2017-2018 ACRP UNIVERSITY DESIGN COMPETITION

Integrated Technologies to Improve Safety of Apron Operations: Apron Intelligent Monitoring and Reporting System (AIMRS)

(January 2018 – April 2018)

Design Challenge: Airport Operation and Maintenance

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1. Executive Summary

The ACRP University Design Competition encourages innovative operation and maintenance procedures to enhance sustainability and resilience at airports (Airport Cooperative Research Program, 2017). Airport apron operations have complex requirements that include operational efficiency, safety, sustainability, and resilience. However, accidents and incidents in the airport apron area lead to US $10 billion yearly costs, directly and indirectly (Flight Global, 2005), and hinder normal operations. Based on existing technologies and products such as facial recognition technology, Global Positioning System (GPS), ADS-B, I.D. Systems®'s AvRamp®, and Axis® Communication's network video solution, this project proposes an Apron Intelligent Monitoring and Reporting System (AIMRS) to monitor ground vehicle movements, enhance identification of ground personnel and their authorized access level, identify potential hazards, and generate safety reports. AIMRS enables airports to conduct real-time monitoring, identifying, and data-collecting of ground vehicles, pedestrians, and aircraft, to avoid potential hazards on the ground surface, and provides information for further safety training. The safety risk assessment, cost-benefit assessment, and sustainability assessment are presented.

The background experience of the design team includes private and commercial pilots, airport traffic management, airport operation, and aeronautical engineering. Professional inputs from three professors in aviation safety area and airport operation area, three industry experts, and two airport managers provided insight and recommendations for our design. This project began in January 2018 and was completed in April 2018.

2. Table of Contents

3. Background and Problem Statement

This project focuses on the design of an innovative apron surveillance and management system for the Airport Operation and Maintenance Challenge. As a part of that challenge, this project addresses listed L. “Operation and maintenance procedures to enhance sustainability and resilience at airports” (Airport Cooperative Research Program, 2017, p.7). The proposed Apron Intelligent Monitoring and Reporting System (AIMRS) monitors the aircraft/ground vehicle/pedestrian on the apron, identifies potential hazards, and accesses the database of accidents, incidents, and near-misses.

The airside of an airport consists of the maneuvering area and the apron. According to International Civil Aviation Organization (ICAO), the maneuvering area is “that part of an aerodrome to be used for the take-off, landing, and taxiing for aircraft, excluding aprons” (ICAO, 2013, p.1-6). The apron can be regarded as a connection between the terminal and the maneuvering area, which “intended to accommodate aircraft for purposes of landing or unloading passengers, mail or cargo, fueling or maintenance” (ICAO, 2013, p.1-3).

In *Ramp Safety Practice* (ACRP, 2011), there was a 15% increase in the number of reported accidents and incidents happened on the apron area in 158 American airports between 2006 and 2007, from 2,633 to 3,026. The accident/incident rate in 2007 would be more than one accident or incident per 4,084 movements (ACRP, 2011, p.1). In 2008, A.D. Balk investigated the aircraft occurrences (accidents and incidents) that happened on the apron. He found that this kind of accidents and incidents happened on the apron would tend to be unnoticed or unreported (Balk, 2008). The Bureau of Labor Statistic (BLS) in the U.S.

also found the ground handling workforce is exposed to much higher accident rates than those working in a construction or agriculture are (BLS, 2013).

In total, these accidents and incidents would lead to over $10 billion costs, directly and indirectly, every year. These costs include rescheduling of flights and passengers, loss of reputation, aircraft repair, insurance costs for staff and operations, and other accident cost (Flight Global, 2005).

In recent years, a lot of work has been done to improve the safety and efficiency in airports, such as Airport Surface Detection Equipment Model X (ASDE-X) (FAA, 2014). At the same time many software companies, such as Axis® Communication, I.D. Systems®, Saab Sensis, AVROGSE, have developed their products that could provide solutions to improve apron safety and operational efficiencies (ACRP, 2011).

However, most of these programs and new products are focused either on the maneuvering area, to optimize the operation of aircraft, or on monitoring a specific aspect of apron safety without further data process and analysis. Such products can only provide limited data to apron safety operators. Apron safety operators still can not know the exact situation on the apron unless apron employees report something to them.

To solve these problems, this report presents the Apron Intelligent Monitoring and Reporting System (AIMRS) that integrates specific existing products and technologies to conduct real-time monitoring of ground vehicles and pedestrians, identify potential hazards and violations automatically, and save useful data into a database for further analysis or training. This system not only helps improve apron safety, but benefit airport from operation, economic, social and environmental aspects. The safety risk assessment, cost-benefit assessment, and sustainability assessment are developed and presented.

4. Summary of Literature Review

The definitions of apron safety and potential hazards are explored, along with Federal Aviation Administration (FAA) regulations related to apron operation and safety. Safety assurance measures and technologies are also introduced. Existing technologies used at the apron area are compared.

4.1 Potential Hazards

Apron safety issues abound at small and large airports. A mix of airplanes, ground vehicles, employees, and even passengers means that an apron needs to be planned and managed to keep everything running smoothly.

According to ICAO Safety Management System (SMS) Manuals (ICAO, 2012), aviation safety is defined as “the state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management” (p. 12). When it comes to apron safety, airport authorities and apron controllers should ensure both aircraft safety and occupation health and safety. Six kinds of hazards that may happen on the apron are: “a) personal injury, b) aircraft damage, c) infrastructural damage, d) Ground Service Equipment damage, e) impact on the environment and f) operational disruptions” (Studic, 2016, p.75).

Personal injury includes the injury to working staff and passengers. Some airports have passengers walking across the apron or shuttling across the apron and milling around outside a plane while enplaning or deplaning. The hazards posed to working staff and passengers on the apron can be split into two groups, outside the aircraft and inside the aircraft. Outside the aircraft there are the possibilities of a people wandering where they are not supposed to, getting lost, getting hit by a vehicle or aircraft, or even being injured by propeller blast or noise. Even inside the aircraft, people are still at risk. A fire could start while refueling, or an incident outside could cause injury to the passengers and working staff inside (Skybrary, 2017).

Ground vehicles, sometimes otherwise known as airside driving, also have a long list of potential hazards that must be considered. The *Airside Safety Handbook* (ACI World Operational Safety Sub-Committee, 2010, p.13) lists these as:

“ 1) Speed limits, prohibited areas and NO PARKING regulations
2) Danger zones around aircraft
3) Engine suction / ingestion; blast, propellers and helicopters
4) Aircraft fueling
5) FOD and spillages
6) Vehicle reversing
7) Staff and passengers walking across aprons
8) Air bridges and other services such as fixed electrical ground power (FEGP)
9) General aircraft turnaround process
10) Aircraft emergency stop and fuel cut-off procedures

11) Dangerous goods

12) Towing

13) Driving at night

14) Driving in adverse weather conditions, particularly low visibility."

Adverse weather can pose a hazard to all parties on the apron. Snow and ice, strong winds, thunderstorms and lightning, sand or dust storms, volcanic ash, low visibility procedures (LVP), and aircraft de-icing may pose hazards to people, vehicles, and aircraft on the apron. Adverse weather may also require special procedures to be carried out to keep all parties safe (ACI World Operational Safety Sub-Committee, 2010).

4.2 Regulations

The responsibility of ground vehicles at airports is largely to be aware of their surroundings and to not interfere with the operation of planes. Operators must know when and where clearance is required, and always know where they are. Operators of ground vehicles generally have more visibility and mobility than large planes so the responsibility to see and avoid falls to them.

