NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

METHODOLOGY TO IMPROVE AVIATION SECURITY WITH TERRORIST USING AIRCRAFT AS A WEAPON

by

Boon Chew Winson Sheo

September 2013

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2013	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE METHODOLOGY TO IMPROVE AVIATION SECURITY WITH TERRORIST USING AIRCRAFT AS A WEAPON			**5. FUNDING NUMBERS**
6. AUTHOR(S) Boon Chew Winson Sheo			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approval for public release;distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The aviation industry is a large network of agglomerated systems that connects people and places. Since the 9/11 attacks, aviation security in the United States has undergone tremendous changes and improvements. Nonetheless, threat detection mechanisms remain imperfect as seen from hijacking attempts by passengers who have gone undetected via security. Alternate ways of thinking and looking at security was explored through a system perspective. The focus was on passenger security system with the intention of identifying potential areas of improvement for aviation security with terrorist using aircraft as a weapon. A supply chain approach was taken as the model to move and deliver people as goods through security checks to the aircrafts. Together with this approach, the concept of risks, uncertainties and the associated risk assessment of potentially defective "goods" were examined. A systems engineering process was used. Through systematic analysis scrutinizing interactions between airport objects and passengers (as objects), this thesis pin-points possible gaps, and thereby identify approaches or means to safeguard and counter these risks. Analysis included the exploration of the trade space between different entities within the system and the interactions between objects, functions, processes, and its associated results.

14. SUBJECT TERMS Passenger security system, Aviation security, Supply chain, Risk index			**15. NUMBER OF PAGES** 91
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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METHODOLOGY TO IMPROVE AVIATION SECURITY WITH TERRORIST USING AIRCRAFT AS A WEAPON

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
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The aviation industry is a large network of agglomerated systems that connects people and places. Since the 9/11 attacks, aviation security in the United States has undergone tremendous changes and improvements. Nonetheless, threat detection mechanisms remain imperfect as seen from hijacking attempts by passengers who have gone undetected via security.

Alternate ways of thinking and looking at security was explored through a system perspective. The focus was on passenger security system with the intention of identifying potential areas of improvement for aviation security with terrorist using aircraft as a weapon. A supply chain approach was taken as the model to move and deliver people as goods through security checks to the aircrafts. Together with this approach, the concept of risks, uncertainties and the associated risk assessment of potentially defective "goods" were examined.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIT	Advanced Imaging Technology
BAO	Bomb Appraisal Officer
CAT-BPSS	Credential Authentication Technology – Boarding Pass Scanning Systems
DPHS	Department of Homeland Security
EBSP	Electronic Baggage Screening Program
EDS	Explosive Detection System
EMMI	Energy, Matter, Material wealth, and Information
ETD	Explosives Trace Detector
FBI	Federal Bureau of Investigation
FFBD	Functional Flow Block Diagram
FOV	Field of view
GAO	Government Accountability Office
ICT	Information and communication technology
IED	Improvised Explosive Device
ID	Identity
LE	Loop Exit
LP	Loop
NCC	National Counterterrorism Center
RI	Risk Index
SFPD	Secure Flight Passenger Data
SE	Systems Engineering
SoS	System of Systems
SPOT	Screening of Passengers by Observation Techniques
TDC	Travel Document Checker
TSA	Transportation Security Administration
VIPR	Visible Intermodal Prevention and Response

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EXECUTIVE SUMMARY

The aviation industry is comprised of various systems, agglomerated into a large network of systems that connects people and places. Each day, millions of travelers rely heavily on this system of systems (SoS) for transportation between domestic and global locations. According to the Bureau of Transportation Statistics, an average of about 1.76 million domestic passengers boarded domestic flights in the United States in 2012. The September 11 hijacking of aircraft in a coordinated terrorist attack in the United States was a milestone in the history of aviation security. Since the 9/11 attacks, aviation security in United States has undergone tremendous changes with a defense-in-depth approach. While improvements have been incorporated into aviation security at airports, threat detection mechanisms remain imperfect as seen from the occasional reports of hijacking attempts by passengers who have gone undetected via the various layers of security.

Alternate ways of thinking and analyzing security were explored through a system perspective. The focus was on passenger security system within the aviation security SoS, with the intention of identifying potential areas of improvement for aviation security with terrorists using aircraft as a weapon. A supply chain approach was taken to model movement and delivery of people as goods through security checks to their respective aircrafts. The analogy is for passengers to pass through various phases in the supply chain, with each phase being the means of detecting "security defects" in the "goods" (i.e., passengers). The purpose is to have a flow of goods through the supply chain in a timely fashion with the end state of delivering defect-free passengers with the appropriate certification of security at the doorstep of each outbound aircraft. Together with this approach, the concept of risks, uncertainties, and the associated risk assessment of potentially defective goods as they flow through the supply chain was also examined.

A systems engineering process premised on problem solving that was iterative, recursive, and illative was used. A systematic analysis of the airport passenger security system was performed, scrutinizing interactions between airport objects and passengers (as objects) to pin-point possible gaps and vulnerabilities that could be potentially

exploited by malicious parties, and thereby identify approaches, means or even measures to safeguard and counter against these risks. The analysis included the exploration of trade space between the different entities within the system and the interactions between objects, functions, processes, and its associated results. Through the analysis, new security measures and processes for improvement were identified.

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr. Gary O. Langford for his constant guidance and encouragement through the thesis journey. He is a man of wisdom, someone who possesses immense patience, and is always approachable. Well-versed and knowledgeable the professor offered interesting perspectives in the field of Systems Engineering, helping me to gain a better understanding and appreciation for the discipline.

I would also like to thank my thesis second reader, Professor Mark Stevens, for taking the time and effort in reviewing and providing valuable feedback for my thesis.

Lastly, but not least, I would like to thank my wife, Hui Peng, for her unfaltering love, support and encouragement that she had provided me with for our years of marriage, especially in the last 18 months when I was in the master's programs, both in NUS and NPS. My kids, for the fun and laughter they have brought to the family.

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I. INTRODUCTION

A. BACKGROUND

The first reported hijacking of aircraft was traced to 1931 in Peru (Jenkins, n.d.). Since then, aircraft have been hijacked for various reasons ranging from hijackers seeking asylum to the exchange of prisoners. Over the years, terrorists have “revolutionized” the hijacking of commercial aircraft by using aircraft-as-weapons to attack targets of interest. Most notably, the simultaneous hijacking of four aircraft by Al-Qaeda-affiliated extremists on September 11 culminated in a coordinated terrorist attack on civilian and government targets in the United States. The magnitude and significance of this attack continues to have lasting effects on the global landscape of aviation security as well as on behaviors and attitudes worldwide. According to the Government Accountability Office (GAO) Report, *Department of Homeland Security: Progress made and work remaining in implementing Homeland Security missions 10 years after 9/11*, “in the aftermath of the attacks, the Department of Homeland Security (DHS) was created with key missions[1] that include preventing terrorist attacks from occurring within the United States” (GAO, 2011).

The current aviation security system in the United States is based on a defense-in-depth approach which implies sequential and layered mechanisms that enact security functions to increase freedom from danger or threat. Multi-layered security enacted through a sequence of overlapping security mechanisms provides validation and verification of performance, as well as time to detect, evaluate and respond to threats. The security risks or threats that are being detected by mechanisms are known as security defects in the context of this thesis. The detection of defects would save lives and minimize damage. Effective detection is based on the principle that the greater the distance and time allotted to detection, the higher the probability there is for detecting defects. These layers of security mechanisms include intelligence collection and analyses, pre-screening of passengers, access control to airport areas, passenger security screening,

[1] Aviation security is one of the Functional Mission Area of the DHS.

passenger checked baggage screening, cargo screening, and on-flight security. While each individual security layer is aimed at a specific threat identified in aviation travel, these layers collectively are intended to provide a secure environment in general for aviation travel. The majority of these security mechanisms across the various security layers is intended to be transparent to an individual bound for air travel as these measures are being implemented and performed in the background. A few exceptions to this intended transparency are passenger security screening[2] and passenger checked baggage screening[3] which involve a direct interaction with the individual traveling. While improvements have been incorporated into aviation security at airports, there are still occasional reports of hijacking attempts by individuals who have gone undetected via the various layers of security.

B. THESIS MOTIVATION AND FOCUS

The objectives of the thesis are to identify different ways of thinking about and looking at security and to identify potential areas of improvement for aviation security. Particular attention was placed on preventing the use of aircraft as a weapon. The thesis focused on the passenger security system within the aviation security system of systems (SoS). The research was carried out over a nine-month period and examined the interactions between airport objects and passengers (as objects) bound for air travel with the purpose of identifying new ways of thinking about security and potential improvements to security, in terms of both mechanisms and processes.

C. PROBLEM DEFINITION

The aviation industry is comprised of various systems, agglomerated into a large network of systems that connects people and places. Each day, millions of travelers rely heavily on this SoS for transportation between domestic and global locations. While the images and effects of the 9/11 attacks remain vividly in the minds of many travelers, the

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[2] This comprises both security checks of carry-on baggage and physical inspection of individuals bound for air travel.

[3] Direct interaction with individuals occurs when the checked baggage poses problems to security personnel during physical inspection.

impact of the immediate aftermath on air passenger travel was overcome when air passenger travel reached its pre-9/11 peak in July 2004 (Notis, 2005). Since mid-2004, the number of travelers has continued to grow. According to the Bureau of Transportation Statistics, a total of 642,202,749 passengers (RITA–BTS, n.d.) boarded domestic flights in the United States in 2012. This magnitude of passengers translates into an average of about 1.76 million domestic passengers per day distributed across the airports in United States.

Since the 9/11 attacks, aviation security in the United States has undergone tremendous changes in security and improvements in passenger safety. With the passage of the Aviation and Transportation Security Act, the National Strategy for Aviation Security implemented a robust system of detection, protection and interdiction through 20 layers of security actions in place at more than 450 airports (Pistole, 2011). Amongst the various systems and elements within the aviation security system, those involving the passenger have a direct impact on the possible use of the aircraft as a weapon to carry out an attack, as demonstrated in the 9/11 attacks. While the authorities continue to refine and enhance the aviation security SoS, the ability to focus on the passenger security system amidst other systems at the airport is of core relevance.

The problem is the existing threat mechanisms for detecting defects are imperfect. Imperfect mechanisms generally require redundancy and sequential implementation. This approach of using overlapping mechanisms can be in either the spatial or temporal domain, or both. Further, the failure of mechanisms that detect and identify anomalous behaviors may allow a breach of security to pass unnoticed without a sufficiency of time to recognize the breach with some form of backup mechanism(s).

Possible alternative solutions include: improving technology; improving mechanisms; increasing depth (the number and the distance-time factor that determines "depth") and effectiveness of the mechanisms, and increasing redundancy through overlap and adding more mechanisms. Additionally, solutions would include changes or additions/deletions to processes (procedures, activities, and acts).

D. APPROACH, AND METHODOLOGY

Airport security currently adopts a risk-based approach toward passenger screening (TSA, 2013e), categorizing the majority of passengers to be low risk. The limitation of such an approach is the shifting of focus to a smaller group of passengers by facilitating faster security clearance for passengers identified and categorized to be of low risk. While this seems to be a logical approach from many perspectives, it is susceptible to the inaccuracy and quality of the categorization of low risk passengers. To improve the detection of would-be-terrorists, the approach taken in this thesis is to view the movement of people through the airport to the aircraft as a supply chain, harnessing its characteristics of defect detection and continuous monitoring.

