A Framework for Analysis of Security Measures Within On-airport Cargo Facilities

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ABSTRACT

The terrorist attacks of September 11, 2001 displayed the shortcomings of aviation security in the United States. Most of the attention on aviation security since that time has focused on airline passengers, their luggage, and their carry-on items, leaving air cargo security on the back burner. The lack of security screening and screening guidelines of cargo traveling by both passenger and all-cargo aircraft is the driving purpose behind this research project: the development of a framework that may be used by individual airports or airlines to analyze various security setups for screening outbound air cargo within an on-airport cargo facility. This was accomplished through airport surveys, a case study at an air cargo facility, and computer simulations testing various setups of security technologies to screen cargo within a facility.

Data collected from surveys sent to major airports around the nation revealed the lack of security in the air cargo environment and validated the need for this research. Information was obtained on security measures utilized for cargo and personnel, as well as the frequency of cargo screenings and information on the size and setups of cargo facilities. A case study was performed at a cargo facility within a major U.S. airport in order to gather data pertinent to the simulations used to test the security setups. Information gathered on truck arrivals, the number of flight destinations, security measures in place, as well as the general facility setup was used to form the basis of the simulations. The simulations, conducted in Arena 7.01, tested the effectiveness and cargo throughput of four security cases. Each case employed a different combination of security measures proven suitable for an air cargo environment. The security setups were evaluated based on the security systems' costs, the overall effectiveness of catching high-risk cargo, and the average amount of time taken to process cargo through the facility.

The Arena simulations present airlines, freight forwarders, and airport authorities with the necessary tool to evaluate various cargo security screening measures that will provide the best security solution for their particular facility or facilities. However, further research is needed on the effectiveness of many security technologies. With this information, government and aviation officials will be able to use this framework as a step toward achieving a well-rounded plan for ensuring the safety and security of our nation's air cargo.

INTRODUCTION

The terrorist attacks of September 11, 2001 spurred the recent focus on transportation security and its apparent shortcomings, including the creation of the Department of Homeland Security and the Transportation Security Administration (TSA). The vast majority of the TSA's new federal security regulations and programs have targeted airline passengers and their luggage, but air cargo has been mostly overlooked from a security standpoint. Very few regulations pertaining to air cargo security have been passed by the federal government, and those that have are vague and non-specific. Major legislation that would outline specific and strict air cargo security regulations has been introduced into Congress, but so far nothing has been passed.

PROBLEM STATEMENT AND PURPOSE

According to the FBI, cargo terminals, cargo transfer facilities, and consolidation facilities are hotbeds for cargo theft. And while 50% to 60% of all U.S. air cargo travels as belly cargo, only about 4% is screened for explosives.[1] The precise effectiveness of most screening methods used (alone and in parallel), along with the effectiveness of screeners themselves, is not known. This, along with the lacking legislation pertaining to air cargo security, has left a large gap in a major sector of transportation security. An effective method for evaluation of various combinations of security measures is needed in order to develop a system that effectively screens as much cargo as the limited time element allows and at a reasonable cost to the industry.

The purpose of this study is to analyze outbound cargo flow through an on-airport cargo facility and develop a systematic framework for evaluating air cargo screening alternatives within an air cargo facility without jeopardizing the crucial time element involved in air cargo transport and with minimal cost. Explosives and explosive materials, drug smuggling, stolen goods, radioactive materials, and hazardous gases are the hazards that have been considered in the analysis. A computer simulation of an on-airport cargo facility can then be used to evaluate various combinations of security technologies used to counteract such risks.

SCOPE

In this paper, four major tasks are described that were undertaken to develop a best-case security analysis framework for on-airport cargo facilities. The first task was a literature review of aviation security regulations and screening methods for use in and around a cargo facility. For the second task, the results of surveys sent to major U.S. airports were analyzed in order to determine the current state of national air cargo security and cargo operations within cargo facilities. Third, various screening methods used for screening cargo itself were analyzed in order to determine what can feasibly be used in an air cargo environment. For the forth task, information obtained from a case study conducted at an on-airport air cargo facility at a major U.S. airport was analyzed in order to form the basis for computer simulation of outbound cargo flow through an on-airport facility. The simulation model was used to analyze varying combinations of security methods from the third task. Inbound cargo and U.S. mail were not included in the analysis. The results of this project can be used to gain insight into the implications of stricter air cargo screening regulations and provide a general outline that airlines, freight forwarders, airport authorities, and government entities can build upon in order to effectively analyze operations and security techniques.