When a tower is not in operation, obviously no clearances are required. When there is a tower in operation, Runway Safety Areas (RSA) require clearance. In both cases, extreme caution is required to operate in RSAs. The RSA includes the runway itself and enough area around it to account for emergencies like veer-offs and short landings. In general, this area must always be clear for aircraft, but allow ground vehicles in special circumstances like mowing or NAVAID maintenance. At towered airport a letter of authorization (LOA) is required to state the specific circumstances that a vehicle is allowed in the RSA during aircraft operations (AC). Runways and taxiways are collectively referred to as movement areas, and in towered airports, to operate any vehicle will require clearance to travel in these areas. Non-movement areas, like a ramp, require no clearance, and thus take more situational awareness to avoid other vehicles.

Training of vehicle operators and even many regulations involving ground vehicles falls to the airport operator, but the FAA does have some rules about it in *AC 150/5210-20A* (FAA, 2016a). Any bid for construction must contain a section on ground vehicle movement during said construction, if the project is funded through AIP. Requirements for training can differ from one airport to another, and are based on what part it is. Part 139 airports must have curriculum for initial, recurrent, and remedial trainings provided to vehicle operators, which include aircrafts not intended for flight.

Vehicular Access is also up to the airport operator to restrict. Every vehicle operator is required training however, and it is also recommended to provide temporary training to people like construction workers even if they are required to move with an escort. Physical barriers to restrict access is encouraged, but not required. Even the procedures for electronic gate codes, including how often to change them, is mostly up to the airport operator. It is recommended to have several tiers of training to fit what kind of access different vehicles and operators will be allowed.

In general, there are no federal or industrywide standards for ramp operations (U.S. Government Accountability Office, 2007). Most rules and regulations that apply to ground vehicle operation are up to the discretion of the airport operator. The FAA has suggestions and information readily available for the utilization by these operators, as they want to create as safe an environment as possible, but much of it is not required.A irport operators to consider regulating are: prohibiting leaving a vehicle unattended and running, use of lights, vehicle parking, service areas, speed limits, right-of-way rules, and more (FAA, 2016a).

4.3 Safety Assurance Measure

Many measures, known as safety barriers, are used to assure the apron safety, which includes physical barriers, functional barriers, symbolic barriers, and incorporeal barriers (Hollnagel, 2004). Physical barriers can prevent or mitigate unwanted occurrences in a physical way. For example, ground service equipment, such as belt loaders, are equipped with bumpers, which can protect the equipment from unwanted occurrences. Another example is that ground service staff are required to wear headphone if they are exposed to noise to protect their ears. Functional barriers can prevent staff undertaking one task only if the logical requirement or pre-conditions of this task are met. The interlock equipped on fuel hydrant vehicles is a good example. This interlock can assure that driver cannot start the vehicles unless the fueling platform is in the lower position and the fuel hoses are correctly stowed (UK HSE, 2000). Symbolic barriers include visual, audio or tactile information that can prevent an unwanted occurrence (Hollnagel, 2004). All of the marking and signs on the apron belongs to symbolic barriers. Incorporeal barriers refer to users’ knowledge and ability to prevent the unwanted occurrence. Policies, procedures, regulations, and training can be used to improve incorporeal barriers.

4.4 Technologies on Apron Surface Management

In order to increase the safety, efficiency, capacity, and resiliency of the National Airspace System (NAS) in the United States, NextGen is developed by introducing new technologies, frameworks, and collaborations by the FAA. NextGen program aims to benefit aviation stakeholders through 2025/2030 and beyond. The FAA utilizes the Airport Surface Detection System-Model X (ASDE-X) surface radar and the Automatic Dependent Surveillance-Broadcast (ADS-B) to achieve a safer and more efficient air transportation system (FAA, 2017).

A three-dimensional (latitude, longitude, and altitude) position information, ground speed, and other data of an aircraft can be transmitted by the implementation of the ADS-B. The aircraft avionics gain the aircraft's information using GPS system and other on-board devices. The aircraft's on-board transponder transmits aircraft's information to ground receivers. Then that information would be transmitted to the controller screens and cockpit displays equipped with ADS-B receiving avionics (ACRP, 2011).

The Airport Surface Detection System—Model X (ASDE-X) utilizes surface radar and satellite positioning technology to allow air traffic controllers to monitor and track the movements of aircraft and ground vehicles on the airport surface. With the help of various sensors and other detection technologies of ASDE-X system, the non-transponder equipped aircraft and ground support equipment on the airport maneuvering area can also be tracked (FAA, 2014).

However, ASDE-X is mainly focused on maneuvering area, to optimize the operation of aircraft, improve efficiency, flexibility, and punctuality. Few attention is put on the apron area.

Table 1.

Surface Management System Products

Company	Product(s)	Brief Description
Axis® Communication	AXIS® D2050-VE AXIS® D2050-VE Network Radar Detector	"Automatic alerts when someone enters a restricted area; high-quality HDTV video images, facilitating incident investigations and identifications; built-in intelligence, offering people counting, motion detection; network access to live and recorded video, allowing multiple authorized persons to view video at the same time" (Axis® Communication, 2018, para. 2).
I.D. Systems®	Keytroller® AvRamp®	"Automatic, on-vehicle driver authentication system, electronic vehicle safety inspection checklists, re-time equipment visibility on the airfield, geo-fencing to secure runways and unauthorized areas, detailed, customizable reporting software and dashboards, vehicle speed management and impact sensing" (I.D. Systems, 2018, para. 4).
Saab Sensis	Airport Vehicle Tracking Airport Surface Vehicle Locators	"Saab's airport vehicle tracking solution enhance airport safety by providing precise vehicle location data to the stakeholders and systems that need it. Knowing the location of vehicles on the airfield at all times and in all conditions is a critical part of managing a safe and efficient operation. Saab's vehicle trackers offer an accurate and reliable source for this information" (Saab Sensis, 2017, para. 1).
Avro GSE	Avro Tracker	"Avro-Tracker fleet management system provides a truly proactive approach for maintaining aircraft support equipment and extending the useful life of ground support equipment. This technology enables monitoring, tracking, maintaining and controlling equipment to reduce cost, improve efficiency and ensure safety" (AVRO GSE, 2017, para. 1).

Note. This table is modified and captured from ACRP report (2011).
The links of the introductions for surface management system products are listed.
Axis® Communication: https://www.axis.com/en-us/solutions-by-industry/transportation/aviation
I.D. Systems®: https://www.id-systems.com/manage-forklift-industrial-trucks/
Saab Sensis: https://saab.com/saab-sensis/air-traffic-management/airport-vehicle-tracking/.
Avro GSE: https://avrogse.com/avro-tracker-aircraft-support-equipment/

Many companies have developed different kinds of intelligent products that could provide airport, airlines, and other stakeholders solutions to track and monitor aircraft, ground vehicles and ground workers on the apron for safety and efficiency. These products provide various features to support the airport apron surface monitoring such as events record and playback, automatic alerts when unauthorized vehicles or pedestrians enter a restrict area, and enhanced visual surveillance offered by high-digital network camera system (ACRP, 2012). See Table 1 for the descriptions of these products.

As mentioned above, the focuses of ASDE-X and ADS-B are not at apron safety. The products developed by many companies are isolated solutions, which means that they only focus on one aspect of apron safety and operations. While these products may improve a specific aspect of apron safety, they are not holistic enough. The information received by apron safety managers is still limited. To solve this problem, this project designed an integrated intelligent system that can collect and analyze data from different sources. This system aims to provide apron safety operators a better idea of what is happening on the apron.