With the intent of adopting different ways of thinking about and looking at security, a systems perspective was taken (as opposed to SoS perspective) on the passenger security system. Langford (2012) defined a system as “a bounded, stable group of objects exhibiting properties that through the interactions and exchange of energy, matter, material wealth, and information (EMMI) provide functions.” A system can also be understood from Maier and Rechtin (2009) as “a collection of things or elements that, working together, produce a result not achievable by the things alone.” Thinking of the passenger security system as a “system” implies that a terrorist is part of the passenger security system (as a participant), but an externality to the system (as a disruptor). Langford (2012) defined an SoS to be “a set of systems that are both integrated and interoperable to achieve a set of metasystem functions in which all the component systems participate.” Jamshidi (2009) has reviewed several potential definitions of SoS and defined SoS as “large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal.” Thinking of the passenger security system as part of an SoS implies that a terrorist is not a part of the “system,” but rather part of another system, i.e., the “terrorist system.” In the SoS construct, the passenger security system interacts with the “terrorist system.”

In the context of this thesis, the passenger security system possessed the conditions to be a system when it was able to exercise control over, for example, the intelligence data that were being made available and fed from external agencies or databases, otherwise known as other systems, into the system. Similarly, if a passenger with security defects was detected and potentially traced or linked to other individuals or organizations residing physically outside the airport boundaries or the passenger security system boundaries, the passenger security system would then hand over the investigation and pursuit of these linkages to the detected defects to other law enforcement agencies (i.e., external systems). This behavior is expected from a system as compared to a passenger security SoS that would otherwise trigger other SoS elements to follow up.

This thesis took a systematic analysis of the aviation system with a specific focus on the airport passenger security system scrutinizing the passenger (as mereological objects) to pin-point possible gaps and vulnerabilities that could be potentially exploited by malicious parties, and thereby identify approaches, means or even measures to safeguard and counter against these risks. This analysis would include the exploration of trade space between the different entities within the system and the interactions between objects, functions, processes and its associated results. A systems engineering (SE) process premised on problem solving that is iterative, recursive and illative was adopted.

This thesis adopted the following structure: Chapter I discusses the background and basis for the thesis; Chapter II examines the current U.S. aviation security system and principles; Chapter III discusses the use of the supply chain as a model to view airport passenger security, relating supply chain characteristics to the airport security model and analysis; Chapter IV identifies the limitations in existing security systems as problems that need to be solved through an SE process involving the use of tools such as functional decomposition, functional flow block diagram and evaluative functional analysis. It also discusses the conceptualization of improvements (or solutions) to these identified problems; Chapter V discusses the development of a risk index (RI) as a form of defect assessment within the supply chain; and Chapter VI discusses the improvements to passenger security system arising from the thesis research and identifies areas for subsequent research.

E. SCOPE

The scope of this thesis is to investigate the passage of passengers through airport security. The broader scope that involves discussion of boundaries beyond the airport physical structures and perimeter are included as part of the movement of passengers through the functional and behavioral boundaries of the airport.

F. RESEARCH QUESTIONS

The thesis utilizes the following questions as a guiding tool in laying out the content.

- What are the (new) possible security measures or processes (resulting from the analysis of interactions) that airport security authorities could possibly consider to help further their view of security?
- How do the (new) potential measures compare to existing security procedures/measures?
- Can the supply chain model of viewing passengers as goods be used in the analysis of the airport passenger security?
- Can the methodological approach of analysis provide a new perspective (new way of doing things) on airport passenger security?

II. UNITED STATES AVIATION SECURITY SYSTEM

A. OVERVIEW

This chapter examines the existing U.S. aviation security system. The current aviation security system is based on a defense-in-depth approach which implies sequential and layered mechanisms that enact security functions to increase state of being free from danger or threat.

- The principle of sequential mechanisms can be stated as: sequential mechanisms provide a higher degree of reciprocity between objects. The greater the number of interactions between objects, the higher the reciprocity by which objects learn more about each other.
- The principle of layered mechanisms can be stated as: overlapping mechanisms validate the failure of one or more of the overlapped mechanism(s). The greater the overlap of the mechanisms, the higher the situational awareness.

In the context of this thesis, the security risks or threats that are being detected by mechanisms are also known as security defects. Security defects are defined as anomalies in security which may result in a loss of life, material or information. Examples include (1) acts or behaviors by individuals which contravene security rules and procedures, (2) materials or artifacts that do not conform to security requirements and (3) information provided that does not reconcile with security guidelines. The detection of defects would save lives and minimize damage; and the greater the distance and time, the higher the probability of detecting defects. As depicted in Figure 1, the multi-layered security is enacted through a sequence of overlapping security mechanisms that provide validation and verification of performance as well as time to detect, evaluate and respond to threats. The different phases in the passenger flow from arrival to departure depict the sequential mechanisms, while the layered mechanisms arise from the multiple layers of security, for example, at the passenger security screening checkpoints consisting of front-line TSA checkers, a second layer of supervision and a third layer of oversight coming from the command center through the surveillance mechanisms.

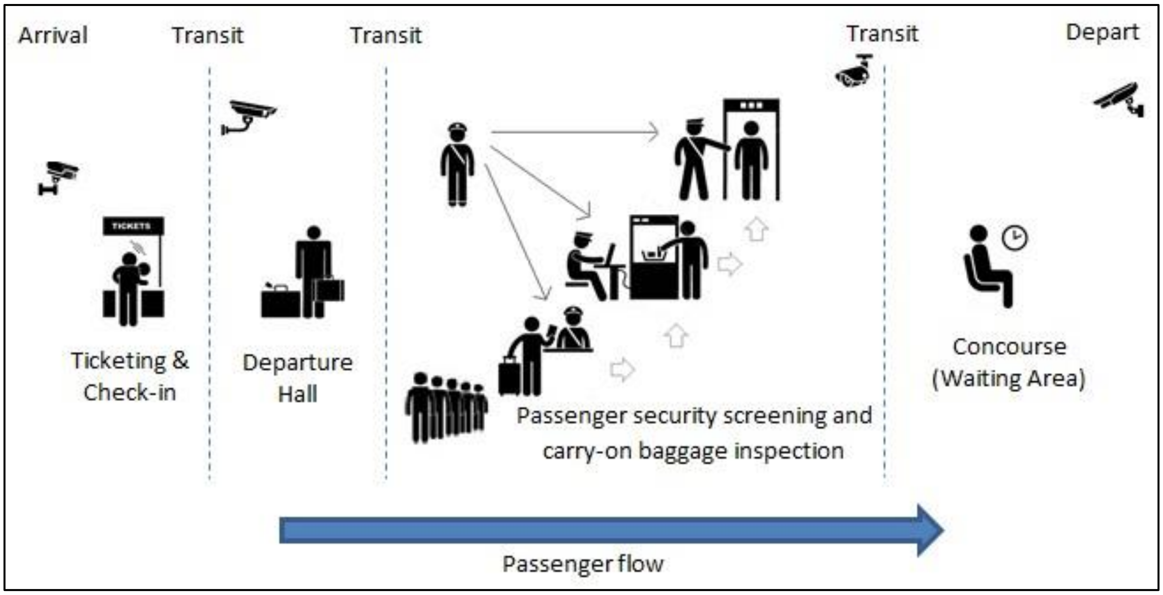

Figure 1. Sequential and Layered Mechanisms Enacting Security Functions (Adapted from TSA, 2013c).

1. Definition of Terms

- Function is defined as "specific or discrete action (or series of actions) that is necessary to achieve a given objective; that is, an operation that the (security) system must perform…" (Blanchard & Fabrycky, 2011). It can also be seen as "an action that is realized when objects interact" (Langford, 2012).
- Sequential is defined as a systematic series of steps, activities or processes that objects would flow through in an airport passenger security system.
- Reciprocity is defined as interactions and exchanges of EMMI between objects.
- Object (airport object or passenger as an object) is defined "as a fundamental element, entity, or representation … Objects have boundaries and may be comprised of other objects, each of which is related by interactions" (Langford, 2012).
- Interaction is defined "as the transfer of EMMI. Interaction is characterized by the transfer of something from one object (sender) to another object (receiver)" (Langford, 2012).
- "Mechanisms are the means by which objects and processes change. The effect of a mechanism is to transform an input EMMI into an output EMMI. A mechanism is that which operates in the context of force" (Langford, 2012).

- Overlapped mechanisms provide partial coverage of the same area of (security) function, or purpose, serving as back-up to the original function, or purpose.
- Situational awareness is defined as the conscious and knowledge of being aware of the activities or occurrence of events within the boundaries of an object or entity in context of the airport security system.
- Validation is "the process of demonstrating the effectiveness of service (security) through an assessment of the operational system that exposes and quantifies the systems' limitations" (Langford, 2012).
- Verification is "the process of confirming the truth or accuracy by describing the characteristics of interactions, the enactments of mechanisms or procedures, or the consequences of EMMI" (Langford, 2012).
- "Performance is the action associated with a (security) function. Performance is measured by the extent to which various standards are met" (Langford, 2012).

B. U.S. AVIATION SECURITY MODEL[4]

The Transportation Security Administration (TSA) has adopted a layered security concept for its transportation system, which includes the aviation system. This concept uses multiple layers of security, each serving a different purpose but cumulatively serving the common intention of stopping a terrorist attack, as shown in Figure 2 (TSA, 2013c). Note: in this thesis, the different layers of security are interpreted as representing different roles and implying distinguishable responsibilities. With a combination of security layers, the combined security effect is multiplied, creating a more secure aviation system. With a total of 20 layers of security in place, the terrorist would need to find gaps in each layer and overcome the combined effect of the layers to have any chance of carrying out a successful attack. These different layers can be categorized generally by type and location of layers. The broad categories are: 1) Intelligence, 2) Security Checks and Inspections at airports and 3) Security Measures on board aircraft.

[4] A study presented by Fletcher (2011) served as a basis of reference for this section.

