.d., para. 2).

Step 9. Start Another Project

After the implementation and analysis of the revenue generating strategy is completed, the airport may choose to end the process or try another strategy. If the airport operator chooses to implement more revenue generating strategies that they have already investigated, then the airport operator should go back to step 6 of the decision making process and implement the strategy. If the airport directors wish to investigate new revenue generating techniques, then the airport directors would want to return to the Pugh matrix to select another beneficial strategy to use. The decision making process can be repeated as many times as necessary to find workable solutions.

7. Example Scenario

The following example scenario illustrates an application of the decision making process developed by this design team. The researchers chose solar energy and alternative fuel sales as two revenue generation options to demonstrate the decision making process. The researchers selected solar energy since it is one of the more challenging options to implement. The alternative fuel sales option was chosen for the example because it is relatively new for the most airport operators. The airport and its information presented in this section are imaginary.

The KKLY airport is a fictitious public GA airport located in a rural area between Lafayette and Indianapolis in Indiana. It owns 600 acres of open land surrounding the airport. Since the airport is close to farms, the numerous airport operations are usually for agricultural purposes. The existing revenue sources of the airport, however, cannot cover its operation cost. Thus, the airport operator is looking for new strategies for generating revenue.

Step 1. Investigate Basic Background Information

After conducting a background investigation, the airport operator did not find any general boundaries or constraints on the airport operating environment, and selects four potential revenue generating strategies that may work at the airport. The strategies to be investigated are solar energy, wind energy, airport commercial leasing, and alternative fuel sales.

Step 2. Use Pugh Matrix

To choose appropriate strategies, the airport operator conducts an analysis using the Pugh matrix created by this research team. The airport operator can weigh each criterion according to the airport situation. For example, the criterion of noise pollution is weighted as 1 (less important) in this scenario because the airport is located in a rural area. If an airport is located in an urban area, the noise pollution would be weighted more than 1. The results of KKLY's Pugh matrix are shown in Figure 4.

The evaluation of the current revenue generation strategies, the baseline, is in the first column of the Pugh matrix, with a total score of zero. Solar energy has a high score of 20 because it will generate revenue, encourage alternate energy use, reduce energy purchased from the power company, and may provide a perceived benefit to the surrounding community. Alternative fuel sales also has a high total score of 19 due to positive scores in the majority of the criteria. Wind energy, however, has a low of 2 due to high start-up costs and safety concerns.

Solar energy and alternative fuel sales are shown to be the most beneficial revenue generating strategies in this scenario, so an airport operator should continue investigating both options. For this example, the solar energy strategy is explored to illustrate the use of the decision making tool.