LITERATURE REVIEW

Introduction

A review of existing and proposed federal security regulations along with efforts to screen air cargo was conducted in order to discover what is currently available and used in the air cargo industry, and also what could be implemented in order to improve the overall security of an air cargo facility.

Federal Regulations for Air Cargo

The only major piece of legislation pertaining to aviation security that has been signed into law is the Aviation and Transportation Security Act, which went into effect in November of 2001 and created the Transportation Security Administration (TSA). This act outlined numerous new regulations and guidelines for security of the transportation sector as a whole; however, only one sentence in the act pertains to air cargo: "Cargo deadline – A system must be in operation to screen, inspect, or otherwise ensure the security of all cargo that is to be transported as soon as practicable after the date of enactment of the Aviation and Transportation Security Act."[2] Since the passage of this act, various other rules have been enacted that relate to air cargo:

1. All cargo aboard passenger flights must be screened[3]
2. All airlines and freight forwarders must have TSA-approved security programs for cargo[4]
3. Physical inspection of air cargo is required, but the exact percentage of cargo to be inspected is classified[5]

Other regulations and guidelines geared toward air cargo security have been debated by the federal government, but nothing has been passed as of November 2004. These include the Air Cargo Security Act introduced into Congress by Senators Kay Bailey Hutchinson and Diane Feinstein[6] and the Air Cargo Strategic Plan, which is being developed by the TSA.[7]

Efforts to Screen Air Cargo

Efforts to screen air cargo include technologies and methods that directly screen the cargo, as well as those that ensure security of persons in and around the facility and the facility itself. The next three sections summarize these technologies and methods.

Direct Cargo Screening. Numerous non-intrusive technologies and methods exist that may be used to screen cargo units directly and specifically for various types of threats. Eight methods are analyzed in this project: pulsed fast neutron analysis, vapor detection, trace detection, canines, x-ray machines, gamma ray, thermal neutron activation, and radiation detection. None of these methods require cargo containers to be opened, but they all have difficulty detecting biological threats.

Pulsed Fast Neutron Analysis. A pulsed fast neutron analysis machine works by measuring cargo density to identify the chemical composition of the container's contents. This machine is classified as an active detection system, meaning that it stimulates the material so that detectors may analyze the effects of stimulation. The cost per machine ranges from $10 million to $25 million, and inspection time takes a minimum of one hour per cargo unit.

Vapor Detection. Vapor detection machines are equipped with a sensor that collects air samples from around the cargo unit. Spectrographic analysis is performed to determine the molecular makeup of the material within the unit. Vapor detection is a passive detection system, meaning it does not require the stimulation of materials to determine a threat presence. The cost per machine ranges from $30,000 to $50,000, and they can process a cargo unit in about 30 to 60 seconds.

Trace Detection. Trace detection machines use a swipe to wipe the cargo unit and pick up particulate matter. Spectrographic analysis is performed on the swipe to determine the molecular makeup of the material picked up on the unit. The cost per unit is $30,000 to $50,000, and they can process a cargo shipment in about 30 to 60 seconds. [8]

Canines. Drug- and explosives-detecting canines are widely considered by security experts to be the most effective way to screen cargo since they have the fewest drawbacks of any method currently available. Dogs have a very sensitive sense of smell, and they can be trained to passively alert handlers of the presence of explosive materials or drugs. Properly trained canines very rarely give false positive alerts. Yearly maintenance costs can range from $7,000 to $50,000 per canine unit (a canine unit consists of 2 to 4 teams with 1 handler and 1 to 2 dogs per team). However, the start-up costs for a canine unit can be quite high. The first year of maintenance and training can cost well over $100,000.[9]

X-ray Machines. X-ray machines scan cargo units by directing x-ray beams at the unit so that the beams interact with the material inside and form an image of the material on a screen. X-ray machines are classified as active detection systems, and they generally take 2 to 5 minutes to scan a cargo unit. A drawback of x-ray machines is that they cannot specifically identify a threat (i.e., differentiate between materials), except for certain systems used with a high-energy transmission. Costs range from $2 million to $10 million.