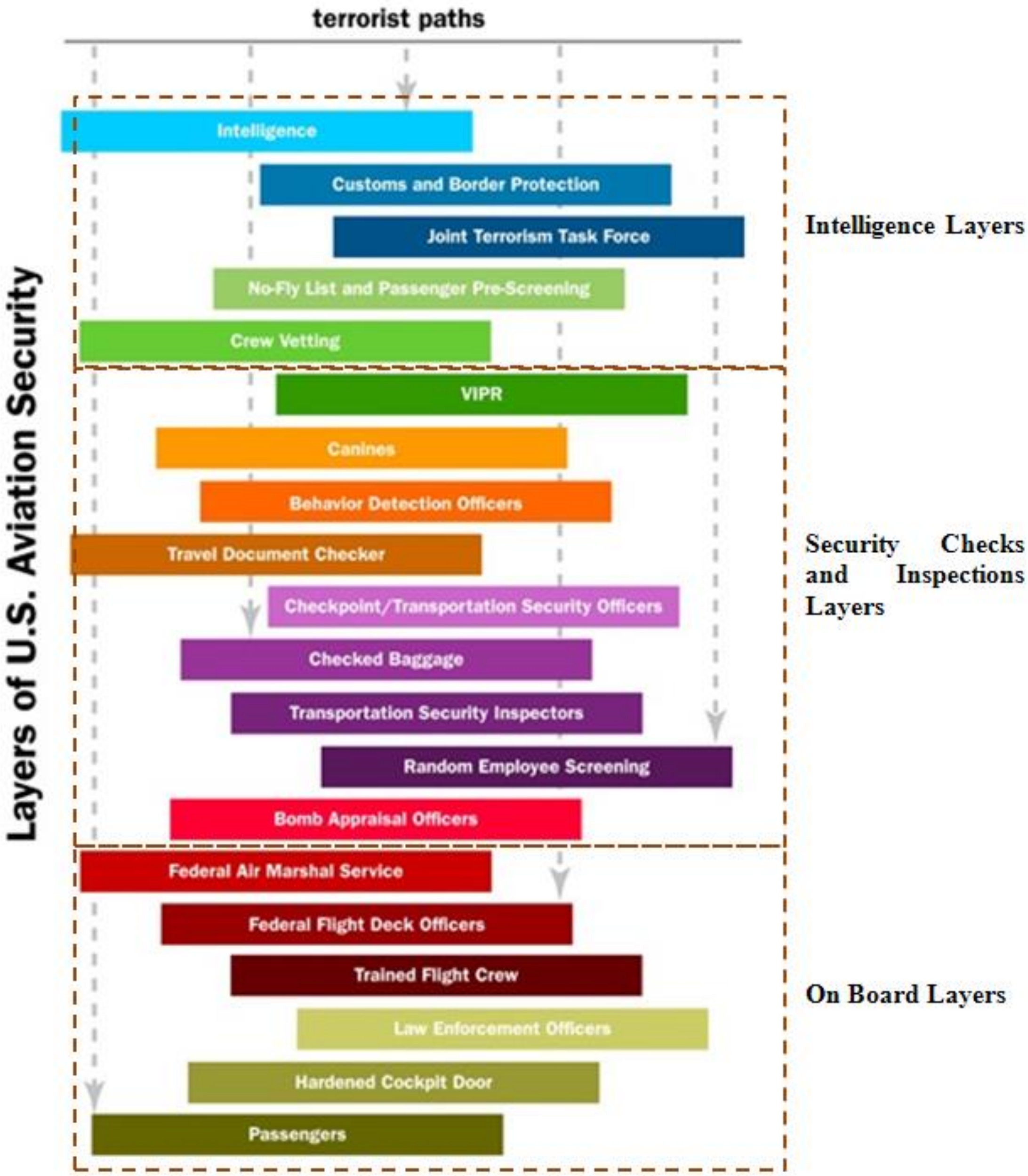

Figure 2. Twenty Different Layers of Security (Adapted from TSA, 2013c).

Similar to other security models, intelligence activities form one of the first layers in aviation security. Intelligence for aviation security is being fed into the system from various information sources within the U.S. intelligence community. These sources include agencies such as the Federal Bureau of Investigation (FBI) and the National

Counterterrorism Center (NCC). In addition, this information is regularly supplemented by other sources of intelligence supplied to the United States by its Coalition partners, and collectively these form the intelligence picture for aviation security. Besides providing valuable information for the aviation security system to support proactive planning and preparation against potential threats, it also serves as a basis of reference for the TSA Secure Flight Program. Under the Secure Flight Program, travelers are required to submit additional personal information[5] to the airline when they reserve or purchase their tickets. The airline in turn submits the information to Secure Flight, which uses it to perform watch list matching based on its existing database which is supported by the intelligence picture. The aim is to deny individuals identified on the "No Fly List" from boarding an aircraft and to identify individuals on the "Selectee List" for additional screening before allowing them to board. After the completion of watch list matching, Secure Flight then transmits the results back to airlines so they can issue passenger boarding passes accordingly (TSA, 2013f).

Moving from the intelligence layers into the security checks and inspections layers, individuals and their belongings could be subjected to a series of scheduled or random security checks and inspections at the airport.

> TSA has taken a risk-based approach in its screening procedures based on the following premises: (TSA, 2013e).
>
> - "The majority of airline passengers are low risk.
> - By having passengers voluntarily provide more information about themselves, TSA can better segment the population in terms of risk.
> - Behavior detection and interviewing techniques should be strengthened in the screening process.
> - TSA must accelerate its effort to optimize screening processes and use of technology to gain system-wide efficiencies.
> - Increase security by focusing on unknowns; expedite known and trusted travelers."

[5] Known as Secure Flight Passenger Data (SFPD), it includes full name, date of birth, gender and redress number (TSA, 2013f).

All checked baggage in the United States has been subjected to 100% screening since December 2003 under TSA's Electronic Baggage Screening Program (EBSP) that uses Explosive Detection System (EDS) equipment and Explosives Trace Detector (ETD) devices as the primary screening technologies to identify potentially hazardous baggage (Kane, 2009). All traveling individuals are required to present themselves with the appropriate travel documents and personal identification papers to the Travel Document Checker (TDC) to commence the scheduled security checks and inspections. At the station, the presented documents are checked for authenticity together with the checking of passengers' identities against a valid boarding pass to prevent any fraudulent use by any other individual to gain access to the concourse area and subsequently to the aircraft. Since October 2011, TSA has also started a pilot program on the use of document verification technology, known as Credential Authentication Technology–Boarding Pass Scanning Systems (CAT-BPSS) to identify fraudulent identity documents and authenticate boarding passes efficiently and effectively (TSA, 2012). Beyond the TDC stage, passengers are directed to one of the lines for checks and inspections of carry-on bags and personal belongings through X-ray machine checks by TSA officers. Passengers are subjected to screening by walking through a metal detector or through Advanced Imaging Technology (AIT)[6]. In addition, a series of security technologies and procedures are employed in this stage of scheduled checks and inspection to aid in the identification of prohibited items[7]. This equipment includes bottled liquids scanners to detect potential liquid or gel threats, CastScope to ensure that a cast or prosthetic does not contain concealed threat, explosive trace detection to screen for traces of explosives, and TSA's 3-1-1[8] for carry-ons. Besides the scheduled checks and inspections, random checks and inspections are also conducted at any time from the moment an individual enters the airport premises until he/she boards the aircraft. These inspections are carried out by the

[6] Imaging technology screening is optional for all passengers. Passengers who do not wish to receive imagining technology screening will receive alternative screening, including a physical pat-down (TSA, 2013, May 21).

[7] The latest TSA Prohibited Items list can be accessed via http://www.tsa.gov/sites/default/files/assets/pdf/prohibited_items_brochure_0.pdf

[8] This includes a 3.4 ounce (100ml) bottle or less (by volume); 1 quart-sized, clear plastic, zip-top bag; 1 bag per passenger placed in screening bin. One-quart bag per person limits the total liquid volume each traveler can bring. 3.4 ounce (100ml) container size is a security measure (TSA, 2013, July 3).

Visible Intermodal Prevention and Response (VIPR) team to detect and respond to potential security threats, explosive detection canine teams, and Screening of Passengers by Observation Techniques (SPOT) program. The SPOT program served to observe normal passenger characteristics and anxieties and to identify anomalies for detecting individuals who may be a security threat to the aviation system (Hawley, 2006). Detected threats are subject to additional screening and checks In addition, TSA has also implemented the Bomb Appraisal Officers (BAOs) program to prevent explosives and IEDs from being introduced into the aviation system and provide on-site assistance to resolve suspected alarms. These layers are augmented by a comprehensive network of surveillance cameras that provide live images and video coverage on activities within the aviation system in support of security.

The final layers of security are those on board the aircraft. These are aimed at safeguarding the flight and its passengers from any threat that was not detected and eradicated by the previous layers. These layers comprise of the federal air marshal service which places trained air marshals on board a flight. Air marshals provide an added measure of security resulting from threat information and intelligence, vulnerabilities and consequence[9] (Lord, 2009), when the flight is on route to its destination. The federal flight deck officers program authorizes eligible flight crewmembers[10] to use firearms to defend against acts of criminal violence to gain control of an aircraft. Trained flight crew assist in handling security incidents that happen on board an aircraft. Moreover, law enforcement officers may be on board the flight, hardened cockpit doors may be in place to prevent unauthorized access to the flight deck and passengers are at heightened awareness should they need to act.

These different layers of security (i.e., different roles and responsibilities for security personnel) constantly evolve and are updated to address emerging threats as a result of improvements to existing measures. Associated with these roles and responsibilities are changes in security procedures and measures to handle the threats, or new approaches and technologies that improve detection capabilities of prohibited items.

[9] The exact deployment criteria of air marshals on board flights are not openly available.

[10] A flight crew member may be a pilot, flight engineer or navigator assigned to the flight.

An example of these evolving improvements is the numerous screening initiatives[11] introduced by TSA over recent times to align to risk-based security more effectively. The various security measures as described in the existing aviation system can be depicted in a model of U.S. aviation security, shown in Figure 3.

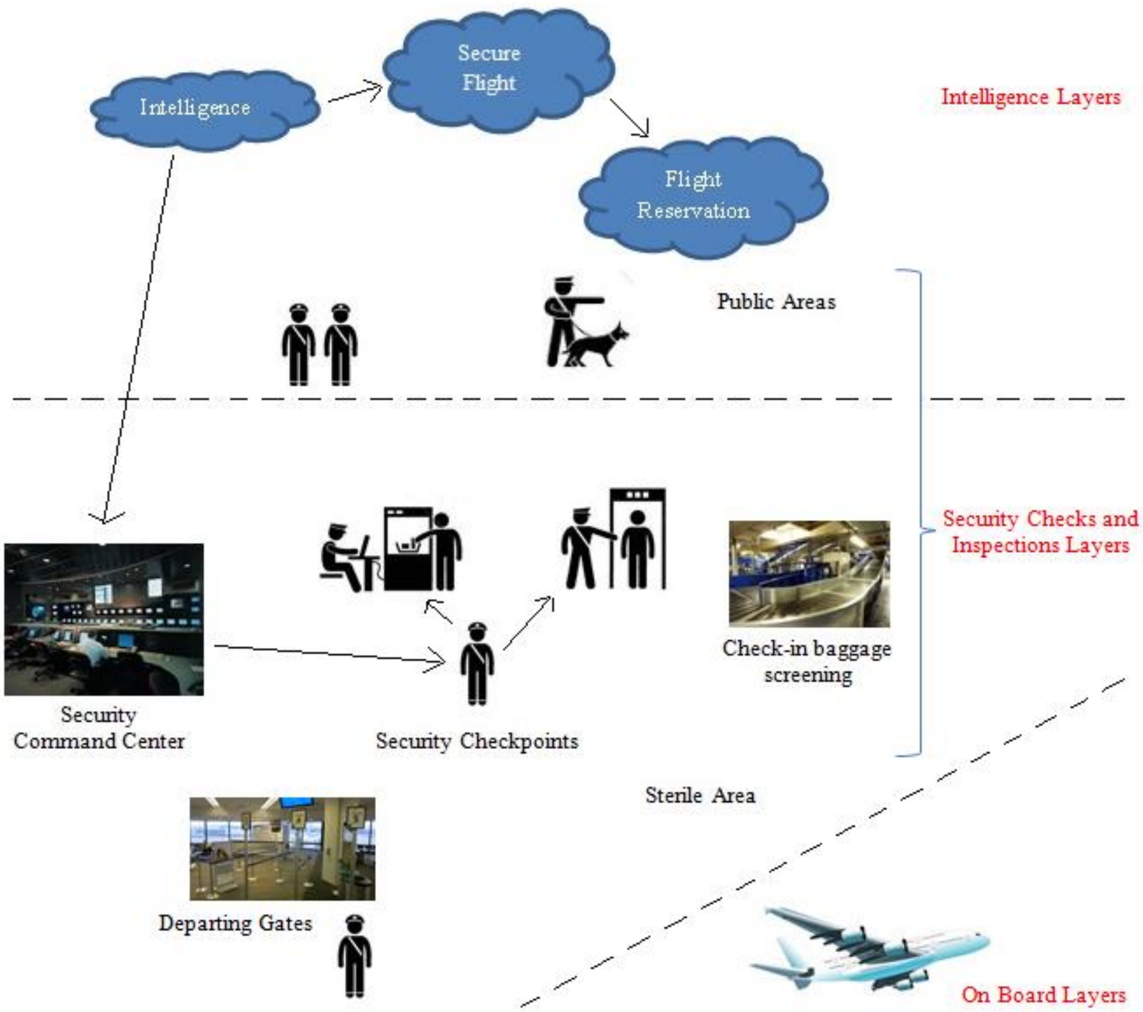

Figure 3. U.S. Aviation Security Model (Adapted from Fletcher, 2011).