Revenue Generation Pugh Matrix for KKLY Airport										
EONS Criteria			Baseline (Current Strategies)		Solar Energy		Wind Energy		Alternative Fuel Sales	
		Wt (1-3)	Rating (-3 to 3)	Score	Rating (-3 to 3)	Score	Rating (-3 to 3)	Score	Rating (-3 to 3)	Score
Economic	**Revenue Generation** (Amount of additional revenue to be generated by the new strategy)	3	0	**0**	3	**9**	3	**9**	2	**6**
	Start-up Costs (purchase and installation of equipment and facilities)	3	0	**0**	-1	**-3**	-2	**-6**	1	**3**
	Maintenance Costs (Any cost to maintain, repair or upgrade facilities, tools or equipment)	1	0	**0**	-2	**-2**	-2	**-2**	-1	**-1**
	Operating Costs (cost to operate day to day including labor, taxes, and energy costs)	1	0	**0**	-1	**-1**	-2	**-2**	0	**0**
	Facilites/Land Available (Is there space that can be used for the strategy including offices, hangars, and land)	3	0	**0**	1	**3**	-1	**-3**	1	**3**
Operational	**Improve Infrastructure and Operations** (Does the strategy help the airport operate more efficiently)	1	0	**0**	1	**1**	1	**1**	2	**2**
	Encourage Alternative Fuel or Energy Usage (Does the strategy improve the use of alternative power sources on the airport)	1	0	**0**	3	**3**	3	**3**	3	**3**
Natural Resource	**Air Quality** (Does the stategy increase or decrease the air pollution in the surrounding area)	2	0	**0**	0	**0**	0	**0**	1	**2**
	Land Pollution (Does the stragtegy create additional pollution to surrounding land)	2	0	**0**	0	**0**	0	**0**	0	**0**
	Reduce Energy Usage (Reduce the amount of power that must be purchased from the power compnaies in the area)	3	0	**0**	3	**9**	3	**9**	-1	**-3**
Social	**Legally permitted** (Is it legilation that prevents you from using the strategy for any reason)	3	0	**0**	0	**0**	0	**0**	0	**0**
	Safety (Does the technology increase or decrease safety of all operation occuring at and around the airport)	3	0	**0**	-1	**-3**	-3	**-9**	0	**0**
	Community Service Opportunity (Is there a benefit for the surrounding community)	2	0	**0**	2	**4**	2	**4**	2	**4**
	Noise Pollution (Does the stragtegy create additional noise or reduce the noise in the surrounding area)	1	0	**0**	0	**0**	-2	**-2**	0	**0**
Total				**0**		**20**		**2**		**19**

Figure 4. Completed Pugh Matrix for KKLY

Step 3. Check Legal Concerns and Considerations

Since the solar energy has the highest score, the airport operator decides to install a solar energy system on the airport. Before installing solar panels, the strategy of solar energy must pass the legal check first. According to the amendment to the "Public Utility Regulatory Policies Act of 1978", the airport is eligible to implement a renewable energy source if the airport meets the following five criteria: (1) the airport has a viable source of energy, (2) it is feasible to install a renewable energy technology, (3) it is feasible to see the project through, (4) there is a reasonable return on investment on the chosen renewable energy source, (5) it provides long-term gain towards airport development and public welfare. The airport can only provide the required energy to power its facilities, however, and may or may not sell the energy produced.

Step 4. Conduct Safety Risk Assessment

As the FAA advises in Advisory Circular (AC) 150/5200-37, the airport should conduct a safety risk analysis before implementing solar energy strategy. Table 1 shows the possible dangers, their risk levels, and possible mitigating management actions associated with the application of solar energy. As analyzed, the glare reflecting by solar panels may cause major accidents when an aircraft is taking off or landing. Thus, the solar panels must be installed in an appropriate place. The FAA has conducted several studies on glare or glint produced by the reflection from solar panels (Barrett & Devita, 2011). The airport can use these guidelines to choose the right places to install solar panels. Also, the heat generated by solar energy system may cause a fire. Although the possibility of fire is small, the airport operator should have a complete response plan. The airports can access more information about the safety risk assessment for airport and the risks associated with the solar energy system from the FAA website and many ACRP publications, such as *ACRP synthesis 28: Investigating Safety Impacts* *of Energy Technologies on Airports and Aviation*. In the case of the fictional KKLY airport, the research team list seven risks that involved with the installation and operation of solar energy panels, as shown in table 1. Another research team, one of 2016 ACRP university design competition winners, initially explored these potential risks and their management actions in their competition project (Burani,, Motevalli, & Thomas, 2016). Among these risks, "cause a fire" is estimated to have the fourth level of severity, the third level of likelihood, and 12th risk level. It means the airport operator must eliminate risk as discussed in section 6.