5. Problem Solving Approach

5.1 System Principle

The limitations of current apron safety management approaches along with the development of the NextGen system and other advanced techniques have presented a unique opportunity to develop an integrate system which would allow airport officials and other stakeholders to manage apron operations more safely and efficiently. The proposed Apron Intelligent Monitoring and Reporting System (AIMRS), which collects and analyzes data from ADS-B, I.D. Systems®, Axis® communication and other commercially available technologies made a step forward to provide airport officials and other stakeholders a clear report about the apron operational conditions related to ground workers and vehicles. The schematic diagram below shows AIMRS's work process and functions.

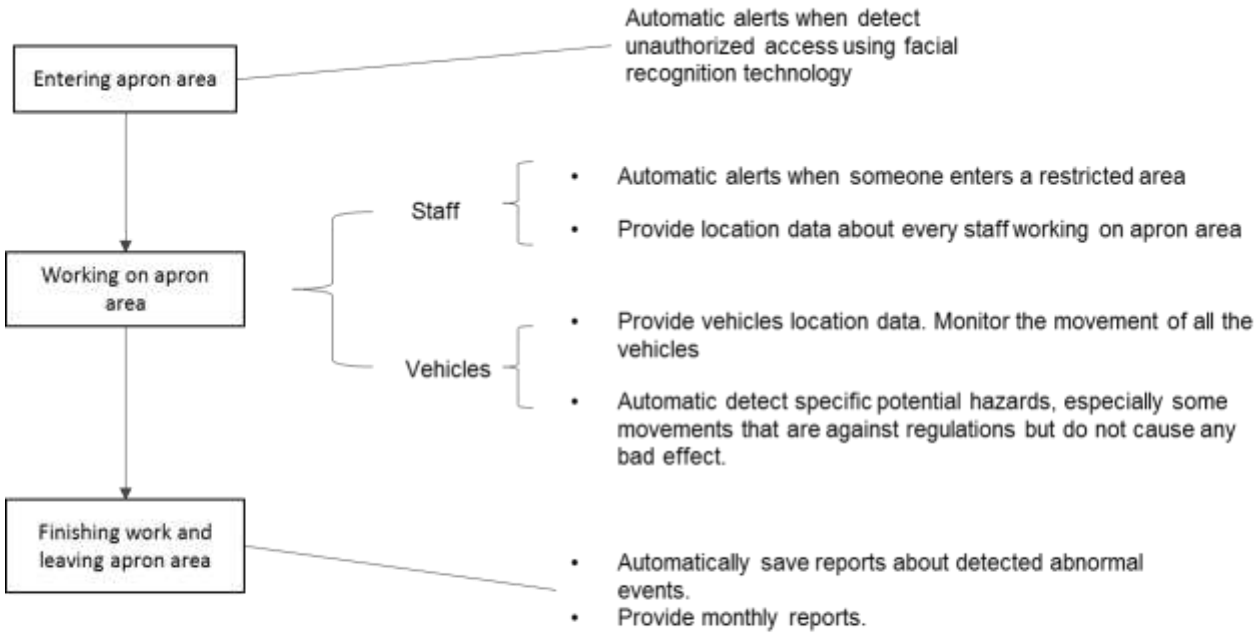

Figure 1. Schematic diagram of AIMRS's work process and functions

AIMRS can monitor the entire work process of staff and vehicles as long as they enter apron area by 1) detecting unauthorized access into apron area; 2) automatically detecting and monitoring staff's and vehicles' movement on apron area; and 3) automatically identifying and reporting potential hazards happened on apron area.

The design (shown in Figure 2.) of the AIMRS was based on three principles:

1) Integration of NextGen technologies with other advanced commercially available apron surveillance products to monitor apron operators and provide more information for further analysis;

2) Customization of the determine conditions of potential hazards based on airport's

parameters and apron operational regulations individually;

3) Full utilization of real-time data collected from NextGen technologies and other commercial products to automatically detect and report potential hazards.

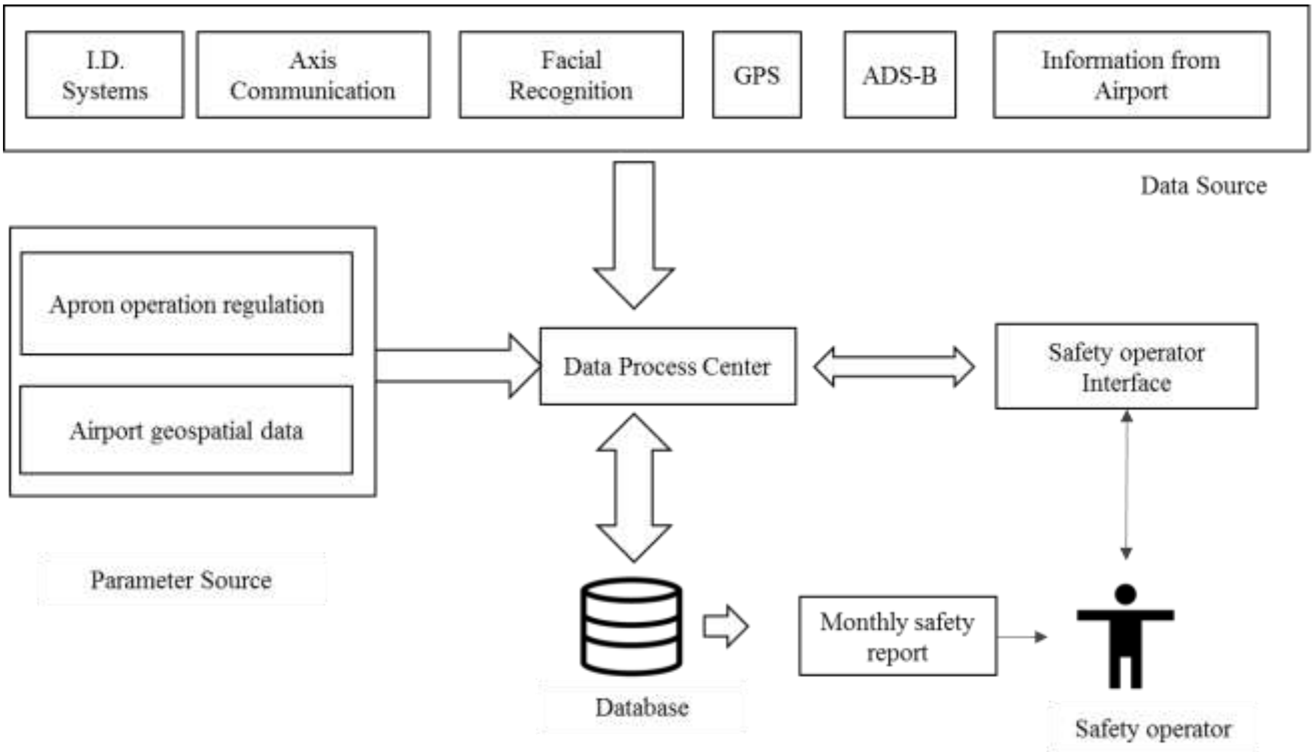

Figure 2. Diagram of AIMRS Layout

5.2 System Design

Principle 1. Integration of NextGen technologies with other advanced commercially available apron surveillance products to monitor apron operators and provide more information for further analysis.