Gamma Ray Machines. Gamma ray systems are active detection systems that use a radioactive element to produce gamma rays, which are directed at the cargo unit. An image is displayed on a screen as the gamma rays interact with the material in the container. The downsides to gamma ray systems are that they cannot identify specific threats, and they have difficulty differentiating between materials when scanning high-density cargo. Costs range from $500,000 to about $3 million per machine, and they can scan a cargo unit in 2 to 5 minutes.

Thermal Neutron Activation. Thermal neutrons are directed at the cargo unit and absorbed by the material within. As a result, a gamma ray photon is emitted and its energy signature is detected by sensors, which can then determine specific element concentrations that might be a sign of an explosive. Thermal neutron activation systems are active detection systems. Costs range from $500,000 to $3 million per machine. The system takes a minimum of one hour to scan a cargo unit.

Radiation Detection. All radioactive substances emit radiation (i.e., x-rays, alpha rays, neutrons), which is detected and measured by a detector in the radiation detection system. High levels of specific types of radiation may indicate a threat object. These machines are classified as passive detection systems. Machines typically cost between $10,000 and $50,000 and can scan a cargo unit in 30 to 60 seconds.

Table 1 compares the costs, inspection times, installation requirements, and identification abilities of the screening methods reviewed in the literature.

	COST	SCREEN FOR	TIME TO INSPECT	MAT'L DISCR.	MAT'L ID	INSTALLATION
ACTIVE SYSTEMS						
X-ray	$1 - 10 million	Explosives, stolen mat'ls, drugs	2 - 5 min	No	No	Mobile or fixed. Fixed sites need power, road access, personnel facilities, and attention to radiation safety. Vehicles needed for mobility.
Standard	$1 - 5 million		2 - 5 min	No	No	
Dual View	$10 million		2 - 5 min	No	No	
Backscatter	$2 - 5 million		2 - 5 min	No	No	
Gamma Ray	$500,000 - $3 million		2 - 5 min	No	No	
Pulsed Fast Neutron Analysis	$10 - 25 million	Explosives, drugs	1 hr +	Yes	Yes	
Thermal Neutron Activation	$500,000 - $3 million	Explosives	1 hr +	Yes	Yes	
PASSIVE SYSTEMS						
Vapor Detection	$30,000 - $50,000	Prohibited gases	30 - 60 sec	Yes	Yes	Portable or desktop equip. operated by battery or wallplug.
Trace Detection	$30,000 - $50,000	Explosives, drugs	30 - 60 sec	Yes	Yes	
Radiation Detection	$10,000 - $50,000	Radiation	30 - 60 sec	No	Yes, for radioactive material	
Canines	$7,000 - $120,000 per unit per year	Explosives, drugs	10 - 60 sec	Limited by amt. of training	Yes	Require care, feeding, shelter.

Table 1 Breakdown of Screening Method Characteristics[10]

Screening Methods for Personnel, Visitors, and Truck Drivers. Some of the most popular methods for screening individuals at airports involve manual and paper-based processes. At most airports around the country, airport employees carry official airport IDs or badges as identification. Some airports issue IDs to frequently-visiting truck drivers, as well. Truck drivers delivering or picking up cargo who are issued airport IDs usually have to check with security personnel upon arriving at the airport, and their arrival is documented by established FAA procedures, which are paper-based.

Visitors who have official business at airports and need access to secured areas do not have many options for gaining such access. One of the most popular screening methods for airport visitors is to simply assign them an authorized escort who has proper clearance.

Biometrics is a newly emerging security technology that many industry and government officials see as the future of access security for airport personnel, truck drivers, and even airline passengers. Biometrics uses biological identification by matching signatures in fingerprints, thumbprints, hands, voices, faces, or irises. A person's signature may be stored either in a central database or on a "smart card," a plastic driver's license-sized card with an embedded computer chip that stores the individual's biological signature. A biometric reader scans the part of the body that it is programmed to read and matches the person's signature to the signature stored in the smart card or a central database.[11]

Perimeter Security and Surveillance. Three of the most popular methods for perimeter security and surveillance are canine patrols, guard patrols, and closed circuit television (CCTV). Canines require a large initial investment for equipment, care and training. However, after the first year, maintenance costs are quite low, and a properly trained canine is considered to be one of the most effective screening and patrol methods available today. Guard patrols can be used virtually anywhere to deter unlawful or suspicious activity. Guard and canine patrols can and often are used together.