Table 1

Example Risk Assessment

Risk	Severity	Likelihood	Risk Level	Risk Management Actions
Physical Penetration of airspace	2. Minor	2.Extremely Remote	4	Ensure installation of solar panels in the Proper place
Communication Systems Interference	1. No Safety Effect	1. Extremely Improbable	1	N/A
Visual Impacts from Glare	2. Minor	1. Extremely Improbable	2	Ensure installation of solar panels in the right place
Cause a Fire	4. Hazardous	3. Remote	12	Proper monitoring & airport fire department training
Injuries During Installation	2. Minor	1. Extremely Improbable	2	Following Safety rules set by the contractor
Injuries During Maintenance	3. Major	1. Extremely Improbable	3	Following Safety rules set by the maintenance provider
Damage to Existing Environment	1. No Safety Effect	2. Extremely Remote	2	Proper initial investigation into airport surrounding environment

Note. The risks and their management actions are from Burani,, Motevalli, & Thomas (2016).

Step 5. Conduct Cost Benefit Analysis

Before implementing the strategy, the airport operator has to conduct a cost/benefit analysis to ensure that financial ability of the airport to afford the project and to make sure that project will be an advantage to the airport. If the airport cannot or does not want to implement the project individually, it may introduce more stakeholders into the project or apply for funds from the government.

According to Kandt and Romero (2014), "The cost of solar photovoltaic (PV)-generated electricity has dropped 15 to 20-fold in the last 40 years. Grid connected PV systems sell for between $0.20 per kilowatt-hour (kWh) and $0.32/kWh in 2011, or about $5 per peak watt (Wp) to $8/Wp, including support structures and power conditioning equipment. Peak-watt is the power rating that a PV system measures under standard test conditions, and under which a panel could be expected to deliver its peak output" (p. 3). Cost information about PV systems is listed in Table 2 based on a National Renewable Energy Laboratory (2016) study that lists the installed cost and operation and maintenance cost of solar photovoltaic systems. For instance, the average installed cost of a PV system which produces power less than 10 kW is $3,897 per kW. The average fixed operation and maintenance (O&M) cost is $21 per kW per year, while the variable O&M cost is zero.

Table 2

Costs by Size of Solar Photovoltaic (PV) Systems

Size of Solar Photovoltaic (PV) System	Average Installed Cost ($/kW)	Average Fixed O&M* Cost ($/kW-yr)	Average Variable O&M Cost ($/kW-yr)	Lifetime (yr)
PV <10 kW	$3,897	$21	n/a	33
PV 10–100 kW	$3,463	$19	n/a	33
PV 100–1,000 kW	$2,493	$19	n/a	33
PV 1–10 MW	$2,025	$16	n/a	33

Notes. * O&M stands for operation and maintenance. The numbers of costs are from NREL (2016).

There are several benefits of a solar energy farm. Depending on the situation, airports can either sell electricity generated by the PV system to the local electricity service provider, or the solar farm can displace electricity that would have been purchased without the system. The airport may apply to receive funds from the FAA. The FAA operates the Voluntary Airport Low Emissions (VALE) program, which helps airport sponsors meet their state-related air quality responsibilities under the Clean Air Act. Through VALE, airport sponsors can be eligible for funds to help support the procurement and installation of PV systems. The Manchester-Boston Regional Airport (MHT) project, in the city of Manchester, New Hampshire, benefited from VALE funds that covered 95% of PV system costs" (Kandt & Romero, 2014, pp. 3-4).

In the case of the fictitious airport KKLY, since the airport cannot sell the electricity generated by the solar energy system, the main benefit of the project comes from offsetting the cost of the airport electricity bill. This scenario assumes that the KKLY airport staff spends 200 hours investigating the potential use of solar energy, including the analyses discussed in Steps 3, 4, and 5 of the decision making process. Their average salary is $25 per hour. The total cost of research and analysis is $5,000. Assuming the airport uses 120,000 kWh of electricity every year, the airport would need a PV system which is at least 90kW. The number of 90kW is calculated by using PVWatts Calculator found at http://pvwatts.nrel.gov/. The PVWatts Calculator provided by the NREL is online calculator which can provide estimates of the energy production of PV systems according to the location, type of PV system, and other information that specific to the potential site of the solar panels.