[11] These include "TSA Pre ✓™ Expedited Screening, Screening for Active Duty U.S. Service Members, Screening for Passengers 12 and Under, Screening for Passengers 75 and Older, Managed Inclusion." (TSA, 2013, March 14).

The measures in the security model (Figure 3) are as follows:

Intelligence layers

- Intelligence and Secure Flight program

Security checks and inspection layers

- Visible intermodal prevention and response team, canine teams and SPOT program
- Security checkpoints (travel document checker, walk-through metal detector, advanced imaging technology, X-ray screening of carry-on bags and personal belongings, bottled liquid scanners, CastScope checks, explosive trace detection, Bomb Appraisal Officers program)
- Electronic Baggage Screening Program

Onboard layers

- Federal air marshal service, federal flight deck officers program, trained flight crew, law enforcement officer, hardened cockpit door, passengers

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III. SUPPLY CHAIN MODEL

This section discusses the use and relevancy of the supply chain model in the context of defects detection in airport passenger security system. Bozarth and Handfield (2006) defined supply chain as "a network of manufacturers and service providers that work together to convert and move goods from the raw materials stage through to the end user." Supply chain management can been seen as a form of SoS architecture with different entities interacting at the various levels and phases with the aim of improved product, reduced cost and reduced time required to deliver the product. With the aim of on time delivery of the required amount of goods to the customer, one of the specific features of best value supply chains is the supply chain information systems (Ketchen, Rebarick, Hult, and Meyer, 2008). This information system includes the ability to have almost real-time monitoring and tracking of goods status, demand and inventory within the supply chain. While the supply chain model can serve as a basis to examine and possibly reduce costs, and to shorten the time through security, the intent of its use in this thesis is to focus on managing risk. The aviation system can be seen as a large supply chain composed of a network of service providers in the form of airports transporting and moving people to their final destinations. Similarly, airport passenger security can be seen as a supply chain model to move and deliver people as goods through security checks to their respective aircraft. The analogy is for the people to pass through various phases in the supply chain, with each phase being the means of detecting security defects in the "goods." The purpose is to have a flow of goods through the supply chain in a timely fashion with the end state of delivering defect-free passengers with the appropriate certification of security at the doorstep of each outbound aircraft. As the goods progress through the supply chain, testing will be conducted to ensure conformance to security requirements.

A. CHARACTERISTICS OF THE SUPPLY CHAIN MODEL

The supply chain model can be seen as an integrated process involving different entities that transform sourced raw materials into finished products for customers. As defined by Beamon (1998), "a supply chain is comprised of two basic, integrated processes: (1) the production planning and inventory control process, and (2) the distribution and logistics process, providing the basic framework for the conversion and movement of raw materials into final products." As implied by the definition, integrated processes can be seen as one of the key characteristics of a supply chain model. The integrated supply chain is the outcome of interactions between the different processes supporting the various phases of a supply chain in the production and delivery of the final product. In the context of aviation travel, integrated processes exist with different entities each having their own procedures and processes, interacting together to support the transportation of passengers to their respective destinations. Similarly, within the aviation travel system, the airport passenger security system can be seen to possess integrated processes working toward providing safe transportation for all passengers.

Another characteristic of the supply chain model is the use of information and communication technology (ICT). Kollberg and Dreyer (2006) considered ICT to be "a key enabler for supply chain management through its ability to support information sharing and shortening information processing time." The harnessing of ICT in the supply chain can provide instant information, forecasting and replenishment knowledge (Lee, 2000), thereby improving situational awareness and facilitating informed decision making. This concept of monitoring and tracking goods and the status of the supply chain is likewise applicable in the context of the airport passenger security system. The status (defective or not defective) and risk profile of each individual passenger can be tracked in real-time as he/she flows toward the aircraft, providing up-to-date information to security agencies for the type of security measures or procedures to activate. Information and knowledge on individual goods, traffic patterns at different airports and at different times of the year can further be collated into trends and databases providing valuable knowledge for the purpose of goods profiling and subsequent referencing.

Quality conformance is the other characteristic of the supply chain model that is of relevance to the airport passenger security system. Bozarth and Handfield (2006) identified "number of defects" and "number of mistakes" as possible measures of quality conformance. "A defect or mistake, by definition, means that the product or service failed to meet specifications" (Bozarth & Handfield, 2006). There is a need to understand the dimensions of quality that are important to users and incorporate the appropriate processes within the supply chain model to meet users' requirements. In the case of the airport passenger security system, the requirement of having defect-free passengers at the doorstep of each aircraft drives the processes and measures required to detect defects in passengers at any point within the supply chain.

B. AIRPORT PASSENGER SECURITY MODEL

The model for integrated security assumes airport passengers participate and can be represented as goods in the supply chain. Each physical object in the supply chain is identified with a risk index that can change with context and environment. This risk index is equivalent to the measure of defects within the notion of goods to be moved. As the goods progress through the supply chain toward the end of production, they undergo various checks and tests to measure the defect level of the goods as part of the supply chain quality control process. Goods that pass the quality control checks will be delivered, while goods that do not meet the quality standards (with an RI exceeding the defect threshold) would be rejected. Given the growing importance of situational awareness, the model focuses on real-time monitoring and tracking characteristics of the supply chain to monitor and track defects in the goods so that the movement of people to the aircraft can be presented to the crew of the aircraft as defect-free goods. This process would include the identification and testing of defects (suspected or identified flaws) in the goods across the different phases, as part of the supply chain. An example of such real-time tracking and monitoring of passengers once they enter the boundaries of the airport system is Project SAMURAI (Suspicious Abnormal Behavior Monitoring Using a netwoRk of cAmeras & sensors for sItuational awareness enhancement) (Centre for Strategy & Evaluation Services, 2011). Defects measured in the form of an RI that would be assigned to every good that is bound for air travel. Depending on the activities, interactions and outcomes, the RI would vary as goods flow through the different phases of the model. The RI and its changing profile would be tracked and monitored in real-time over the phases to determine if the final goods to be loaded onto the aircraft are within the acceptable defect threshold.

While the concept of RI will be discussed in greater detail in Chapter V, at this point RI can be broadly categorized as Low, Medium or High. Anyone who boards any mode of transportation with an end terminal at the airport would be assigned a low RI. Someone who disembarks before reaching the airport would have his/her RI reset and the relevant information stored and archived. Depending on the exhibited actions, behavior and interactions during the trip or over multiple trips towards the airport, the RI of the individual would vary. When the RI exceeded the TEST threshold, the individual would be tested through built-in tests along the phases. The RI level can be a reduced, increased or maintained RI depending on responses and observations during testing (e.g., nervousness, dry mouth) and the outcome of testing. While an unclear act may result in a maintained RI, a suspicious act would definitely increase one's RI. The RI and its profile would be tracked and monitored in real time for decision making, which could mean going through other testing or even being refused final clearance to board the aircraft.

IV. INTEGRATIVE FUNCTIONAL ANALYSIS

Integrative functional analysis is a method that shows how interactions between objects result in functions that help describe the potential uses of an object or system (Langford, 2012). This method is premised on a systematic approach to analyzing the consequences of interactions between objects that comprise another object, system or system of systems. Through the technique of decomposing functions into sub functions, the partitioning of objects into modules that comprise single inputs and output, and the interactions between modules of each object to be analyzed, this method provides a framework to sift through processes and procedures to identify potential areas of improvement.

A. SYSTEM BOUNDARIES

The airport system comprises many different objects and each of these objects has its own set of unique boundaries evolving around how the object would exist on its own within the system or interact with other objects as part of the airport system. As part of the analysis of the airport system, the study of the system boundaries provides insights into the characteristics of the system and an additional dimension of the problem at hand. A change in boundary conditions could result in emergence that impacts the entire system. For example, allowing the carrying of pocket knives on board a flight (Ahlers, 2013) would have an impact on overall system operations and the interoperability of all constituent systems especially if the change in policy runs contrary to existing state law (Durkin, 2013).

1. Behavioral, Functional and Physical Boundaries

People bound for air travel will pass through defined boundaries and domains as they make their way to departure gates and boarding areas. These boundaries and domains are the behavioral, functional and physical aspects of limitations that characterize travel to board aircraft.

a. Behavioral Boundary

Generally, transportation lines to the airport are planned and designed to terminate at the airport with the airport being either the final destination or starting point for the airport system. These lines can be in the form of a road network, railway tracks or even pedestrian walkways. People on the various modes of transportation on these lines may be bound for all possible destinations that are linked or interconnected to the lines. People bound for different destinations with various purposes may behave and act differently on each of these transportation lines. The behavioral boundary signifies the behavioral perimeter where the airport system functions and objects influence the behavior of the individuals who are traveling to the airport. This is the point beyond which the behaviors observed of the remaining individuals on the transportation lines would be similar to those of all people going to the airport even though they may be traveling to the airport for different purposes, such as working at the airport and traveling as a passenger. This behavioral boundary also serves as the boundary where the intention of all remaining individuals on the transportation lines becomes clear that they are all bound for the airport. The context and perspective of the travelers serve to identify behavioral boundaries.

b. Functional Boundary

Functional boundaries are formed at the interface of objects due to the interactions of objects (Langford, 2012). In the airport system, functional boundaries are determined by interactions between the objects of transportation that link the airport and individuals using them. For individuals with a perspective of going to the airport, any embarkation point on the transportation lines (be it a bus stop, a train station or any point along the way) signifies the functional boundary of the function of ‘to transport’ as signified by “going to the airport.” In essence, the functional boundary of the airport system is a function of interactions between objects residing both within and outside the system and can change depending on the dynamics of interactions between the objects. The traveler’s use or lack of use of the objects associated with and comprising the transportation links identify the functional boundaries.

c. Physical Boundary

Physical objects can be thought of as the exterior perimeter of a solid object, a network of physical objects, and structures with holes, voids and gaps. The structures may be rigid or flexible or small or large (Langford, 2012). In the context of the airport system, the domain of “close proximity” signifies the physical perimeter boundary of the airport system. The corporeal boundary can also be conveniently considered and used as the extended physical boundary of the airport passenger security system.

B. AIRPORT PASSENGER SECURITY SYSTEM AS A SUPPLY CHAIN MODEL

The airport passenger security system can be thought of as the supply chain in a manufacturing model; it moves and delivers people (passengers) as goods through security checks to the respective flights. The analogy is for the people to pass through various phases in the supply chain, with each phase being the means of detecting security defects[12] in the “goods.” Security errors are defined as mistakes committed by individuals intentionally or unintentionally which could potentially result in downstream security defects. Defective individuals are defined as individuals who deliberately commit a security error or contribute to a security defect. In the airport passenger security system, security defects can be associated with passengers or carry-on items or belongings, i.e., objects, functions and behaviors. The aim is to have a smooth flow of goods through the supply chain in a timely manner with the end state of delivering defect-free[13] passengers with the appropriate certification of security at the doorstep of each outbound aircraft. As the goods progress through the supply chain that is grounded in the physical world of objects (i.e., physical locations are used to inventory or inspect the progress of goods through a sequence of physical objects; for example, checkpoints, can be considered a like-kind equivalent for security at airports), testing will be conducted to ensure conformance of security requirements.