Data is the lifeline for an intelligent system. One of the major innovation of AIMRS is that it merges NextGen technologies (ADS-B) with other advanced commercially available apron safety products (I.D. Systems®' s AvRamp® and Axis® Communication's network video solution) and technologies (facial recognition and GPS) in order to provide airport officials, airliner airport manager, and other stakeholders more information about apron operation situations.

NextGen's ADS-B technology can provide the information of aircraft's position and ground speed, which is of great importance to GSE's and surrounding awareness.

I.D. Systems®'s AvRamp® is an integrated system that utilizes a variety of technologies to improve the safety of ground support equipment (GSE). I.D. Systems® claims that AvRamp® can prevent unauthorized personnel using the equipment, keep GSE away from secure runways and unauthorized areas, and manage vehicles' speed. It can also provide the real-time position of each GSE by collecting each GSE's GPS information. So, I.D. Systems®'s AvRamp® could provide information about the while work process of ground support equipment. (I.D. Systems®, 2018)

For ground workers, one of the main problems is unauthorized access to apron areas. Traditional physical access control solution (PACS) simply use key cards or personal identification numbers (PINs) to keep unauthorized people out of apron areas. One obvious disadvantage of PACS is that instead of ensuring a person who enters the area is authorized, PACS can only make sure that the key card or PINs the person used is authorized. The emerging facial recognition door lock, however, identifies each person's facial features which are unique and hard to copy. So using facial recognition door lock to replace traditional PACS between terminal building and apron area can eliminate the risk of unauthorized access.

Axis® Communication's network video solution can monitor apron area and automatically alert safety operator when someone enters a restricted area. It can also provide high-quality HDTV video images for incident investigations. The limitation of Axis® Communication's network video solution is that it can not identify who person entering the restricted area is. To cover this limitation, each ground worker is required to equip a solar-powered GPS tracker with a unique identification number. Then, when Axis® Communication's network video solution detects that someone enters a forbidden area, AIMRS can use the GPS and identification number to find out the identity of this person (Axis® Communication, 2018).

The team shows that the combination of facial recognition door lock, GPS tracking technology, and Axis® Communication's network video solution is a way to monitor the whole work process of ground staff on the apron.

Principle 2. Customization of the determine conditions of potential hazards based on airport's parameters and apron operational regulations individually.

As mentioned in the previous literature review, there are no federal or industrywide standards for ramp operations (U.S. Government Accountability Office, 2007, p.49). Most rules and regulations that apply to apron operations are up to the discretion of the airport operator. So it is of great importance that AIMRS allows apron operators to customize the parameters based on each airport's geospatial information and their own operation regulations. For example, apron area can be categorized as apron taxiway, aircraft stand taxi lane, and service roads (Studic, 2016). Airport operators can set prohibited areas' GPS information based on their airports' situation. Also, apron operators can set each GSE's own working and parking areas, which means that it is in these areas that the GSE can stop for long time.

Each airport can define potential hazards and their severity levels. The severity can be divided into five levels: insignificant, negligible, moderate, serious, and major. The description of each severity level is listed in Table 2. All of the abnormal events detected by AIMRS can be categorized into these five groups based on their severity levels defined by apron operators.

Table 2.

Severity Level for Risk Analysis

Severity	Description	Level
Insignificant	No injuries / Low financial loss	1
Negligible	Non-reportable injury / minor financial loss	2
Moderate	Reportable injury / Moderate damage to property	3
Serious	Single death or multiple injuries / high financial loss	4
Major	Multiple deaths / significant financial loss	5

Principle 3. Utilization of real-time data to automatically detect and report potential hazards.

Another innovation of AIMRS is that it can analyze the data collected from these different sources and compare the data with customized determine conditions to identify potential hazards and irregularities. All of the detected potential hazards and irregularities would be reported to safety operator immediately. AIMRS would save the data related to these detected hazards and irregularities automatically, and generate a report regularly. As mentioned in Principle 1, AIMRS can obtain data about many aspects of apron operations using the integrated system. Principle 2 introduces that AIMRS allows apron safety operators to set the determine conditions of potential hazards and irregularities based on airports' geospatial data and regulations. AIMRS would compare the collected data with these determine conditions automatically, and identify a situation as “hazard” or “irregularity” based on the program results.

For example, when AIMRS detects that the speed of one GSE suddenly decreases to zero (using data from AvRamp®), it will check if this GSE is at the default working areas or parking areas. If this GSE is in such areas, AIMRS will identify this parking as normal and continue surveillance. However, if this GSE stops outside the working or parking areas, and AIMRS detects that there are no coming aircraft (using ADS-B information), vehicles (using data from AvRamp®), or ground workers (using data from GPS trackers), AIMRS would decide that this GSE violates the parking regulations. Then the system will notify apron operators based on the default severity level of such situation, and save a report into the database for further training. The flowchart of this process is shown below (figure 3).

The information about detected abnormal situations would be saved into the system's database for further investigation and analysis automatically. Using these data, the system could generate safety reports regularly. These reports would help apron safety operators to have a holistic idea about the safety level on the aprons. From these reports, operators can identify the main safety risks that need to be solved on the aprons, and take appropriate countermeasures (such as changing regulations, adding some corresponding training, and so on) to reduce such risks.