To install a 90 kW PV system, the airport owner needs to spend approximately $311,670 (90×$3,463). At this time, the research team would recommend installing a 100kW PV system that would cost $249,300 (100×$2,493). The costs of PV systems are average numbers, so the actual costs would vary by types and sizes of the solar field. Table 3 shows the initial cost of a solar field for the KKLY airport. The O&M cost of this 100kW PV system is $19 per year. This solar system can operate 33 years, so the total O&M for 33 years would be $59,400 (100kW×$19×33years). The total cost the project for its lifetime would be $313,700.

Table 3

Costs of Solar Photovoltaic (PV) Systems in KKLY Airport

Cost	Rate	Quantity	Subtotal	Remarks
Research & Analysis	$25/hour	200 hours	$5,000	Time that project team spent
PV systems	$2,493/kW	100 kW	$249,300	Purchase & Installation
O&M for 33 years	$1,800/yr	33 years	$59,400	Operation and Maintenance for the lifetime of the system
Total			**$313,700**	Total cost of the project for its lifetime

Notes. PV systems include solar panels, support structures, and power conditioning equipment.

The tangible benefit of the solar farm is the offset on the electricity bills of the airport. The unit price of electricity is $0.1/kWh in Indiana. As assumed, the airport uses 120,000 kWh each year, thus airport would receive a $12,000 benefit per year. The total benefit would be $396,000 ($12,000×33 years), as shown in Table 4.

Table 4

Total Benefit of Solar Photovoltaic (PV) Systems in KKLY Airport

Benefit	Rate	Quantity	Subtotal
Offset electricity bills of airport	$12,000/year	33 years	$396,000
Total			**$396,000**

The Return on investment of capital (ROIC) is equal to the difference between cumulative net annual gains from investment and the total cost of investment divided by the total cost of investment, as shown in the equation:

$$\text{ROIC} = \frac{\text{Cumulative net annual gains from investment} - \text{Total cost of investment}}{\text{Total cost of investment}}$$

According to the equation, the ROIC of the solar energy strategy for KKLY airport is 0.26.

$$\text{ROIC} = \frac{396{,}000\ - \$313{,}700}{\$313{,}700} \approx 0.26$$

The return of solar energy field will cover the total investment within 27 years. The results are not showing that the solar energy strategy is an ideal investment project. However, the KKLY airport is awarded the VALE from the FAA. The reward can cover up to 95% of the cost of PV system that is $236,835 ($249,300×95%). Thus, the airport would spend $76,865 ($5000 + $249,300 × 5% + $59,400) on the total investment instead of $313,700. The new ROIC is 4.152

$$\text{ROIC} = \frac{396{,}000\ - \$76{,}865}{\$76{,}865} \approx 4.152$$

In this case, the return on investment can cover the total cost within eight years. At this time, the solar energy would be a very beneficial project. In addition, many other benefits cannot be measured by cost savings above. For example, the airport may receive a positive social reaction from local communities.

Step 6. Pick a Strategy to Implement

After conducting the three analyses, the fictitious KKLY airport operator finds that there are no legal restrictions or prohibitive safety concerns related to the solar energy strategy, and that the airport can afford the initial investment of the solar farm. The airport operator may decide to install the solar panels at the airport.

Step 7. Implement the Strategy

During the implementation of the solar panels, the airport will assess how the installation is progressing. If the airport continues to run into problems, then the airport directors would want to assess whether the solar panels are worth the continued time, money and effort. The airport directors of KKLY decided that the implementation issues were not severe and choose to continue with the installation of the solar panels at the airport.

Step 8. Conduct Post Implementation Assessment

The installation of solar energy strategy is not the end of the project. The airport operator must monitor and assess the project to determine if the strategy meets its goal. Otherwise, the airport operator may stop the project. The concept of EONS, which is described in section 6 of this paper, can be applied for establishing the standards for a sustainability assessment. In this scenario, the solar farm first has to generate enough electricity to meet the operating requirements of the airport, saving the electricity expense of the airport. The KKLY airport operator should also determine if the installation and operation of the solar field will introduce some risks to surrounding environment and wildlife or improve the operational efficiency of the airport facilities. The airport operators may ask local communities if the installation of the solar farm has positive or negative impacts on society.