CCTV has the capability to monitor and store video of any area in which a video camera is installed. Within an air cargo facility, properly placed cameras can record container loading, unloading, and handling so that any improper activity can be seen by personnel monitoring the videos. CCTV is limited in the fact that it does not provide any actual protection from cargo tampering.[12]

Summary

Regulations currently in place that pertain to air cargo fail to fully address the issue of security. Legislation that addresses specific concerns, threats, and security goals is needed. Ensuring air cargo security must involve more than just direct cargo screening – methods to validate personnel and truck drivers, and ensure perimeter security will help ensure a more comprehensive security program. Strategies to determine the most efficient and effective way to directly screen cargo as an integral part of a comprehensive security approach will be discussed subsequently.

AIRPORT SURVEYS

Introduction

In August of 2003, a survey containing questions about air cargo facilities, operations, and security measures (titled "Air Cargo Operations and Security Survey") was sent out to 118 airports around the U.S. The survey's purpose was to gather information on facility layouts, the cargo operations, and security measures used in order to gain an understanding of the layout of a typical on-airport cargo facility and the process of operations within it. Only 19 of the 118 surveys were returned. Since aviation security has been a sensitive subject since September 11, 2001, this may have discouraged many airports from returning the survey. Also, as noted earlier, not much has been done to enhance air cargo security since that time. However, the results did provide supplemental information to meet the project objectives for developing a framework for analysis of security measures.

Operations, Facilities, and Cargo Volumes

The first section of the survey asked questions pertaining to airports' cargo operations, the size of their facilities, and the types and volumes of cargo carried. The first five questions asked for information on the number of companies sorting cargo and leasing space at the airport, the size of the cargo facilities themselves, and the number of aircraft parking positions at each facility. The next five questions dealt with the method of cargo sorting, the number of facility employees, the percentage of cargo handled as belly freight, the percentage of cargo as international freight, and the method of transport between the facility and the plane. The final two questions in this section asked for a listing of common cargo types handled and quarterly cargo volumes. The intent of this section was to gain an understanding of the scale of the operations within air cargo facilities, along with information on the nature of the cargo itself.

Security

The second section of the survey was targeted toward security measures in place at airports that would have bearing on air cargo. The first four questions asked for the amount of cargo screened and the methods available to do so, how employees working in secure cargo areas are screened, and if visitors are allowed in the cargo facilities. The next four questions asked for the percentage of cargo coming from known shippers, information on screening trucks and truck drivers, and whether or not international cargo is handled at the airport. The final four questions asked about the clearance times and screening methods of international cargo, surveillance of dumpsters, and plans to expand on current security technologies. The intent of this section was to gather specific information on how employees, trucks, truck drivers, and cargo itself is screened for security purposed and to what extent.

Results

Despite a low return rate, the airport surveys gave an insightful look into the security practices at the nation’s airports. Over half of the responding airports rely on x-ray machines to screen their cargo, while close to half reported using canines, as well. Only 9% of the respondents reported using physical inspection to screen cargo (the survey was conducted before the TSA required carriers to physically inspect a certain percentage of their cargo). It is a standard practice among most of the responding airports to verify the identification of both facility visitors and truck drivers delivering cargo. Inspection of the trucks themselves was quite varied, ranging from “never” to “always.” The most alarming statistic gathered from the surveys is that three quarters of the respondents screen less than 10% of their air cargo, thus validating the need for this project.

EVALUATIONS OF SCREENING METHODS

The direct cargo screening technologies previously discussed were evaluated based on the technologies’ cost, screening time, and applicability in an air cargo environment. The technologies that met the requirements for these criteria were deemed suitable for testing in Arena, a discrete-event stochastic simulation program. Both pulsed fast neutron analysis and thermal neutron detection were eliminated due to excessive screening times of 1 hour or more per cargo unit. Pulsed fast neutron analysis also has potential to carry a large cost. Canines were eliminated due to lack of detailed information on their screening times. No methods were eliminated due to applicability issues. For simulation testing, the remaining screening methods (x-ray, gamma ray, vapor detection, trace detection, and radiation detection) were evaluated in various combinations to determine which method or combination of methods results in the lowest cost and time required, as well as the greatest detection coverage of various threat materials. A range of effectiveness was incorporated into the simulation for each screening method. The evaluations in Arena are discussed in a later section.