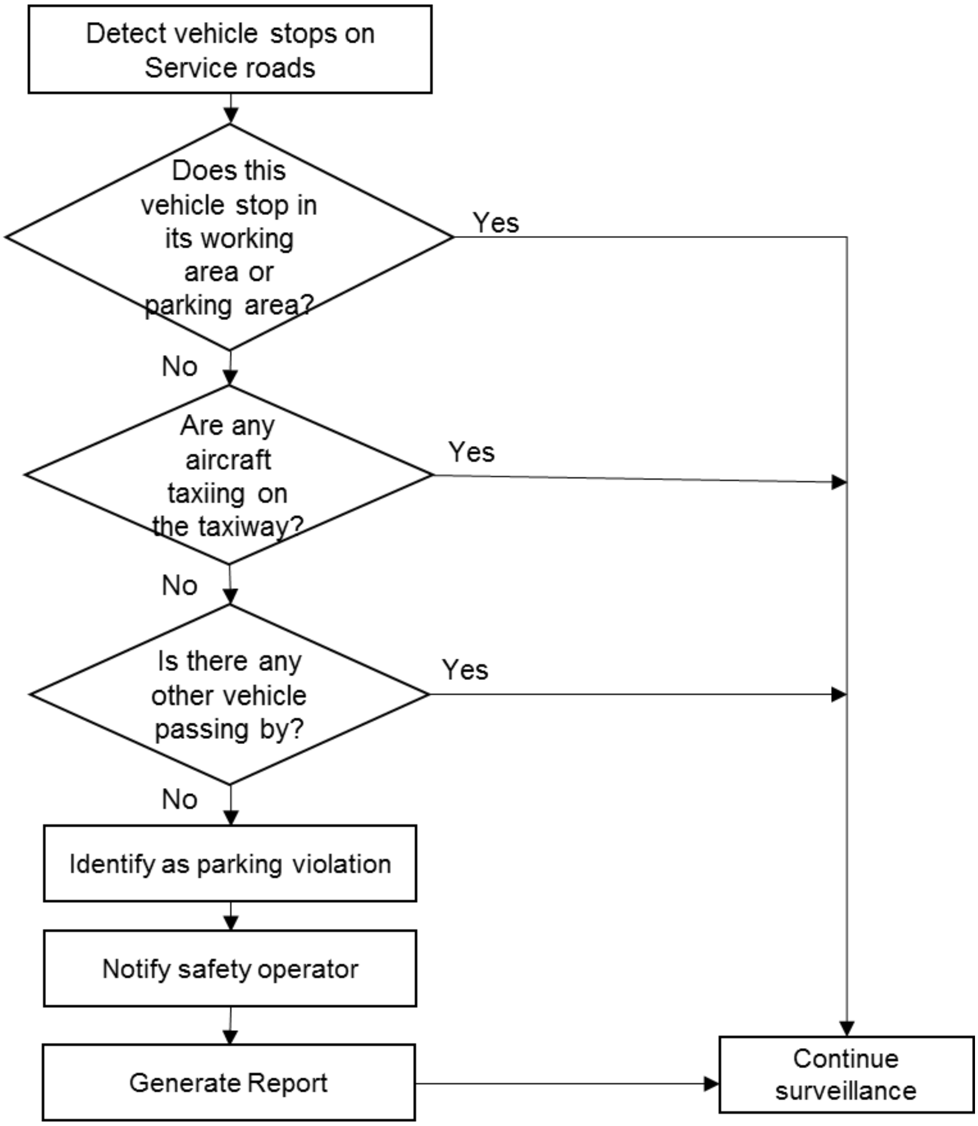

Figure 3. Flowchart of identifying a parking violation

6. Safety Risk Assessment

According to Standard Process for System Safety (MIL-STD-882E), risk is a function of probability and level of severity (Department of Defense, 2012, p.7). *AC 150/5200-37* (FAA, 2007) suggests to use a safety matrix to assess risk in aviation area. The probability and level of severity of each potential hazard would be evaluated separately, the product of which would be the final risk score. Meanwhile, the probability and severity can be divided into five levels and four levels respectively. The safety matrix classifies all the potential hazards into four groups based on the final scores: low risk, moderate risk, high risk, and unacceptable risk. The risk assessment matrix used in this report is shown in Table 3.

Table 3.

Risk Assessment Matrix

Low Risk: 0-5 Moderate Risk: 6-10 High Risk: 11-15 Unacceptable Risk: 16-20	**Severity**	**Insignificant** No injuries / Low financial loss	**Negligible** Non-reportable injury / minor financial loss	**Moderate** Reportable injury / Moderate damage to property	**Serious** Single death or multiple injuries / high financial loss	**Major** Multiple deaths / significant financial loss
Likelihood	**Level**	**1**	**2**	**3**	**4**	**5**
Rare May occur only in exceptional circumstances	**1**	**1**	**2**	**3**	**4**	**5**
Unlikely Could occur at some times	**2**	**2**	**4**	**6**	**8**	**10**
Moderate The event will probably occur at some times	**3**	**3**	**6**	**9**	**12**	**15**
Probable Is expected to occur in most circumstances	**4**	**4**	**8**	**12**	**16**	**20**

Based on the assumption that Risk = Likelihood×Severity, the Table 4 illustrates the potential risk assessment via potential situation, likelihood, severity, risk, and possible solutions. While AIMRS is designated to improve the safety of apron operations, latent hazards still exist at airports. In Table 4, the majority of the situation including GPS tracking system problem, sensor damage, and algorithm malfunction result in low risk. Additionally, the worst risk scenario is human errors which possibly damage to sensors' systems resulting from poor maintenance or incorrect operations. Most risks can be mitigated or eliminated by improving system design and troubleshooting system. Most of the hazards are low risks in the proposed system as shown in Table 4.

Table 4.

List of Potential Risk Assessment

Situation		Likelihood	Severity	Risk	Possible Solutions
1	GPS tracking system cannot work	1	1	1	Software engineers troubleshoot the system
2	Data link break down	1	1	1	Software engineers troubleshoot the system
3	Fail to prevent unauthorized access to ground vehicles	1	3	3	Technicians regular maintenance
4	Sensor damage due to terrible weather	1	3	3	Install a new sensor & water/ hail resistant design
5	Sensors fall down	2	2	4	Improve resistant design
6	Algorithm malfunction	2	2	4	Software engineers troubleshoot the system
7	Data saving failure	2	3	6	Weekly maintenance
8	Facial recognition malfunction	2	5	10	Backup system (swipe ID)
9	Power outage	2	5	10	Backup power
10	Human errors including poor maintenance or incorrect operation	3	4	12	Regular training & maintenance

Note. Scores for likelihood, severity, and risk level are evaluated according to Table.

7. Cost-Benefit Assessment

The cost and benefit analysis of the proposed system is vital to the actual practicality and implementation of the system. The cost and benefit estimation is based on a fictional application of AIMRS at the Central Illinois Regional Airport (BMI) in Bloomington-Normal (IATA airport code: BMI) in Illinois.

7.1 Cost Assessment

The cost analysis of the system includes framework design and test cost, initial field cost test cost, installation/implementation cost and operational/maintenance cost. For each phase, the cost analysis also includes labor (researcher and workers), material (equipment, device and parts), and expense (service supported by third party) cost, as shown in Tables 5-9.

Research and Development Cost at Purdue University (Alpha)

Table 5 presents the costs associated with the initial alpha research and development stage of the project. The costs include labor costs for system development at Purdue University.

Table 5.

Cost Analysis of the System for Central Illinois Regional Airport (Alpha)

Item	Rate	Quantity	Subtotal	Remarks
A. Research & Development (Alpha) (4 months) (One-time cost)				
Labor-University Design Competition				
Student	$25/hr	160 hrs	$4,000	4 students-40 hrs ea.
Faculty Advisor	$100/hr	40 hrs	$4,000	1 Faculty Advisor-40 hrs
Subtotal			$8,000	

Note.
This table was inspired by Guidance for Preparing Benefit/Cost Analysis(Byers,2016)

Research and Development Costs (Beta)

Table 6 shows costs associated with the beta development stage. In beta stage, system is developed and tested by professional engineers and technicians.

Table 6.

Cost Analysis of the System for Central Illinois Regional Airport (Beta)

Item	Rate	Quantity	Subtotal	Remarks
B. Research & Development (Beta) (6 months) (one-time cost, not for all airports)				
Labor- Academic Research & Development				
IT Technician	$100/hr	960 hrs	$96,000	2 workers-480 hrs ea.
Electrician/Engineer	$80/hr	960 hrs	$76,800	2 workers-480 hrs ea.
Expenses				
Material (Test Sample of Camera, Radar Sensor, Workstation, Ground Vehicle Controller and Biometric Access Control Device)			$17,280	The estimate cost of device for developing and testing
Subtotal			$190,080	

Note.
This table was inspired by Guidance for Preparing Benefit/Cost Analysis(Byers,2016)

System Installation & Implementation Costs (Initial Investment)

Table 7.