Step 9. Start Another Project

If the new strategy is a success, the airport operator can pick another strategy to implement. In this scenario, the strategy of alternative fuel sales has the second highest score according to the Pugh Matrix. The airport operator can conduct the same analysis described in Steps 3, 4, and 5 of the decision making process to determine whether to add alternative fuel sales at the airport. If the airport decides to implement this strategy, the airport operator must ensure the airport has sufficient capacity (e.g. professional personal) to operate multiple projects simultaneously.

8. Industry Interactions

8.1 List of experts contacted

Airport Operations

1. Purdue University Airport Manager - Adam Baxmeyer

Alternative Fuels and Fuel Uses

1. Swift Fuels - Tre Strayer
2. Swift Fuels - Jon Ziulkowski

8.2 Responses from Industry

8.2.1 Purdue University Airport Manager Our team was able to meet with the airport manager at Purdue University, Adam Baxmeyer. Adam's knowledge and experience at multiple GA airports was extremely helpful to our research and project direction. His responses are paraphrased by the team.

1. What are GA airports' top three sources of revenue?

For most airports, the biggest sources of revenue would be hangar rent, fuel flowage fees, and land leases. However, some airports may be different. Most airports charge about $0.06 per gallon of fuel pumped on the airport property. Bloomington Normal in Illinois pumps about 3.1 million gallons of fuel a year, and O'Hare was pumping 3.1 million gallons a day. With pumping 3 million gallons, the airport is making about $180,000. Anytime an airport finds a way to generate revenue outside of aeronautical sources is a great opportunity.

2. What are the three biggest expense items to general aviation airports?

Most airports will spend the most on employees, fuel, capital expenditures, or operations and maintenance.

3. Has the airport authority considered any of the following ideas for revenue generation?

a. Alternative Power Generation
  i. Solar
  ii. Wind
b. Electric Vehicle Service
c. Adding unleaded avgas sales
  i. For aeronautical use
  ii. For non-aeronautical use (people other than pilots)
d. Educational classes not under Part 61, 147, or 148 (STEM education for high schools)
e. Leasing of land for alternative uses
  i. Farming
  ii. Commercial use

Solar panels are becoming very popular. KIND is an example of an airport that has been very successful with solar energy. Wind turbines might not be a good idea for airports. The rotating blades may be a major safety hazard for flying aircraft. However, small wind turbines on buildings could power a small facility. Midway Airport in Chicago used a wind turbine on a rental car facility to power that one building.

Bloomington Normal airport researched using an electric truck for ground support. At the time, the electric truck was about $40,000 more than a normal gasoline truck, which would cover a lot of gasoline for the truck. The airport would have to look at upfront costs versus the return on investment to see how long it would take to make the money back. Airport users would probably not be willing pay extra for the use of an electric tug versus the standard gasoline powered tug.

The good thing about STEM education is that it is non-aeronautical and would not be as volatile as the general aviation market. Farming is a great way for airports to generate revenue. Bloomington Normal has about 700 acres of land used for farming. However, the airport has to make sure not to get into the runway protection zone and that the land would have to be compatible for farming. Most farmers would want to lease land for 3 to 5 years at a time. Leasing land to business such as gas stations or small restaurants is also an option. However, these are more difficult because the airport would need to be more along busy roads. Also, when leasing to businesses, the owner is going to want 20+ year lease which can sometimes be hard to justify to the FAA that it would not be used for aviation in that amount of time. The airport would want to set up a minimum annual guarantee, which would say the company must pay a certain amount or a percentage of gross sales whichever is higher.