CASE STUDY

Introduction

A case study was conducted at an on-airport air cargo facility owned by a major U.S. airline at a major U.S. airport in order to expand upon the information obtained from the surveys and gain a more detailed understanding of how a cargo facility is laid out and the process of outbound cargo operations within it. Also, data was gathered on security measures in place, truck arrivals, and cargo processing times for use in Arena. Information on the airline's known shipper program and truck schedules was also obtained. The information gathered from the case study facility formed the basis of the Arena simulations that will be discussed in the following section.

Facility Layout and Operations

The air cargo facility is divided into two sections: the right side of the facility is used to process outbound cargo, and the left side is used to process inbound cargo and U.S. mail. The outbound cargo side is considered for this project. Figure 1 shows the layout of the outbound cargo side (the right side) of facility.

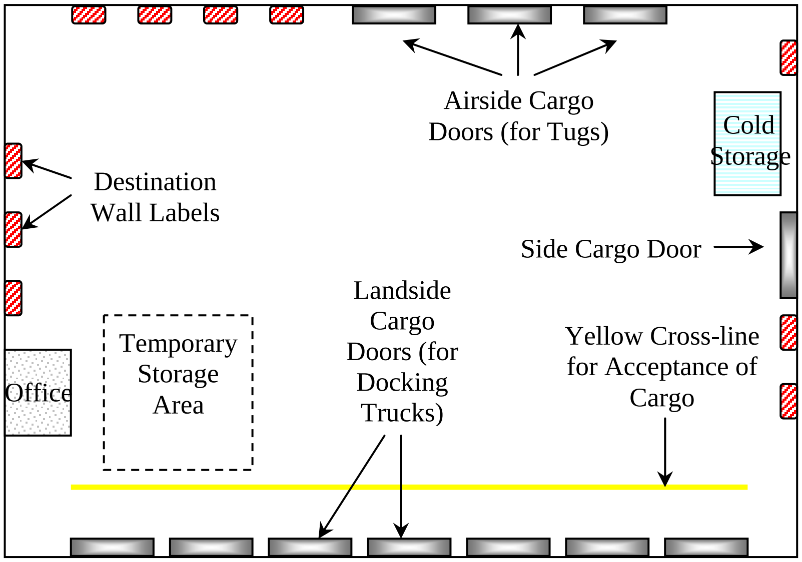

Figure 1 Case Study Facility Layout, Outbound Side

The facility consists of 7 landside cargo doors and 10 flight destinations that are labeled along the walls of the facility. The yellow line traversing the width of the facility is the dividing point between the delivery area and the processing area. Cargo is not officially accepted by the airline until it has crossed the yellow line. On the date that data was collected from the facility, an average of 6 employees were working in the facility (not including the forklift operators) and 4 forklifts were available for use.

The basic procedure for processing cargo through the facility is outlined below.

1. Trucks arrive and dock at one of the 7 landside cargo doors.
2. Truck drivers have their paperwork verified and the cargo's flight status is checked.
3. Cargo is unloaded. Once it crosses the yellow line, it has been officially accepted by the airline.
4. Cargo is taken to the temporary storage area for dimensioning, labeling, and possible physical inspection.
5. Cargo is sorted by destination and is placed on the floor under the appropriate destination wall label. The cargo is held in this area until its intended flight departure time nears.
6. Cargo units bound for the same flight are placed in unit loading devices (ULDs) and loaded onto tugs.
7. Tugs leave through the airside cargo doors to take ULDs to the aircraft.

The airline delivers cargo to both domestic and international destinations. The cutoff time for domestic cargo is 2 hours, and the cutoff for international cargo is 4 hours. Cargo units are usually unloaded and sorted by forklifts. Cargo is taken by tugs to the aircraft 20 to 30 minutes before the scheduled takeoff. All but around 10% of arriving outbound cargo is shipped the same day it arrives at the facility.

Security

The airline relies mainly on the known shipper program, x-ray, and physical inspection to keep their facility and cargo secure. The airline does business only with known shippers. In order to verify a new potential customer as a known shipper, the airline will send a cargo manager to the customer's location to ensure that they have a physical address, will be shipping legitimate goods, and can pay the shipping fees. The airline uses x-ray and physical inspection to ensure cargo security once cargo is in their possession. The x-ray machines are not in plain sight, and information on the number of machines, their exact location, and frequency of use could not be obtained. The airline mandates that 25% of their outbound cargo undergo physical inspection, which is more than the amount required by TSA (the actual amount required by TSA is classified). However, they cannot open any shipments from the U.S. government, and they will only inspect shipments that can easily be opened and re-sealed.