Cost Analysis of the System for Central Illinois Regional Airport (System Installation & Implementation)

Item	Rate	Quantity	Subtotal	Remarks
C. System Installation & Implementation (1 month) (Initial Investment for BMI as example)				
Labor- Manufacturing & Installation				
Company Representatives	$50/ hr	80 hrs	$4,000	Supervising the installation of system
Electrician	$45/hr	160 hrs	$12,800	Technical experts on electrical components installation
IT Technician	$50/hr	24 hrs	$1200	Technical experts on installation of software
Airport Staff	$50/hr	80 hrs	$4,000	Supervising the system
Expenses				
Thermal Network Camera	$2400 ea.	11	$26,400	384×288 thermal detection, up to a 200-meter range
HD Network Camera	$950 ea.	11	$10,450	4K video quality in full frame rate
Work Station	$9,600 ea.	1	$9,600	Storage: 24TB HDD 7200rpm
Surveillance Radar Detector	$1,100 ea.	15	$16,500	Enable auto-tracking for PTZ cameras, up to a 50-meter range.
Ground Vehicle Controller	$1,400 ea.	32	$44,800	Real time positioning and speed-monitoring, access control, anti-theft and keyless ignition for ground service vehicle.
ADSB Receiver	$1000 ea.	1	$1,000	
GPS Nano Transponder	$30 ea.	80	$2,400	Positioning for authorized pedestrians in apron
Biometric Access Control System	$500.00 ea.	30	$15,000	Facial recognition, fingerprint, RFID or password for terminal-apron gate access control.
Subtotal			$162,950	

Note.
This table was inspired by Guidance for Preparing Benefit/Cost Analysis(Byers,2016)

Table 7 represents the costs associated with the system installation and implementation stage. The data in Table 7 will specifically lists the costs associated with the final product that may be implemented at BMI. The costs listed in Table 7 for the final product were estimated based on the final system's principles listed in Section 5.1.

System Operation & Maintenance Costs (Annual Costs)

Table 8.

Cost Analysis of the System for Central Illinois Regional Airport (System Operation & Maintenance)

Item	Rate	Quantity	Subtotal	Remarks
D. System Operation & Maintenance (Annual Costs)				
Labor- Operators' Personnel + Technical Support Representative				
Company Representatives	$80/ hr	48 hrs	$3,840	Twice a month maintenance visits, two-hour sessions
Technical Support	$500/day	10 days	$5,000	Dependent on occurrence of issues (10 days as estimated)
Airport Staff	$50/hr	240 hrs	$12,000	Supervising the system
Expenses				
Operators in airport				
Support service by third parties	$100/month	12 months	$1,200	
Subtotal			$22,040	Varies with cost of support needed

Note.
This table was inspired by Guidance for Preparing Benefit/Cost Analysis(Byers,2016)

Table 8 represents the costs associated with system operation and maintenance. The costs in this table are mainly associated with the labor/travel costs for the technical support and operators of this system that will conduct routine maintenance or troubleshooting, and service fee from third parties. For example, currently the GPS service on ground service vehicle are offered by a third party, then this system user can receive data by making a payment to the third party each month.

Due to the maturity of surveillance technology, the prototype design and test and the initial field test will cost $198,080. Applying existing technologies and integrate them together into airport operation are the major challenges. System installation will cost $162,950. Over a period of 10 years, the total cost is estimated to be $581,430.

7.2 Benefit Assessment

Qualitative Benefits Analysis

AIMRS can provide real-time and intelligent monitoring in the apron area, alerting the safety manager when a potential hazard is detected. It also works by integrating and analyzing the data from aircraft, ground service vehicles, and pedestrians. This data is recorded so that it can be used to analyze the root causes of accidents/incidents and improve airport shareholders' safety culture. Additional safety training can then be carried out to prevent future accidents/incidents.

Quantitative Benefits Analysis

ICAO classifies injuries as either minor, severe, or fatal, and have an average dollar amount for each one. Minor injuries are estimated to be worth $28,800; Severe as $2,428,800; and fatal as the full human life price of $9.6 million (FAA, 2016b). A study done in 2006 and 2007 by ACI tallied the number of accidents and incidents on the apron and the injuries that resulted. The rate of each injury classification by 1000 aircraft movements is then calculated. Multiplying these rates by the estimated price of each injury gives us the amount of money spent on apron-accident injuries per 1000 aircraft movements (Table 9).

Adding these gives us a total injury cost of about $13,500 per 1000 movements. Flight Safety Foundation estimates $5 billion lost per year from 'apron damage.' A third of that is from actual apron and equipment damage (Vandel, 2004). $1.7 billion a year divided by the average 31.3 million aircraft movements per year over the last ten years (Statista, 2018) adds $53,000 per 1000 movements. This gives us a grand total of $66,500 per 1000 movements lost in preventable apron accidents.

Table 9.

Probability and Estimated Cost spent on apron-accident injuries per 1000 aircraft movement

Severity	Probability (per 1000 movements)	Estimated cost (per 1000 movements)
Fatal	0.0000809	$777
Severe	0.0048542	$11,790
Minor	0.03333	$960

Note. The probability of apron-accident injures is estimated according to ACI-NA Accident Report. The cost of apron-accident injures is estimated according to ICAO Injury Classifications (ACRP, 2011; FAA, 2016b).

We chose to do an example cost-benefit-analysis on Central Illinois Regional Airport (BMI). The BMI is a small airport with eight gates and daily scheduled service. According to the Form 5010, BMI has about 8,800 non-GA aircraft movements a year (GCR Inc, 2018). Multiplying this by our $66,500 per 1,000 movements, BMI may lose $585,200 every year because of apron accidents and incidents. Assuming that AIMRS could reduce the numbers of accidents and incidents by 20%, AIMRS would help BMI to save $117, 040 every year.

Based on the analysis above, the whole cost of AIMRS over 10 years' period is $581,430, while the estimated benefit is $1,170,400. The benefit outweighs cost with the benefit-to-cost ratio is 2.01, which means that AIMRS is beneficial to BMI. See table 10 for detailed information.

Table 10.

Benefit vs. Cost Analysis at Central Illinois Regional Airport (BMI)

Item	Subtotal	Qty	Total	Remark
Cost				
Development & Test & Installation	$361,030	1	$361,030	Table 5 &6 & 7
Operation & Maintenance	$22,040 / year	10 years	$220,400	Table 8
Total Cost (first 10 years)			$581,430	
Benefit				
Apron-accident injures	$117,040 /year	10	$1,170,400	
Total Benefit (first 10 years)			$1,170,400	
Benefit to Cost Ratio			2.01	Benefit outweighs cost

Note.
This benefit vs. Cost analysis is estimated according to the system development, test, implementation, operation and maintenance at BMI for the first 10 years.

8. Industry Interaction

We talked with three professors in aviation safety area and airport operation area, three industry experts, and two airport managers:

1) AAAE Certified Member, FRAeS, Purdue University Limited Term Lecturer: Dr. Stewart Wayne Schreckengast,

2) Purdue University Director of the International Center for Biometric Research, Professor: Dr. Stephen Elliott

3) Purdue University Associate Professor: Dr. Chien-Tsung Lu,

4) Kent State University Associate Dean: Dr. Richmond Nettey,

5) Aviation Fury, LLC President: Mr. Alex Gertsen.

6) Purdue airport safety manager: Ms. Stephanie Brown

7) Central Illinois Regional Airport Deputy Director of Operations and Facilities: Mr. Javier Centeno

8) I.D. Systems® Northeast Region Sales Manager: Richard Thompson

This section reflects the team's understanding of the discussions with the experts; mistakes are possible and are the teams.

In discussions with Dr. Lu, one big issue on airport apron was the unauthorized access to apron area: different kinds of working staff would have different levels of authorization, but it may be hard to distinguish these differences. Workers from different airlines or stakeholders could walk to other areas without permission. Finding a way to record relevant data and process it was another issue. Airports were looking for potential approaches to encourage workers to report potential hazards happened on the apron.