[12] Refer to Chapter 2 for the definition of security defects.

13 Defect-free is being equated to having a security RI that is acceptable to the security authorities.

1. Passenger Physical Flow in Airport System

Anyone with the intention of traveling to the airport would need to board one of the available transportation lines to make their way to the airport. As the individual travels toward the airport, he would enter the behavioral boundaries of the airport system as observed through the exhibited behavior of the individual traveling to the airport. The interactions between individuals (who are to be or are bound for the airport) with airport system functions or other individuals (or objects related to air travel and the particulars that distinguish the traveler) would determine the behavioral boundaries of the airport system. The interactions between the individual and the functions of the transportation lines would determine the entry into the functional boundaries of the airport system as the individual travels beyond doubt toward the airport. The crossing of the individual into the perimeter boundary of the airport signifies the entry into the physical domain of the airport system. This physical flow of the passenger within the airport system is as shown in Figure 4 and discussed in the following sub-sections.

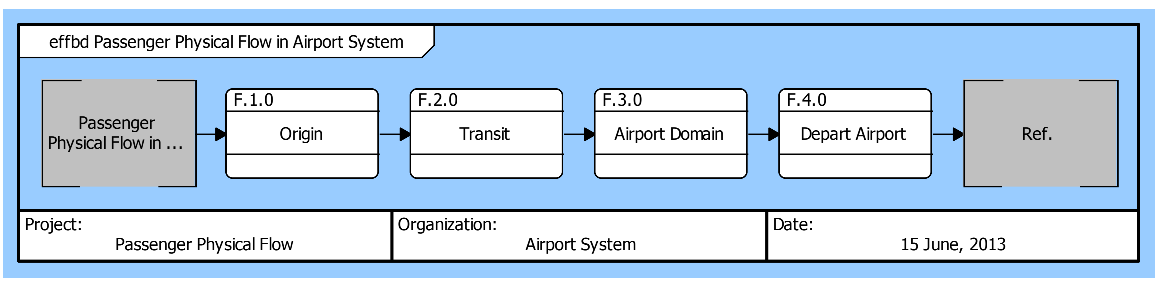

Figure 4. Movement of Passenger through Airport System Boundaries.

a. F.3.0 Airport Domain

On entry to the physical domain of the airport system, the individual would undergo a typical physical travel[14] to the airport departure gates as shown in Figure 5. Individuals arriving at the airport domain (airport building) have the option of commencing the required travel procedures with the respective airlines. There is a

14 While there could be other passenger flows within the airport domain, for example, individuals transiting at the airport undergo a different flow process; the discussion in this section focuses on a typical passenger flow in the airport domain

presumed expectation by the airport authority and security that passengers who travel to the airport domain involve some interest in the functions of the airport. This analysis of airport functions will be discussed in greater detail under the decomposition of the airport system.

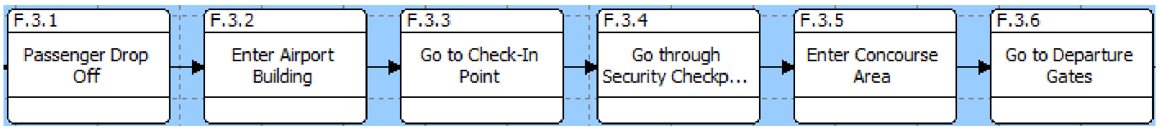

Figure 5. Typical Passenger Flow within Airport Domain (Object Movement Route).

(1) F.3.1 Passenger Drop Off. Regardless of the mode of transportation used to commute to the airport, all passengers arriving at the airport domain would generally commence their movement through the different phases (Figure 5) from the passenger drop off area. The starting point could be the vehicular drop off area by the curbside, the train station platform, or the bus terminal serving shuttles. Passengers residing in a hotel within the airport domain may enter the system via other connection means such as internal transit system or even by foot.

(2) F.3.2 Enter Airport Building. From the drop off point(s), passengers would enter the confines of the main airport building to start the traveling procedures as required by airlines and airport authorities.

(3) F.3.3 Go to Check-In Point. The confirmation of an individual's intention to board and fly on the scheduled flight could be performed via one of the many means available. According to Delta Air Lines, a passenger could possibly adopt one of the five different ways[15] to check in on any given traveling day (DELTA, 2013). With different airlines having varying check-in procedures, individuals who have checked in online could potentially proceed straight to the next phase of security checks upon arriving at the airport, completely bypassing the need to visit any airline counter or airport kiosk. Individuals who are checking in at the airport domain would need to

[15] The five ways are (1) to check in physically at the airline counter, (2) online check-in, (3) Handphone application and eBoarding Pass, (4) physically at airport kiosk and (5) physically at airport curbside.

process their check-in by physically going to one of the check-in points available within the airport domain.

(4) F.3.4 Go Through Security Checkpoints. Depending on the nature of the travel to the airport, travelers going to the airport for different purposes[16] undergo various forms of security screening. A centralized airport passenger security screening has been implemented for all traveling individuals to identify the presence of security defects. Checking of travel documents, inspection of individuals through the use of walk-through detectors, and physical inspection of carry-on items are being conducted here. Besides providing a physical demarcation for a security boundary within the airport domain, separating the sterile area (commonly known as the concourse area) for security screened passengers from the non-sterile area or the common public accessible domain, this centralized security screening also serves as a zone of interaction between security screeners and the traveling passengers.

(5) F.3.5 Enter Concourse Area. After passing through ("clearing") security, passengers could move through hallways connecting the concourse area or enter the concourse area directly, leading to the access area beyond the security checkpoints to their respective departing gates. This sterile area is an out-of-bounds area except for all security screened passengers and the relevant support personnel working within the area.

(6) F.3.6 Go to Departure Gates. Within the concourse area are the departure gates. The final access points to the respective flights are defined by the doorway to the aerobridge connecting the aircraft to the terminal or the doorway to the tarmac for boarding directly from tarmac. Current procedures require individuals traveling through airports to present certain types of documentation, e.g., boarding passes and sometimes photo identification, at the various gates for boarding. As shown in Figure 6, a typical layout of the above listed parts make up the whole of the airport security and its boundary types.

[16] Some examples include delivery of goods, individuals working at the airport within the concourse area, aircraft cleaners.

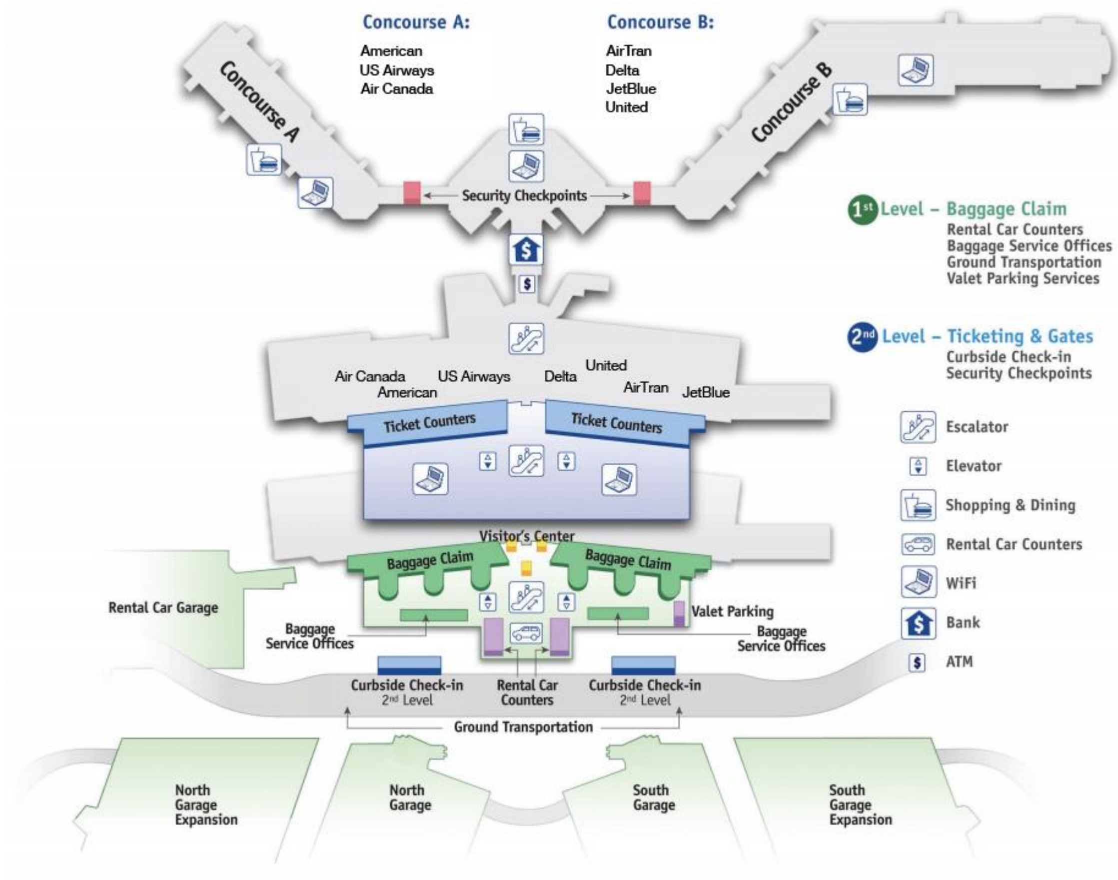

Figure 6. Typical Layout of Airport Terminal ("Terminal Guide–Richmond International Airport," n.d.).

C. DECOMPOSITION OF AIRPORT FUNCTIONS AND PROCESSES

Decomposition of airport functions and processes entails breaking down the airport system into its constituent functional parts to facilitate the analysis of the system and the interactions of the objects within the system.

1. Airport Process Decomposition

While the airport system exists to serve many different functions within its physical boundaries, the focus of this study is on the functions and processes relevant to the passengers as stakeholders in the analysis of the airport passenger security system. See Figure 7 for the process decomposition of the airport system.