4. Other information that you wish to provide.

Some airports use farm animals to “mow” grass rather than employees on machines. One example he gave was O’Hare using goats to “mow” their grass fields. Food trucks could come at certain hours of the day, and airports could lease the right to sell food. An airport could also have community/urban garden on site at the airport for the public to use. The airport size would really effect which of these strategies had on revenue.

8.2.2 Alternative Fuels and Fuel Uses Our team first contacted Tre Strayer from Swift Fuels, a company that manufactures and sells UL94, an unleaded aviation gasoline. Tre then referred used to Jon Ziulkowski. Jon was very knowledgeable about the needs of general aviation airports, and the information we gained from the interview gave us great insight into how our project could help airport operators.

1. How does it benefit a general aviation airport to sell UL94?

The main obstacle to general aviation airports adding new sources of revenue generation is resistance to change on the part of airport managers. Swift Fuels is trying to change the paradigm. Airports that sell UL94 have experienced increased aircraft traffic, with reports of pilots flying 100 miles out of their way to access the new fuel. UL94 is a novelty that people want to try, and since not every airport has the new fuel, it is a draw. When aircraft fly into an airport for the UL94, the airport also gets revenue from other services, such as landing fees or rental cars.

Another significant benefit to general aviation airports is UL94's liability insurance coverage. If an airport sells automobile gasoline the owner, operator, board, or municipality would be liable for any damages, not the distributor. "Mo-Gas" is sold with restrictions that it is not to be used for military or aviation. Swift Fuels is properly insured so the airport would not be exposed to liability for misfueling.

2. *Is there an example of an airport that successfully increased their revenue by selling UL94?*

The Aircraft Owners and Pilots Association (AOPA) wrote an article about Brooks Field in Marshall, MI. They realized the quality of the fuel, and it passed the information on to other airports.

3. *Do airports sell UL94 to people other than pilots?*

Swift Fuels distributes UL94 for use in aircraft, and it is taxed as aviation fuel. Some local communities, however, buy UL94 for boats, lawn mowers, and weed-whackers because UL94 can be stored longer than regular gasoline. Also, at Sebring Regional Airport in Florida, race car drivers prefer UL94 to other gasolines, so the price of UL94 goes up on race days!

4. *What are the start-up costs to start selling UL94?*

Swift Fuels has many options for delivering UL94. They sell a turn-key tank set-up that airports install, or they sell the fuel in portable containers or drums. Existing tanks can be upgraded for UL94, or Swift Fuels can help an airport operator locate a fuel truck, which is self-contained and easy to fill. They also offer month-to-month leases or lease-to-purchase options on fuel equipment. In some cases, they even offer to give tanks to airports. Start-up costs can be as little as $5,000 and airports can see a return on investment within 36 months.

5. Any other additional information?

It is very important to "stay ahead of the power curve" and attract the next generation.

9. Projected Impact and Conclusion

9.1 Projected Impact

This design project described six sustainable strategies that can be used to improve revenue generation by GA airports. We created a process for the systematic implementation of potential revenue generation strategies that can be used for any strategy, not just those presented in this design. Airport operators can directly follow the decision making process to collect one or more revenue generating strategy/ies that are best for each airport. These strategies will help GA airports survive financial difficulties. The sustainable strategies presented in this design also introduce a new thinking that is different from traditional revenue generation strategies, such as the example of the LNN airport that repurposed an unused hangar and rented it to a local business for developing a sports park. Also, the implementation of sustainable strategies will improve the operational efficiency of airports by utilizing the idle facilities of airports, such as land or offices. At the same time, the application of the decision-making process and the sustainable strategies will minimize negative impacts on natural resources and local environment, avoiding harming public welfare.

9.2 Conclusion

The ACRP University Design Competition has identified that creative approaches to airport revenue generation for general aviation airports are needed to maximize airport capabilities (Airport Cooperative Research Program, 2016-2017). This design project team investigated several innovative and sustainable strategies for revenue generation and developed a decision-making process for airport operators to use to select the best strategy for their airport.