Truck Arrivals

Data on the time between truck arrivals was obtained from the airline's truck schedule and observations of local truck arrivals to the facility. Data on local truck arrivals was taken on February 19, 2004. Figure 2 shows that the time between arrivals was usually 20 minutes or less.

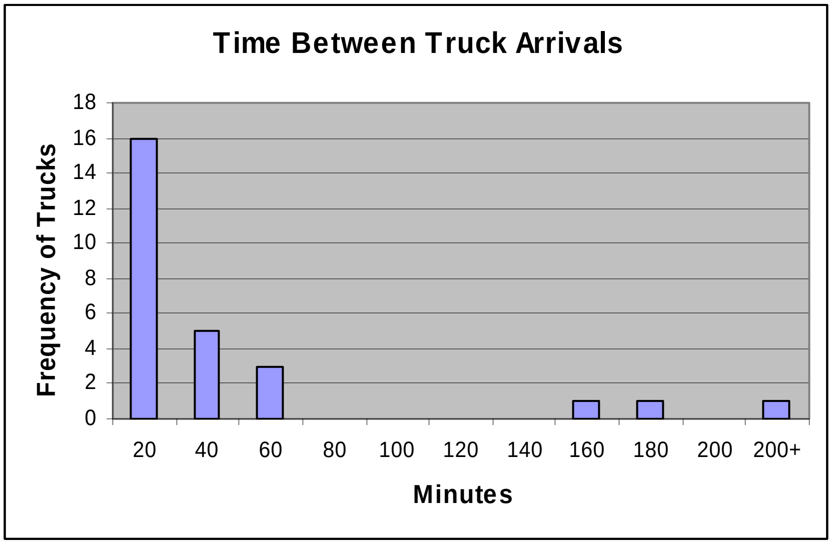

Figure 2 Histogram of Time Between Truck Arrivals to Case Study Facility

In order to properly represent this pattern of time between truck arrivals for use in simulation, the data was put into a statistical analysis program within Arena called the Input Analyzer in order to determine the statistical distribution that best fit the data set. The Input Analyzer found that a Weibull distribution of the equation $-0.001 + 15.4(0.382)^{-15.4}x^{15.4-1}e^{-(x/0.382)^\wedge 15.4}$ gave the best representation. The Weibull distribution equation takes the form

$$f(x) = a + \alpha\beta^{-\alpha}x^{\alpha-1}e^{-(x/\beta)^\wedge\alpha)} \qquad \text{if } x > 0$$

where

a = offset from y-axis

α = shape parameter of the distribution, and

β = scale parameter of the distribution.[13]

This equation was used to generate both trucks and their cargo arriving to the facility in all the simulations.

Summary

The layout of the case study facility and its operations serves as the basis for the simulations of the cargo facility. The processes described in this section can be duplicated in Arena, and the data gathered from the truck arrivals can be used to generate truck and cargo arrivals. The next section discusses the simulations in detail.

ARENA SIMULATION OF CARGO FLOW THROUGH AN ON-AIRPORT CARGO FACILITY

Introduction

Arena was used to evaluate 4 separate combinations of security measures in conjunction with data gathered from the case study. Each combination simulated ran for a period of 5 years. Some of the major factors from the case study that were incorporated into Arena are the following:

1. Truck arrival times
2. Distribution of cargo units per truck arrival
3. Number of facility employees and forklifts
4. Number of flight destinations
5. Allowable time in which processing must be completed
6. Inclusion of random physical inspection (for the purposes of this project it was assumed that the TSA physical inspection regulation requires 10% of all cargo to be physically inspected, so this amount was incorporated into the cargo processing separate from the testing of the other security measures).

Simulation Setup

At the beginning of the simulation when the cargo units were created, 0.1% of the units coming through were assigned a high-risk status. All units assigned a high-risk status were also assigned one of the 5 specific types of high-risks: explosives, illegal drugs, stolen materials, radioactive materials, or dangerous gases. Table 2 shows which of the simulated screening methods can detect these risks.