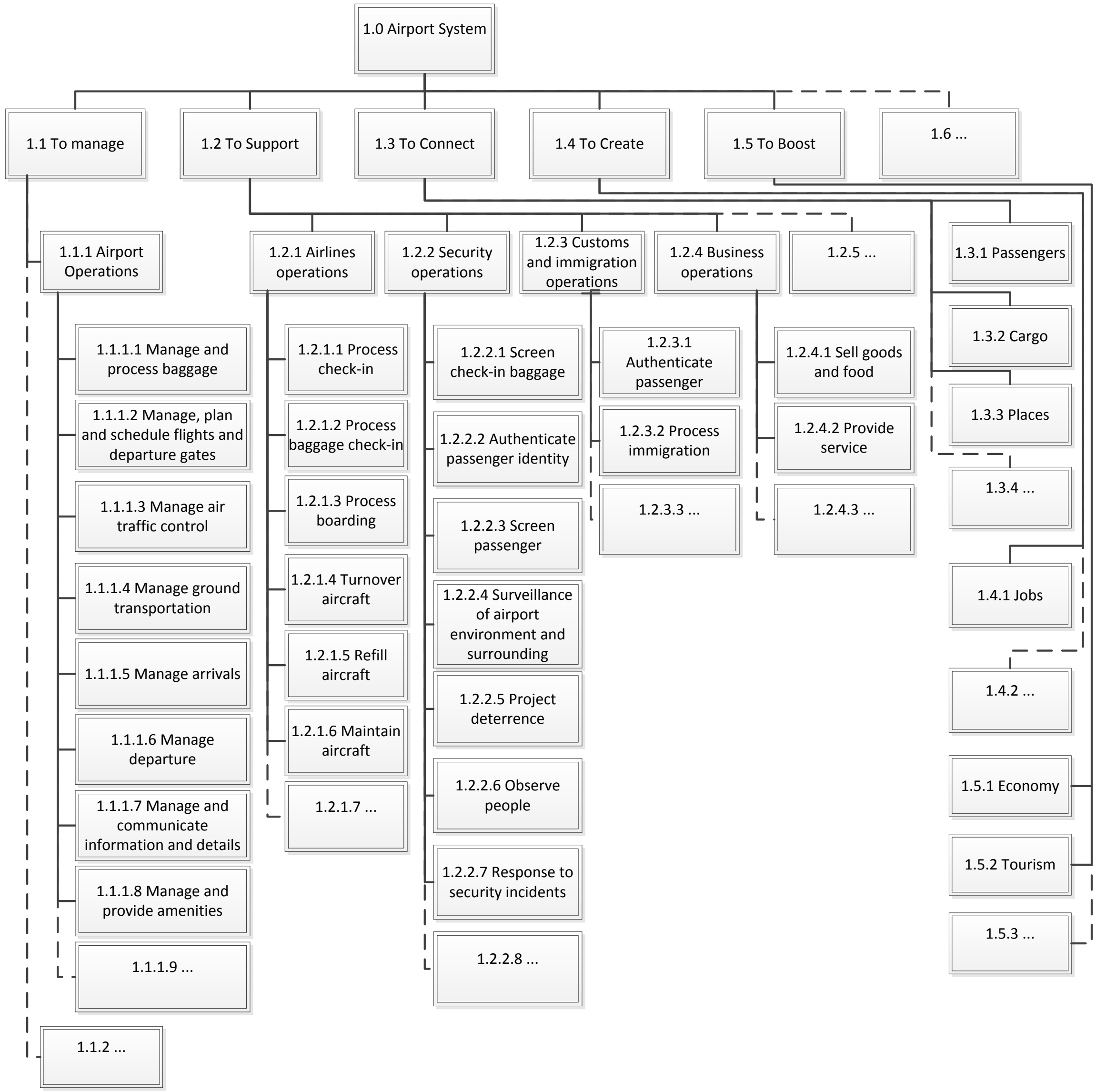

Figure 7. Process Decomposition[17] of Airport System.

2. Passenger Process Decomposition

As each stakeholder has a significantly different perspective of the airport system and the system's requirements (Buede, 2009), each of them will behave, interact and response differently within the context of the system based on their effective needs and motivation. While there are many stakeholders involved in the airport system, the focus

[17] There are other processes under the airport system that are reflected as "…" since they are not be the focus of this decomposition.

on passengers within the system is predicated on the intent to use the aircraft as a weapon. The process flow block diagrams in Figures 8 to 13 depict the typical passenger process and the detailed breakdown of its associated processes.

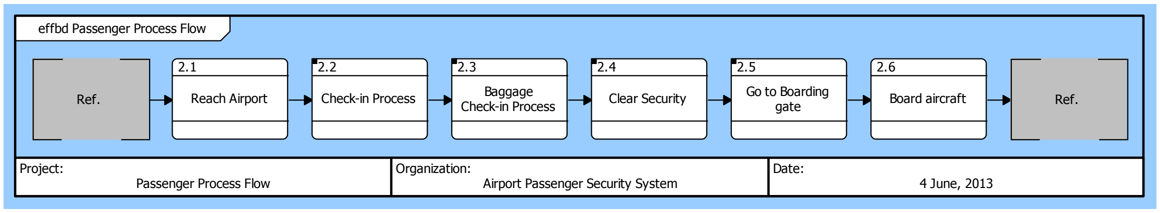

Figure 8. Typical Passenger Process Flow Block Diagram.

A typical passenger in the airport system would generally perform the processes shown in Figure 8 as part of the airport process flow to get on board a scheduled flight.

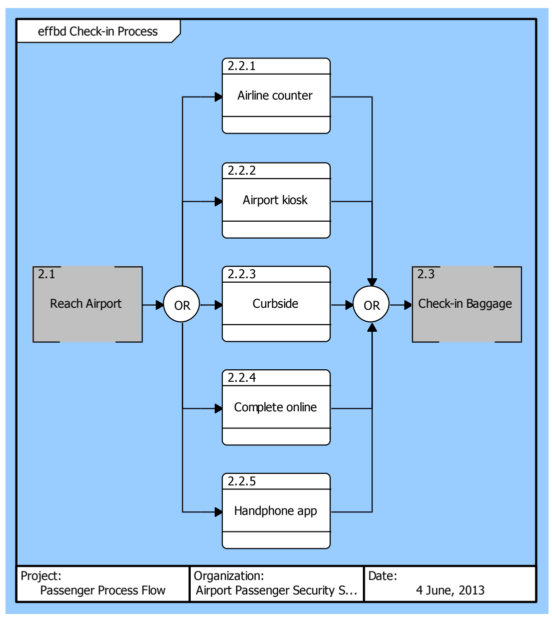

Figure 9. Check-in Process.

The check-in process can be performed through one of the five possible ways by the stakeholder (in this instance, the passenger) and could possibly vary between passengers or even between flights by the same passenger.

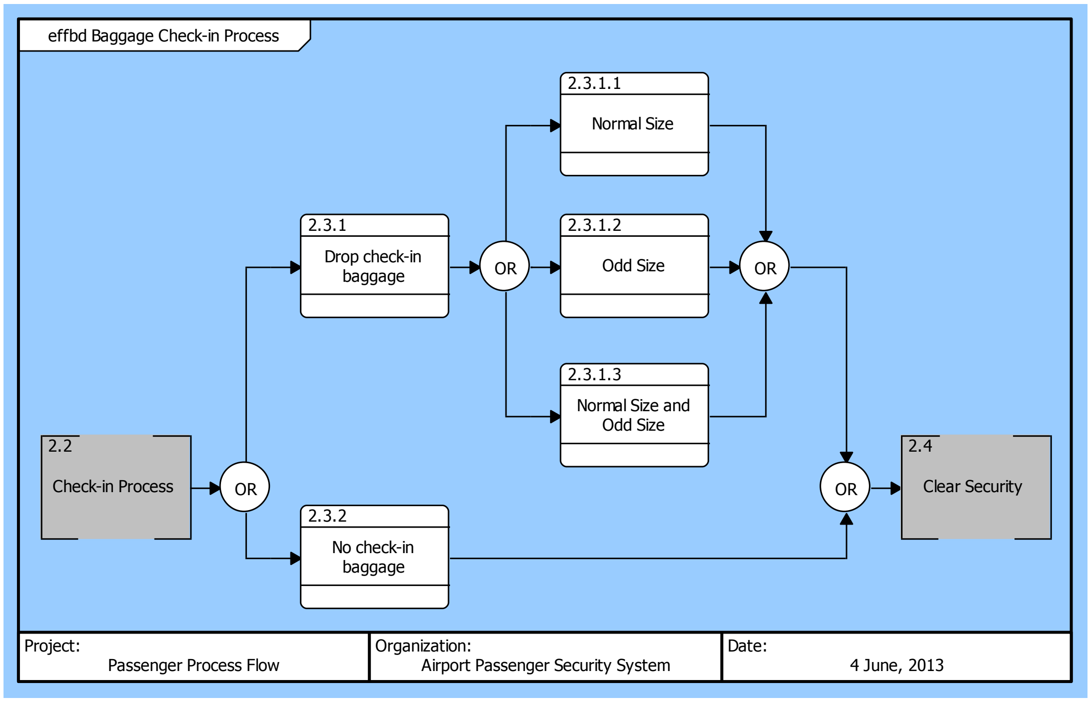

Figure 10. Baggage Check-In Process.

Depending on what the passenger brings along for the flight, he has the ability to perform this process of baggage check-in whenever necessary.

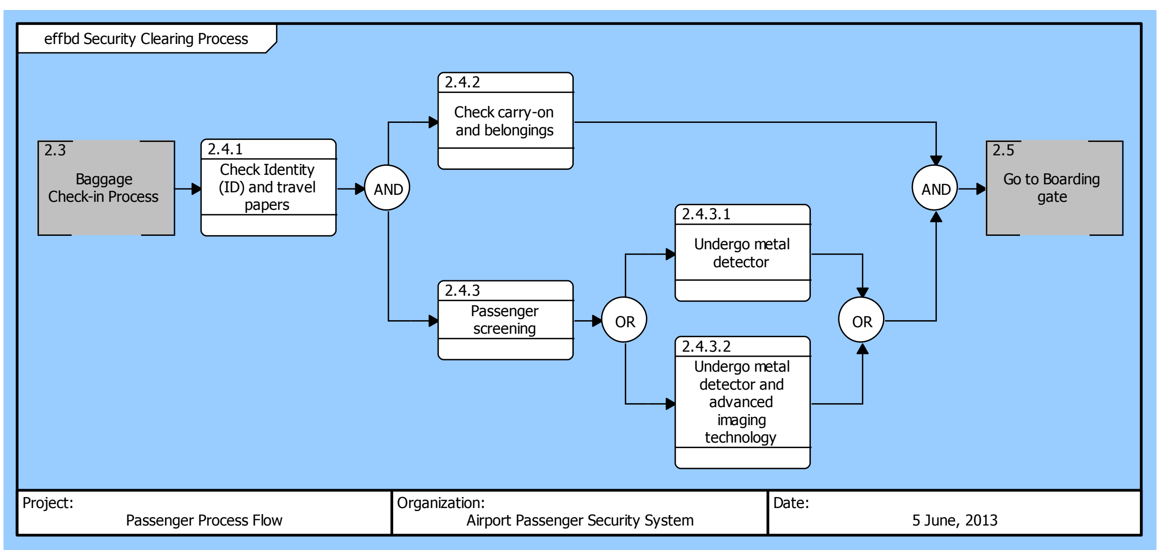

Figure 11. Clear Security Process.

All passengers would be mandated to perform this process to be security screened and cleared for boarding on any scheduled flight.

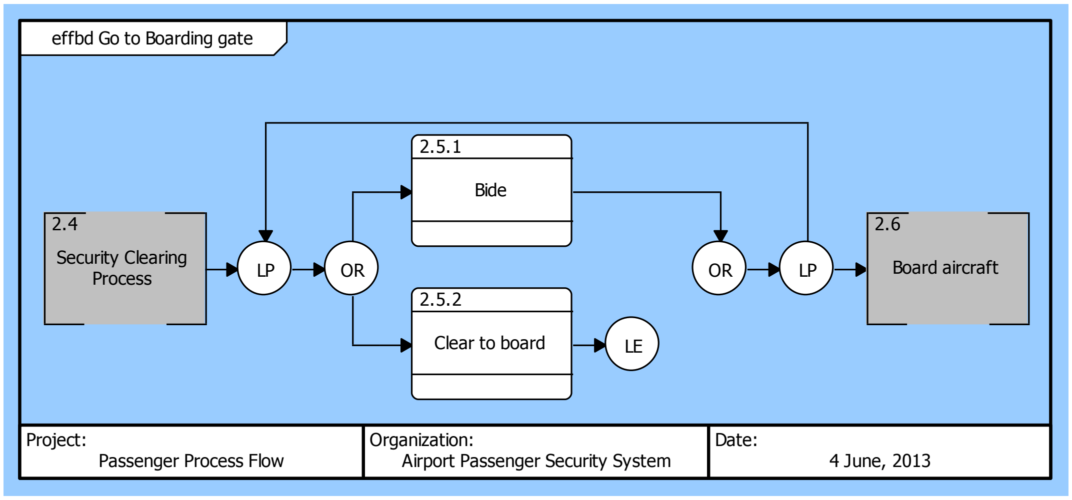

Figure 12. Go to Boarding Gate Process.