The application of these strategies and process will help airports achieve economic growth and social responsibility without compromising the natural resources and environment.

Appendix A: List of Complete Contact Information

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Appendix B: Description of the University

About Purdue University:

Purdue University in Indiana is a public university in the Big 10 conference. It was founded in 1869 as a land and sea grant university. Known for science, technology, engineering and math education, it provides students from around the world the opportunity learn, innovate, and contribute to scientific progress. The Purdue Polytechnic Institute combines innovative learning methods, real-world experiences, and industry partnerships. In fall of 2016, there were 40,451 students enrolled at Purdue, with students from all 50 states and nearly 130 countries.

About the School of Aviation and Transportation Technology:

Purdue states, “The mission of the School of Aviation and Transportation Technology is to support the missions of the Purdue Polytechnic Institute and Purdue University in serving the citizens of the State of Indiana, the nation, and the world, through learning, scholarship (discovery), and engagement activities that extend aviation technology education, aviation technology discovery efforts and technology transfer, and implementation (application) of emerging technology for the global aviation industry. Student learning is advanced by discovery and engagement activities that enhance economic and social development” (Purdue Polytechnic, 2016).

Students in the School of Aviation Transportation Technology can earn an undergraduate degree Aeronautical Engineering Technology, Aerospace Financial Analysis, Airline Management and Operations, Airport Management and Operations, Aviation Management, Professional Flight, or Unmanned Aerial Systems. Graduate students can earn a master’s degree in Aviation and Aerospace Management or a Ph.D. in Technology.

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

N/A

Appendix E: Evaluation of the Education Experience Provided by the Project

Student Response:

The following evaluation is a team response:

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?

Yes, the design completion what a very valuable experience. Our team has been exposed to many new ideas and challenges that the general aviation community faces today. We learned many techniques to gather data quickly so that we could find where issues are in the industry. The in depth exploration of the topic made use think about how the general aviation operates which made us look at the issues from many perspectives to develop a process that would be useful to airport operators. Our team also learned about the different tools used to assess aviation innovations such as the cost-benefit analysis and the safety risk assessment.

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

The major challenges our team encountered was coming to a consensus on decisions that had to be made throughout the project, overcoming the cultural barriers, and finding the best task for each team member to take advantage of each person's abilities. We overcame these issues by having team meetings once or twice a week throughout the entire process to discuss our progress and upcoming steps. Our team also had to work with schedules of busy industry professionals who did not always have spare time to meet with us. In order to work with these professionals, we always made first contact and found out what the easiest way for them to communicate was whether it be phone, email or in-person.

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

In our research on sustainability and general aviation, we realized that many general aviation airports are struggling to stay open because of the lack of revenue. Our team believed that if airports could utilize any sustainable technologies or other resources to generate revenue other than the more traditional methods, the airport might be able to stay open for years to come. Although we realized that not every airport was the same so we would need a way for the airport administration to select which strategies would work the best for the airport.

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

The industry experts that we talked to were great! They helped narrow the scope of the project as well as giving us insight into the general aviation industry and the resources that can be used at airports. Also, talking to many of the experts, our team felt that our process was innovative and useful for airport administrations

.

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?

Our team learned planning skills required to put together and entire project in one semester. Our team also learned how tell what information we gathered was actually useful and applied to our project, and how it could be applied to the project. We also learned how a team would put together a proposal for any industry project. Since some of the team members are planning to continue on to further studies, it would act as a framework for future studies or research projects.

Instructor's Response:

Faculty responses prepared by Dr. Mary E. Johnson, team advisor

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

This competition is a valuable educational experience for the students in my graduate level aviation sustainability course because it provides a vehicle for the students to explore the applicability of sustainability to real-world airport design challenges. Two of the course objectives are applicable to the design competition:

A. The student will be able to evaluate sustainability projects affecting aviation and aerospace using multi-attribute analysis techniques such as triple bottom line analysis.