Screening Method	Risks Detected
X-Ray	Explosives, stolen/mislabeled goods, illegal drugs
Gamma Ray	Explosives, stolen/mislabeled goods, illegal drugs
Vapor Detection	Dangerous gases
Trace Detection	Explosives, illegal drugs
Radiation Detection	Radioactive materials

Table 2 Detection Capabilities of Simulated Screening Methods

Once a base case simulation (with no security measures except the 10% physical inspection) was completed and evaluated, the combinations of security methods were incorporated for evaluation and comparison to the base case. The rate of 10% physical inspection was included in these cases, as well. The combination cases consisted of the following screening methods:

<u>Case 1</u>: x-ray
<u>Case 2</u>: x-ray, trace detection, vapor detection
<u>Case 3</u>: x-ray, trace detection, vapor detection, radiation detection
<u>Case 4</u>: x-ray, trace detection, vapor detection, radiation detection, gamma ray.

Table 3 shows the number of methods in each case that can screen for each type of risk.

	Case 1	Case 2	Case 3	Case 4
Explosives	x	xx	xx	xxx
Stolen/Mislabeled Goods	x	x	x	xx
Illegal Drugs	x	xx	xx	xxx
Illegal/Dangerous Gases		x	x	x
Radioactive Materials			x	x

Table 3 Number of Screening Technologies In Each Case Capable of Detecting Each Threat Type

Once a cargo unit was chosen for security screening, it was inspected by all the security methods included in the case unless one of the methods detected a risk. If this occurred, the cargo unit was taken out of the security queue to undergo physical inspection in order to verify the risk. If the risk was verified, the unit was immediately removed from the facility. If the risk was not verified (thus resulting in a false positive on the part of the method that detected the "risk"), the unit was routed to the cargo sorting area. Screening for all five high-risk cargo types occurred simultaneously.

Each combination case was divided into 3 categories. The first category in each combination randomly screened a total of 10% of the cargo entering the facility, the second category randomly screened 25% of the cargo, and the third randomly screened 50% of the cargo. These percentages do not include the 10% physical inspection. Each of these categories underwent 3 replications. The screening time for each category in each case was evaluated, and comparisons of costs and screening times were made among the different combination cases. Statistics were collected on the number and types of high-risk cargo units caught, the number and types of high-risk cargo units not caught, the number of true and false positives, and the total process time.

Since very little data on the effectiveness of the screening methods was available, assumptions had to be made within Arena to account for variability and the possibility of false positives. Each method was assumed to perform at an average rate of 70% effectiveness for catching threats. Variability was addressed by assigning each screening method a triangular distribution with a minimum effectiveness of 60%, an average effectiveness of 70%, and a maximum effectiveness of 80%. The triangular distribution takes the form

$$f(x) = [2(x-a)]/[(b-a)(c-a)] \quad \text{if } a \le x \le c$$

$$f(x) = [2(b-x)]/[(b-a)(b-c))] \quad \text{if } c < x \le b$$

where

$$a < c < b$$

a = a location parameter; the minimum possible value

c = the shape parameter; the value that maximizes the density function, and

$b - a$ = a scale parameter; b is the maximum possible value.

A uniform false positive rate of 1% to 3% was also assumed for each screening technology. The uniform distribution takes the form

$$f(x) = 1/(b-a) \quad \text{if } a \le x \le b$$

where

$$a < b$$

a = a location parameter; the minimum possible value, and

$b - a$ = a scale parameter; b is the maximum possible value.[14]

Results

As more screening methods were added to each subsequent case and the cost to implement each case increased (Table 4), the added security measures decrease the amount of cargo that is processed within a given time as compared to the base case. However, among just the 4 cases, the average cargo processing time did not uniformly decrease as expected. This was attributed to a problem inherent in Arena in which units that are “batched” together to form a single unit all take on the properties and attributes of the first unit in the batch.

Cases	Avg. System Cost	Avg. Units Processed Per Case	Avg. Process Time Per Case
Base	-	579,354	99
Case 1:	$5,000,000	574,568	108
Case 2:	$5,580,000	569,981	108
Case 3:	$5,610,000	571,170	109
Case 4:	$7,360,000	568,280	119

Table 4 Case Costs and Processing Times

Table 5 shows the results from the screenings for each high-risk cargo type. The base case is not included since there were no screening technologies incorporated in the base case simulation.