As shown in Figure 12, security screened passengers would either wait for the departure gates to be opened or would proceed directly to board if boarding has already commenced when they reached the departure gates.

Any time during the passenger's process flow within the airport system, the passenger has the option to perform any activities associated with the "Fulfill Wants/Needs" process as shown in Figure 13. The sub-processes could be performed by the passenger any time between the main functions that he undertakes the moment he arrives at the airport domain until he reaches the gate to board the scheduled flight.

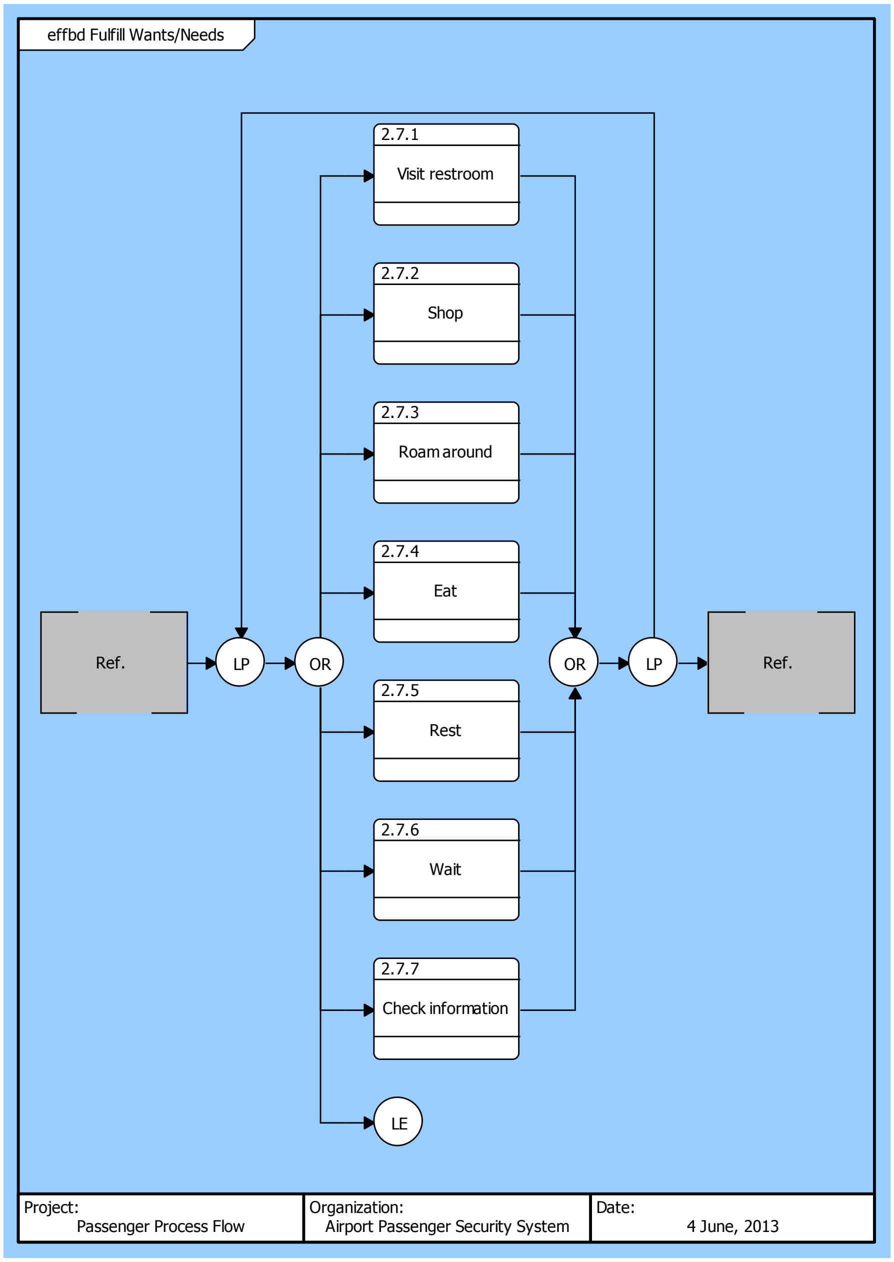

Figure 13. Fulfill Wants/Needs.

D. INTERACTIONS BETWEEN OBJECTS TO CREATE FUNCTIONS

Objects within the airport system interact intimately with stakeholders such as the passengers since the airport system provides services through its functions and processes, and passengers use these services to meet their wants and needs. This section examines and discusses the results of some of the core interactions between the objects (and their derived functions) within the airport system with the passenger stakeholder.

1. Process Passenger Check-in (airport kiosk perspective) versus Process Check-in (Passenger Perspective)

The airport kiosk serves as one of the available means for a passenger to check in for a scheduled flight. In this instance, the airport kiosk interacts with the passenger to provide the function of passenger check-in to fulfill the passenger's check-in function. See Table 1 for the tabulation of the results of the interactions between the objects of airport kiosk, passenger and airport building.

Table 1. Results of Interactions between Functions and Processes of Airport Kiosk, Passenger and Building.

Airport System		**Passenger**		**Building**	
Physical Object	**Function**	**Process**	**Physical Object**	**Function**	**Physical Object**
A1.0 Kiosk	1.2.1.1 Process passenger check-in.	2.2.2 Process Check-in.	P1.0 Passenger	F1.0 Provide Support (e.g., physical floor, lighting).	B1.0 Floor
Results of Interactions					
		Walk up to kiosk.			
A1.1 Display	Display menu/options.	Select check-in option.			
A1.2 Card Reader	Transfer card to reader.	Insert credit card.			
	Read card.				
	Transfer card to passenger.	Remove credit card.			
A1.3 Check-in processing system	Process card information (match database, retrieve, display).				
A1.4 Display	Display passenger flight details.	Assess details.			
A1.3 Check-in processing system	Process check-in confirmation.	Confirm and check-in (presses option)			
A1.5 Printer	Prints boarding pass(es).	Remove boarding pass(es).			
A1.6 Kiosk Structure	Support kiosk.			Support structure.	
		Stand on floor.		Support passenger.	

Arising from the initial analysis of interactions between the objects of airport kiosk and passenger, additional interactions are identified that may enhance airport security. For example, airport building surfaces can be used as another object to interact with a passenger. In this instance, the building support structure provides a means to record the shoeprint while the passenger is checking in at the airport kiosk. From the interaction between the passenger and an appropriate sensor on the building floor, one could record or identify a shoeprint. For example, a hyper-spectral sensor could compare bands of equal energy partitioning with a standardized set of observable parameters (e.g., pollen, soil composition, material constituents). Multiple spots within the airport system could provide opportunities for such interaction with the passenger. Two measurements of the passenger's attributes may provide an exploitable means for security analysis:

- A passenger's shoes could be scanned by optical sensors performing a hyper-spectral analysis to identify materials and compositions underneath the shoes.
- The passenger's weight could be captured in database records for subsequent reference and matching.

Applying the methods of physical, functional, and process decomposition within a supply chain structure provides an opportunity for capturing additional information pertaining to the passenger. This hyper-spectral information (Hammer et al., 1996; Hammer et al., 2001) could tell a story of where the passenger had been prior to the airport. Measurement of weight and spectral content could be incorporated and designed into interaction spots between the passenger and the building floor at strategic locations across the paths of passenger flow from the moment the passenger arrives at the airport until reaching the boarding gate. While the passenger may not walk or stop over the designated interaction spots (e.g., a passenger may choose to check in online instead of at the airport kiosk), data could still be collected so long as there are sufficient collection points spread across the entire airport system. These data points could provide a profile of the passenger as he passes through different phases of the passenger flow (refer to flow as depicted in Figure 8) in the airport system. From a single profile of one passenger, multiple interactions with the same passenger could result in a pattern of behavior that accumulates over different trips, thereby providing a database and records. Similarly, collecting information on all passengers will uncover common patterns of behavior that can be used for the identification of behavioral anomalies in passengers. Security would now be able to better assess and profile a particular passenger based on the possible places that he could have been to or on the particular activity that he could be involved with prior to traveling to the airport. In a like manner, the weight information captured, when matched against existing records of the passenger(s), could also shed some light on the passenger since the last time he traveled. Any drastic fluctuation of passenger weight as he flows through the airport system toward the departure gate could possibly signify that he may be carrying additional weight on his body, something that might be worth verifying by security.

2. Process Baggage Check-in (Airline Counter Perspective) versus Check-in Baggage (Passenger Perspective)

Passengers on domestic flights commuting for business purposes or short trips would likely be traveling light with only hand-held baggage compared to other passengers traveling for vacation, relocation and extended visits on both domestic and international flights. Such passengers are likely to have check-in baggage. For each of the available passenger check-in options, there are corresponding baggage check-in options (James, n.d.) to support passengers traveling with baggage that needs to be checked in. In one of these options, the airline counter interacts with the passenger to provide the function of processing baggage check-in.

The decomposition of the baggage check-in process and the results of interactions between the objects of airline counter system[18] and the passenger based on a typical case for a passenger processing check-in baggage are shown in Table 2.

[18] The different objects at the airline counters supporting the baggage check-in function and associated processes.

Table 2. Results of Interactions between Functions and Processes of Airline Counter System and Passenger.

Airport System		Passenger	
Physical Object	**Function**	**Process**	**Physical Object**
A2.0 Airline Counter System	1.2.1.1 Process baggage check-in.	2.3.1 Drop check-in baggage.	P1.0 Passenger
Results of Interactions			
		Walk up to airline counter.	
A2.1 Weighing Scale	Support check-in baggage.	Place check-in bag on weighing scale.	
	Measure weight of individual bag.		
	Display weight of individual bag on screen.		
A2.2 Airline ground crew	Check ID and travel documents and process check-in baggage.	Present ID and travel documents.	
	Key in passenger details to computer system.		
A2.3 Airline computer system	Assign check-in baggage to passenger records.		
A2.2 Airline ground crew	Check weight of check-in bag		
	Print bag label(s) for bag.		
A2.4 Printer			
A2.2 Airline ground crew	Remove bag label(s) from printer.		
	Peel bag label(s) and affix on bag(s).		
	Transfer baggage onto baggage conveyor belt (part of baggage handling system).		
	Starts baggage conveyor belt to move check-in baggage for screening, processing and loading.	Remove labeled odd-size baggage[19] for separate check-in.	
	Give claim check for baggage to passenger.	Check number of pieces of check-in baggage against number of claim check for baggage.	
	Return ID and travel documents.	Keep ID and travel documents.	
A2.5 Bag label(s)	Provide identification details (destination, reference number) for baggage.	-	
A2.6 Claim check for baggage	Provide copy of identification details for baggage.	Safe keep claim check for baggage.	
A2.7 Baggage conveyor belt	Move check-in baggage for screening, processing and loading.	-	
		Leave airline counter.	

[19] Depending on the specific airport procedures, passengers may be required to bring the labeled odd size baggage from the airline counter to a separate the TSA counter accepting and processing odd size check-in baggage.

From the analysis of the interactions between the objects of the airline counter system and the passenger, it can be seen that the airline ground crew is the key object providing the interface for the baggage check-in processes. The assumption taken in the airline counter system is that the airline ground crew handling a particular baggage check-in process is a reliable person who has passed some form of personnel screening (Morrison, 2002) as part of the employment process and is trusted to perform the processes without undermining baggage security. In the design of the EBSP layer of security measures, trusting the airline ground crew to handle check-in baggage processes without undermining baggage security is further backed up by the 100% screening of all check-in baggage to identify any baggage that could potentially compromise security. Similarly, in the case of a passenger self-help baggage check-in at the airport kiosk, any act by the passenger to tamper with the check-in baggage[20] would likewise be discovered by the EBSP. Nevertheless, this screening of check-in baggage could only be as effective as the individuals operating and running the system. This provides a potential area where airport security could exploit the existing monitoring system on the EBSP to extend the coverage to include monitoring of activities around and within the EBSP.