When talking with Dr. Schreckengast, he introduced us to new technologies used on the apron area, along with future plans some airports were considering. We also discussed some details about our design with Dr. Schreckengast, such as the power sources of some ground vehicles, the feasibility of high solution camera using on the apron, the shortage of identifying workers using ID card. We learned that some airports were trying to apply automatic driving technology to ground vehicles, which would turn vehicle drivers into "observers". Some airports now have already used cameras to monitor staff who works on the apron areas, but there should be someone sitting before the screens to watch and identify potential abnormal behaviors.

From our discussion with Pr. Elliott, we learned the strengths and limitations of facial recognition technology. Facial recognition technology is safer and more convenient than traditional identification technologies. But it may not work well when the people wears a hat or glasses. Also, the existing technology is able to detect that someone enters a specific area, but it would be hard to identify who the person is.

In discussion with Dr. Richmond Nettey and Mr. Alex Gertsen, they each acknowledged movement safety as one of the biggest safety issues on the ramp. Vehicles and people are frequently entering the movement area without the proper clearance, and this has the potential to create big problems. Some examples include someone on foot chasing something like a plastic bag into the area, unsecured runaway luggage carts, and even just vehicle drivers who don't seem to realize that they must stop before the movement-area line. We learned from Mr. Gertsen indicated that there are lots of instances where a driver drives up to and holds short of the movement area, parks, and gets out to walk into the movement area, not remembering that they still need clearance.

Ignorance of procedure is one issue, but another prominent one is fatigue and the effect it can have on even the strictest rule-follower. When people get tired they may become less observant and more complacent, and an incident is much more likely to occur. Drivers of vehicles especially provide a hazard and need something to improve their situational awareness. Tracking and providing this information to them is thus very feasible provided we keep the cost low.

With Stephanie Brown we discussed the difference between airport-owned vehicles and areas vs airlines-owned. Leased gates will be owned and operated completely by one airline, and most likely have that airline's own ground vehicles. This could restrict our solution to only airport-owned vehicles and those in use at shared gates. At these leased gates, areas where we can place cameras are also limited to these owned by the airport. We learned that the airport manager knows little about what is happening with their ground vehicles unless something is voluntarily reported, which may not happen very often. Close call after close call could happen, but without damage to prove it, the manager remains unaware and the dangerous behavior may continue.

As we selected Central Illinois Regional Airport (BMI) as an example scenario, we called its director of operations and facilities Mr. Javier Centeno about the ground operations. He provided us information about numbers and types of airport-operated ground vehicles including general use vehicles, snow removal vehicles, aircraft rescue and firefighting (ARFF), mowers, tractors, and specialty equipment. We used these statistics in our case study and to estimate costs in our cost-benefit analysis.

To get detail information about I.D. Systems®'s product, we called I.D. Systems® and talked to the Northeast region sales manager, Mr. Richard Thompson. He recommended that we use a combination of their 601 and 602 products for monitoring our vehicles, and gave us individual price breakdowns for each piece of equipment. The system is fairly customizable, with optional speed sensors, impact sensors, and alarms that can be equipped in any combination on each vehicle. This gives the airport plenty of control over their system's features and costs.

9. Projected Impacts of Design

9.1 How This Project Meets ACRP Goals

Apron can be regarded as the link between terminal area and maneuvering area. There are a lot of innovations on terminal area and maneuvering area, aiming to attract more passengers, increase aircraft efficiency, and improve airside capacity. All of these mean that there will be more aircraft, passengers, and cargos on apron area. If apron's performance fails to be enhanced to meet such requirements, apron would impact the sustainability and resilience of the whole airport system. However as mentioned above, the functions of existing apron operation systems are limited. To solve this problem, the proposed system integrates many technologies to provide apron operators full access to data relevant to apron safety. The system can also analyze the data and provide some useful information to apron safety operators. Using such information, apron managers could adapt apron operations to solve safety problems or meet the new challenges.

9.2 Sustainability Assessment

FAA adopts "EONS" (economic vitality, operational efficiency, natural resources, and social responsibility) to describe airport sustainability (FAA, 2017). The proposed Apron Intelligent Monitoring and Reporting System (AIMRS) is designed to improve vehicles' and ground workers' safety by monitoring their movement and detecting irregularities and potential hazards. Besides improving safety, this system also has its operational, economic, environmental, and social impact on aprons and airports.

Operational Impact

AIMRS has many potential impacts on apron and airport operations. Using this system, apron operators would be able to know the locations and movements of every GSE and worker on the aprons. The apron operators then can optimize the operations with such information. For example, after noticing that a container loader is not in place while the aircraft has arrived in the stand, apron operators can check with the employee in charge of this container loader and solve this problem before this problem delay the whole turnaround of the aircraft too much. Also, accident, incident, and even near-miss happened on the aprons would affect apron area's operational efficiency dramatically, resulting in flight delay, an increment in ground workers' workload, and financial loss. Aprons that adopt AIMRS to improve safety are likely to reduce accident, incident, and near-miss rate, which would ensure the efficiency of apron operations.

Economic Impact

Accidents/incidents and daily operations in apron are recorded in a huge database; this information can be shared by stakeholders and related research institutes. Also, the airport safety manager can analyze and identify the causes of accidents/incidents, the violations of aircraft/ground service vehicles/pedestrians, and potential hazards on apron, thus accidents/incidents will be reduced in the future, human fatalities and property damage will be decreased and less insurance cost of airport or airlines as well. Furthermore, the system can offer the manager a real-time and comprehensive overview of apron operations, help managers to optimize their apron planning and management, more efficient of apron operations will be achieved. Thus total turnaround time of gates can be reduced. With more flights and less cost of maintenance, ultimately the economic benefits will be brought to aviation stakeholders.

Environmental Impact

As mentioned above, the proposed monitoring system that is integrated with existing technologies assists the airports to monitor the apron. Monitoring the movements of both pedestrians and vehicles significantly reduce the possibility of entering into unrestricted areas. This results in a frequency decrease of aircraft turning in runway, which brings the reduction of pollution and carbon emission as wells as propeller noise. Additionally, the decreasing number of turning aircraft has the potential to mitigate and eliminate both risks and potential hazards including accidents, incidents, and near-misses.

Social Impact

Successful implementation of our system at an airport will lead to a safer work environment for all those whose jobs operate on the apron. It provides necessary safety data unattainable through the current reliance on voluntary reporting, giving management a previously impossible level of awareness. Armed with the knowledge of the problem areas for their ground vehicles, airport managers can make the necessary changes to make improve operational safety. The rates of unreported incidents will go down, and analyzation of the data collected from these incidents can prevent more serious accidents from occurring. This then helps to stop unsafe behaviors and fix oversights before they have a chance to cause real issues. A new culture of ground vehicle safety will be introduced, creating a higher ‘acceptable’ level of incidents in the industry.

10. Conclusion

In this design project, the proposes the Apron Intelligent Monitoring and Reporting System (AIMRS). One innovation of AIMRS is that by integrating several commercially available products and technologies into one system, AIMRS can obtain much more data than any of the existing systems. Another innovation is that AIMRS could automatically analyze the data to identify potential accident/incident and violations. The criteria of potential hazards used by AIMRS can be customized by apron safety managers based on airport’s parameters and apron operational regulations individually. Such customization guarantees that AIMRS can be used in different airports. All the data of the detected abnormal events would be saved into a database automatically. AIMRS would generate a safety report according to this database regularly. Therefore, AIMRS can provide apron managers more information about what is happening on the aprons, build an accident/incident/violation database and generate safety reports which can be used as guidelines for further training.