	Case 1			Case 2			Case 3			Case 4		
	10%	25%	50%	10%	25%	50%	10%	25%	50%	10%	25%	50%
Explosives												
% Found from Screening	69%	69%	66%	75%	92%	97%	93%	87%	90%	100%	93%	97%
% Found from Screening (Case Avg.)	68%			88%			90%			97%		
Total % Found	5%	14%	35%	5%	19%	43%	8%	15%	37%	9%	16%	43%
Total % Found (Case Avg.)	**18%**			**22%**			**20%**			**23%**		
Stolen Goods												
% Found from Screening	100%	58%	68%	86%	66%	70%	69%	74%	76%	83%	85%	87%
% Found from Screening (Case Avg.)	75%			74%			73%			85%		
Total % Found	8%	11%	32%	7%	14%	32%	5%	14%	37%	11%	16%	37%
Total % Found (Case Avg.)	**17%**			**17%**			**19%**			**21%**		
Illegal Drugs												
% Found from Screening	86%	69%	73%	89%	86%	85%	86%	95%	95%	100%	100%	98%
% Found from Screening (Case Avg.)	76%			87%			92%			99%		
Total % Found	7%	18%	34%	9%	14%	32%	6%	19%	45%	11%	22%	38%
Total % Found (Case Avg.)	**19%**			**18%**			**23%**			**24%**		
Dangerous Gases												
% Found from Screening	N/A	N/A	N/A	62%	75%	69%	56%	67%	75%	61%	69%	69%
% Found from Screening (Case Avg.)	N/A			68%			66%			67%		
Total % Found	N/A	N/A	N/A	8%	15%	35%	6%	14%	31%	8%	19%	34%
Total % Found (Case Avg.)	**N/A**			**19%**			**17%**			**20%**		
Radioactive Materials												
% Found from Screening	N/A	N/A	N/A	N/A	N/A	N/A	92%	74%	63%	50%	69%	64%
% Found from Screening (Case Avg.)	N/A			N/A			76%			61%		
Total % Found	N/A	N/A	N/A	N/A	N/A	N/A	5%	16%	30%	4%	13%	29%
Total % Found (Case Avg.)	**N/A**			**N/A**			**17%**			**15%**		

Table 5 Detection Results for All Five High-Risk Cargo Types

The % Found from Screening reflects the percentage of high-risk cargo found based only on the cargo that was randomly selected for security screening. This statistic exhibits an increase moving throughout the case averages when more screening methods are added that address a specific threat. This can be seen most clearly in the results for explosives and illegal drug detection (see Table 3). The Total % Found reflects the percentage of high-risk cargo found based on *all* the cargo entering the facility, regardless of whether or not it was screened for threats. This statistic exhibits an increase among the categories within each case, which can be seen in all 5 high-risk cargo types. This increase is much more apparent within each case as opposed to the case averages because the percentage of all cargo screened was increased within each case. In order to achieve the most infallible security case, a variety of screening methods that can cover a myriad of threats is needed. But in order to catch the largest percentage of high-risk units in a facility, an increase in the amount of cargo screened is necessary.

Significance Testing

Significance testing based on 95% confidence intervals was performed on the results. For the % Found from Screening, no significant differences were found in the 10% random screening category, but some significant differences were found in the 25% and 50% categories. No significant differences were found in any of the categories for the Total % Found.

CONCLUSIONS, AND RECOMMENDATIONS

The results show that the framework developed in this research can be used to evaluate the performance of screening methods in an individual air cargo facility. With a few minor changes to the simulations and the proper sets of data, this method can be applied to any individual cargo facility. Government entities, airport authorities, air carriers, and freight forwarders could benefit from the implementation of this framework for their own security testing purposes. Also, a tool such as this can help the federal government develop better, more specific legislation that is needed to regulate air cargo security. The detailed data that can be provided from numerous simulations could be used to set national standards and performance measures for the air cargo industry.

In order to improve the methodology used in this project, research is needed on the efficiency of the screening technologies, thereby reducing the need for assumptions in the simulations. This information is essential to properly determine what type or types of security setups will work effectively in an air cargo setting.

The most effective best security setup for an air cargo facility will be a comprehensive approach consisting of direct cargo screening in conjunction with other measures such as perimeter access control and personnel and truck driver screening, which ensures back-ups in case of a failure in one area. Direct cargo screening, the portion of air cargo security explored in this project and used alone will not ensure the security of air cargo, but it is an integral part of the complete picture.

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