B. The student will be able to develop, communicate and defend an analysis of a sustainability initiative in the aviation or aerospace industry.

The structure of the design package deliverables is the first formal design requirements package that many of these students have seen. In the course, the students must prepare responsive deliverables, show how they have used the evaluation checklist, provide status updates to the class, and present their final reports. The amount of detail required by the ACRP closely correlates to my experience with proposal requirements in industry. ACRP emphasis on total cost of ownership, safety analysis and risk analysis are important elements of understanding the potential impact of their designs on aviation sustainability. The design challenges presented on the ACRP website are starting fodder for creativity and brainstorming. In my course, the design teams purposefully have students with different aviation backgrounds, sometime from different countries; and sometimes with team members new to aviation. The active learning of working in teams to accomplish a long-term goal (12 weeks) is one element of their preparation for entering the work force. I also use this project to instill the habit of lifelong learning. While many of the students are already familiar with locating research articles and perhaps three or four Federal Aviation Regulations, they may not be familiar with the entire breadth of 14 CFR regulations or with the wealth of information produced by other credible sources. By showing the students where they may find information to support their project work, the students now have first-hand experience in turning to the TRB, FAA, ICAO, and aviation trade groups such as ATAG, A4A, Airports Council International (ACI), and IATA for industry-specific information from around the globe. The value associated with the incentive of participating in a competition cannot be understated. The students embrace these projects with a zeal that can be best attributed to the fact that they know that their results will be reviewed by a team of aviation experts and are competing against other collegiate design teams. Thank you for allowing my students the opportunity to learn and compete.

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

Yes. The ACRP design challenges and ideas for projects are used by the project teams to develop their ideas for the design competition. The course is a one-semester course. The project duration is 12 weeks. Because airport sustainability has been adopted by the FAA and more and more aviation organizations are including the EONS model, these students know that their project will be valued when they are interviewed by potential employers.

3. What challenges did the students face and overcome?

These three graduate students in the Purdue Aviation and Aerospace Management program each have at a common background of aviation maintenance and have expressed a passion for keeping GA airports sustainable. Two of the team members are FAA certificated pilots and A&Ps, and the third team member has interned at a US regional airport in the airport management office. Each team member has a different personality, and the cultural differences were also evident as one team member is from the Midwest, one from the Mid Atlantic, and one from China. By deciding to work together, they also decided to find a way to better understand each other and to work with each other to bring out their individual interests. At first, finding information on why GA airports had closed was relatively easy when compared to the difficulties in finding details on how GA airports were finding innovative ways for generating revenue. By becoming resourceful in contacting GA airport managers, looking in the aviation trade magazines, and finding ACRP reports, the team developed a short list of projects that the team decided would be effective for GA airports. In addition to a list of projects, they knew that airport managers would need to have a way to select the right project, so they decided that their design is a method for narrowing down a list of potential revenue generating projects by evaluating the potential impacts to the airport. Developing the sustainability analysis was difficult due to a low amount of data availability, especially for revenue generation factors and cost reduction factors. They overcame this by developing estimates from interviews and from publications.

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

Yes, definitely. The competition instructions are clear and the challenges address real problems for US airports. The materials are understandable, but not easy to perform. The expectations for safety, risk and total cost analyses are directly applicable to my course. The videos on analyses were especially helpful to the teams. The teams choose their projects.

Because the teams have so many ideas to choose from or to use to generate their own ideas, the competition appeals to the team members' intrinsic motivation as the project is something that they want to learn more about.

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

A suggestion to consider is to encourage the use of the EONS sustainability model in the analyses presented in project reports. http://www.aci-na.org/static/entransit/Sustainability%20White%20Paper.pdf, https://www.faa.gov/airports/environmental/sustainability/ and ACRP reports on aviation sustainability are good starting points.

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