Details of the principles of this system, the risk assessment, the cost-benefit assessment, and sustainability assessment are also presented in this report. The results demonstrate that AIMRS can not only improve apron safety, but also benefit airports in operational, economic, social, and environmental aspects, while not increasing in airport’s financial burden dramatically. In general, airport’s sustainability and resilience can be enhanced by the implementation of the proposed Apron Intelligent Monitoring and Reporting System (AIMRS).

Appendix B: Description of the University

About the University (from www.purdue.edu):

Purdue University, located in West Lafayette, Indiana, is a public research university. As a vast laboratory for discovery, Purdue has been well-known not only for science, technology, engineering, and math programs, but also for our imagination, ingenuity, and innovation. It's a place where those who seek an education come to make their ideas real - especially when those transformative discoveries lead to scientific, technological, social, or humanitarian impact.

Founded in 1869, the university proudly serves its state as well as the nation and the world. Academically, Purdue's role as a major research institution is supported by top-ranking disciplines in aviation, pharmacy, business, engineering, and agriculture. With embracing the diversity of cultures, Purdue community has more than 39,000 students from all 50 states and 130 countries. Add about 950 student organizations and Big Ten Boilermaker athletics, and people get a college atmosphere that's without rival.

School of Aviation and Transportation Technology Mission Statement (from website):

Economic forecasts suggest that a steady increase in traveling passenger and air cargo requirements will fuel a dramatic expansion of the aviation industry, and require a complete restructure of the existing air transportation system architecture. This industry growth is generating a wide range of leadership opportunities in the aviation industry for individuals who possess aviation and aerospace management skills such as operational analysis, safety systems development, project management, systems integration, environmental sustainability, and related interdisciplinary skills.

Purdue University's School of Aviation and Transportation Technology, one of six departments and schools in the Purdue Polytechnic Institute, is recognized worldwide as a leader in aviation education. All seven of Purdue's Aviation and Transportation Technology undergraduate majors are world-class educational programs. The aviation and aerospace industry is in the midst of a technological sea change. The School of Aviation and Transportation Technology emphasizes on improving students' skills such as operational analysis, safety systems development, and environmental sustainability. The programs in the School of Aviation and Transportation Technology are focused on making sense of the changes and helping plan for aviation's future. Our research centers provide many opportunities to make an impact through research and problem solving. Pursuing a degree in aviation at Purdue University will assist students in striving towards their occupational dream. The school is continually looking at ways for students to reach their academic goals faster.

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

Not Applicable.

Appendix E: Evaluation of the Educational Experience Provided by the Project Students (Answer were discussed by all team members)

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, this competition was a meaningful learning experience for our group. This project, requiring teamwork, time management, collaboration, and imagination, provides us an great opportunity to apply both knowledge and skills that we have learned from class into addressing real-world problem in the field of aviation. As a group, we split the work and cooperated well. Started from brainstorming, to explore research and regulation of apron safety, to interview airport managers and academic experts, then to integrate current technologies and products, the whole process let us know apron operation and safety better. Through this process, we developed our academic skills including writing literature review, conducting cost benefit assessment and risk assessment, and using comprehensive methods to solve a practical problem. Not only we have a clear understanding of synthesizing fragments into whole, but also the difficulties that we encountered become the one of our greatest treasure.

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

During this competition, we encountered several changelings. One of big challenges our team encountered happened during our literature review. There are few available research and reports related to apron safety. Among the research and reports we found, most of them were written before 2008. We were concerned that these reports could not represent the current situation on apron area. As students without first-hand experience in the industry, it's hard to know some of the issues that need fixing, or to come up with a reasonable solution that somebody with much more experience has not already thought of. Therefore, our team contacted as many industry and academic experts as we could, asking their opinions about apron safety. Such interactions helped us a lot to have a better understanding of our topic.

Another challenge that we faced was developing this safety system which can be customized and applied to different airports which have complex shareholder relationships. We needed to find out all information including the price of each product and system. However, those information was not displayed in the Internet. We tried to email them to ask the price of one of monitoring product, SAAB VL-4G, but no one replied us. We also tried to call SAAB company but the customer servicer told us they needed the certain product's part number which could not be found on website. We overcome it by integrating not only the alternative surveillance devices but also portable location equipment, which could make the system to have a flexible capacity to monitor the apron.

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

Our project aims to apply existing technologies of monitoring systems to improve safety of airport apron. The first step to achieve this project was to gain knowledge of apron from reliable resources. Therefore, in our literature review part, we reviewed the definition of apron, occurrences happened in aprons, and existing problem at aprons. Then we interviewed several industrial and academic experts to identify safety issues in apron area. At the same time, we began to integrate a monitoring technology by using current system and products. We once proposed to utilize the biometric technologies such as facial recognition, iris recognition and footprint recognition to monitor the apron surface. Due to the extremely weather condition in United States, however, these technologies still have limitations to be applied to outdoor surveillance system currently. We tried to shift our target by utilizing other technologies such as GPS Nano chips vest or I.D. Systems®. Throughout discussing with industry experts and professors in Purdue University and Kent State University and analyzing the technologies, we thought it would be a good idea to combine several available products including ADS-B, I.D. Systems®, and Axis® Communication together. Thus, the proposed Apron Intelligent Monitoring and Reporting System (AIMRS) came out. At last, cost-benefit assessment, risk assessment, and sustainability assessment were conducted to verify the practicality and feasibility of the proposed design.

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

The participation by industry in the project was appropriate, meaningful, and useful as it taught us not only about the industry but also about working on a research team. As a team, we have conducted both phone and face to face interviews with industry experts and professors. Overall, those interactions gave us a better understanding of apron safety and let us are able to make our proposed system “down to earth”. We learned what the current situation for apron monitoring is and received feedbacks and cost estimates of our proposed system.

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?

This project helps us to develop our project management skills, team cooperation skills, research skills, writing skills, and analytical skills that we need in our further study and career. The project is complex and each of team member spent lots of time on it. Even though the process is full of toughness, it is meaningful.

Faculty

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

The values of the educational experience are: learning more about working as a team over a 12-week period, preparing an in-depth response to a detailed list of requirements for a formal proposal, using creativity and technical knowledge to solve an open-ended problem facing real airports, and including risks and sustainability in their cost-benefit analysis.

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

The course is a one-semester graduate level course in aviation sustainability. These students learn sustainability concepts and apply this knowledge to an industry-based open-ended problem. The materials provided at the competition website were useful to the team, especially the videos on risk and cost/benefit analyses. The list of recommended experts was also useful.

3. What challenges did the students face and overcome?

This team selected several ideas before settling on one. The team was comprised of students from different backgrounds: flight, engineering, and management. One of the first things they needed to do was develop into a team. Through discussions of airport regulations and reports, the team learned to be better and better at sharing perspectives, dividing the work, and trusting one another. Another challenge to be overcome was the uncomfortable feeling when contacting industry experts that they did not know. While the competition website contains a list of experts, it is still difficult to make those first cold calls or cold emails to ask for help. The experts were amazingly friendly and encouraging to the team. I think now that they have made cold calls, this will serve them well in their careers.

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

I would use this competition in the future. The students are inspired by the real-world airport problems, contact with industry experts, and focus on a solution with risk analysis and cost/benefit analysis. Frankly, the fact that they know that this is for a national competition is also very engaging.

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

If possible, an improvement would be to only require the electronic submission.

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