3. Screen Passenger (Security Checkpoint Perspective) versus Clear Security (Passenger Perspective)

The passenger security screening system itself is an SoS composed of the X-ray system (A3.1) and its associated objects, the metal detector system (A3.2) and its associated objects together with the human system in the form of the checkpoint security officer (A3.3). Collectively, these systems and objects interact with the passenger based on the defined security processes to provide the function of screening passengers and certifying them for entry into the concourse area and eventually to board the scheduled flight. The decomposition of the clear security process and the resulting interactions are shown in Table 3.

20 This includes odd-size baggage that is checked-in separately.

Table 3. Results of Interactions between Functions and Processes of Passenger Security Screening System and Passenger.

Airport System		Passenger	
Physical Object	**Function**	**Process**	**Physical Object**
A3.0 Passenger Security Screening System	1.2.2.3 Screen Passenger.	2.4 Clear Security Process	P1.0 Passenger
A3.1 X-ray System	1.2.2.3.1 Screen carry-on and belongings.		
A3.2 Metal Detector System	1.2.2.3.2 Screen individual.		
Results of Interactions – between X-ray system and Passenger			
A3.3 Checkpoint security officer	Control, direct flow and instruct passengers to different screening station lines.	Enter passenger security checkpoint.[21]	
	Evaluate passengers entering the screening system.		
A3.1.1 Table	Support items (trays, carry-on, belongings.	Put belongings on table.	
A3.1.2 Tray	Hold carry-on and belongings.	Pick up tray.	
		Put carry-on in tray.	
A3.1.3 Conveyor system	Support tray(s).	Put tray with carry-on on conveyor belt.	
	Present tray(s) to X-ray machine at a particular rate of flow.		
A3.1.2 Tray	Hold carry-on and belongings.	Pick up another tray.	
		Remove belongings and put them in tray.	
		Remove electronic items from bags and put them in tray.	
		Remove water bottle, food container, 3-1-1 carry-on from bag(s) and put them in tray.	
		Empty pockets, remove belt and shoes, and put them in tray.	

[21] This refers to the point after the passenger has cleared the DTC checks and is next in the line to enter the security checkpoint.

A3.1.4 X-ray operator	Switch on conveyor system.	Put tray with belongings on conveyor belt.	
	Move conveyor belt forward.	Proceed to go through metal detector screening (see interactions with metal detector system).	
A3.1.5 X-ray machine	Reproduce image(s) of items in tray(s).		
	Send image to display unit.		
A3.1.6 X-ray display unit	Display received image.		
A3.1.4 X-ray operator	Assess and evaluate image on display unit.		
	Stop, reverse conveyor belt if necessary.		
	Request assistance for additional physical check(s) on suspicious item(s).		
A3.3 Checkpoint security officer	Identify and ask owner of suspicious item(s) to step aside for additional check(s).	Acknowledge as owner of bag(s).	
	Request owner to open up bag(s) containing suspicious item(s).	Assist and open up bag(s).	
	Examine, check and evaluate suspicious item(s).	Remove suspicious item(s) for additional check(s).	
	Conduct test (if necessary) on suspicious item(s).	Keep checked item(s).	
	Transfer tray(s) from end to start of conveyor system.	Take carry-on off tray(s).	
[redacted]		Keep belongings from tray(s).	
		Take belt, shoes and wear them.	
		Return tray(s).	
		Exit security checkpoint.	
A3.4 Queue post and lines	To separate and demarcate lines and the different screening stations.	Stay within lines.	

Results of Interactions – between Metal detector system and Passenger			
A3.2.1 Security officer manning metal detector station	Trigger and direct passengers to come through metal detector.	Wait for turn to go through metal detector as instructed.	
A3.2.2 Metal detector	Transmit signal to test for metallic object(s.)	Walk through metal detector.	
	Receive reflected signal.		
	Analyze reflected signal.		
	Sound alarm if metallic object(s) detected.		
A3.2.1 Security officer manning metal detector station	Observe passenger as they go through metal detector and watch for triggered alarm.		
A3.2.3 Anti-static mat	Support passenger.	Step aside for additional check(s) if alarm is triggered.	
A3.2.1 Security officer manning metal detector station	Check, assess and evaluate offending item(s).	Remove item(s) that triggered alarm.	
	Perform hand-held scan on passenger.	Present item(s) to security officer.	
A3.2.4 Hand-held metal scanner	Trigger alarm if metal is detected.	Wait for additional check(s) to be completed.	
[redacted]	[redacted]	Go through metal detector again if necessary.	

Analysis of the interactions between X-ray system and the passenger revealed a trade space between the elements of the X-ray technology, the competency of X-ray operator, the rate at which trays flow through the system and the processes governing the screening of carry-on baggage and belongings. From the function of presenting trays loaded with carry-on baggage and belongings by the conveyor belt to the X-ray machine for assessment, there is a possibility to speed up and improve the performance of security by means of resolving any bottleneck caused by the X-ray machine process. Similar to a supply chain, the bottleneck determines the throughput of the supply chain. This throughput is directly dependent on the number of trays waiting in the line (conveyor belt) to undergo security screening and the rate at which each of these trays clears screening. In an X-ray system, the conveyor belt is usually not fully optimized with trays lined up back to back. By providing more trays, passengers could potentially get ready well ahead of reaching the screening point, removing all carry-ons and belongings and putting these items into the trays. Compared to a bottleneck in a supply chain, when passengers remove their carry-on baggage and belongings right in front of the X-ray machine, the conveyor belt often runs without trays briefly. The speed at which trays clear screening is dependent on the X-ray technology and the corresponding flow rate associated with the conveyor belt, as well as the defect assessment competency of the X-ray operator(s) in keeping up with the flow.

While there are means to improve these elements, they are fundamentally dependent on the rule set as defined by the TSA screening guidelines. This set of security rules defined by the TSA has a causal effect on the passenger flow rate through the passenger security screening system and the total amount of time each passenger spends at the security checkpoint[22]. This defined rule set also provides the basis for the identification of known defects that the passenger security screening system is designed to undertake. Depending on the complexity of each rule, there is a function relating to the amount of time required for that rule to be checked off passengers going through the passenger security screening system. In additional to the rule set, there is a corresponding consequence on time spent at the security checkpoint as a result of known defects arising from the violation or ignorance of the rule set on the part of the first-time or non-frequent flyers who may not be familiar with the requirements.

The configuration of the security checkpoint in terms of the number of checking stations and lines and the number of security officers manning each of these offers a trade space for the throughput of the passenger security screening system. Given the same number of deployed security officers, there are two possible models of configuration. A configuration in which resources are spread out to maximize the possible number of checking stations and lines versus one with fewer stations and lines but with each being more optimally staffed. In the model of spreading out available security officers to

[22] A passenger whose carry-on and belongings have undergone x-ray screening and have personally gone through the metal detector may still need to spend time to resolve any alarm triggered by suspicious item(s), thereby increasing his time at the security checkpoint.

achieve the maximum number of security stations and lines, there would likely be stoppages in the flow of passengers in the passenger security screening system when suspected known defects are being stopped for assessment and evaluation by the security officer manning the station and line. While a fewer stations and lines configuration's defect assessing capability at any time is lower, it could potentially minimize stoppages in the flow of passengers through the system even in the presence of suspected defective passengers. Security officers who are not deployed to man the additional stations and lines could be redeployed to augment the remaining stations and lines by handling and resolving all potentially defective cases. These defective passengers could be "pulled" out of the line for separate assessment and evaluation by the redeployed officers while the continuous flow of passengers through the system continues undisrupted.

Observing and analyzing each and every passenger to identify potential defects[23] as they flow through the system provides another trade space for consideration. A centralized airport passenger security screening model only supports the observation and analysis of passenger behavioral traits with a broad common baseline that all of them are passengers scheduled for an upcoming flight. Decentralizing this security screening through relocating and deferring the security checkpoints to the respective departure gates or groups of departure gates would provide a more defined and narrowly scoped baseline in terms of having to observe and analyze behavioral traits and activities of passengers who are scheduled to be on the same flight. Chances are, passengers traveling on the same flight to the same destination may exhibit commonalities in behavioral traits associated with the particular flight or destination, thereby providing a more distinct basis for the identification of anomalous behavior compared to a more generic basis. In addition, pushing out the security checkpoints and screening to the departure gates also has other benefits. It would minimize the existing security requirements placed on all other non-passengers within the concourse area. In this configuration there is no longer a need to maintain a sterile area to match the security certified passengers after they clear the security checkpoint and enter the concourse area. With the security checkpoints at the

[23] These are not known defects as defined and listed by the TSA rule set but are rather behavioral aspects of individuals that could provide the slightest of indication that the passengers could be defective.

respective gates, the available time and space between clearing security checkpoints and boarding the flight at the respective gates reduces the set space for any possible change of passenger status to defective. There would be less opportunity for any passengers with a malicious intent to act and behave in a manner that would result in defects from the time they clear the relocated security checkpoint until they board the schedule flight. While this improves aviation security with terrorist using aircraft as a weapon, it can potentially open up and present other security risks to the airport operations or infrastructure now that security screenings are being pushed forward to the respective gates.

It can also be seen from the analysis of the interactions that a data capturing opportunity rests at the point before the start of the passenger security screening system. Passengers can scan their boarding pass to register the time of security screening before sending their carry-ons and belongings on tray(s) to the X-ray system. The ensuing results of the security screening or any subsequent details could be tagged to the records and data of the individual passenger. Similarly, the X-ray images could also be time stamped and tagged to the respective passenger. Besides providing useful information as part of real-time monitoring and tracking, this information collected over multiple travels of the same passenger could provide a reference profile for security exploitation and could come in useful during investigation. Any additional verification conducted on suspicious item(s) should also be time stamped and tagged to the respective passenger's records and data. The walk-through metal detector could also serve as one of the designated interaction spots for the collection of weight and hyper-spectral information pertaining to the passenger.

4. Surveillance of Airport Environment and Surrounding (Surveillance Camera Perspective) versus Fulfill Wants/Needs (Passenger Perspective)

Table 4. Results of Interactions between Functions and Processes of CCTV Surveillance System and Passenger.

Airport System		**Passenger**	
Physical Object	**Function**	**Process**	**Physical Object**
A4.0 CCTV Surveillance System	1.2.2.4 Surveillance of airport environment and surrounding	2.7.2 Fulfill Wants/ Needs (Shop)	P1.0 Passenger
Results of Interactions			
A4.1 Surveillance Camera	Capture footages within field of view (FOV) of surveillance camera.	Enter shop. Enter field of view of a specific surveillance camera. Walk around to browse merchandise. Pick up merchandise from display units to see, feel, "play" with item. Put merchandise back down on display units. Speak to a sales person to find out more about specific merchandise. Pick up shopping basket, push cart. Remove merchandize from display unit and put in shopping basket or push cart. Exit field of view of existing surveillance camera to enter sector (FOV) monitored by another surveillance camera. Leave shop to enter common airport domain.	
	Streaming of LIVE footage captured to video management system.		
A4.2 Video Management System	Receive incoming footage streams from various surveillance cameras.		
A4.3 Video Storage System	Record and store streamed footages in accordance to time sequence.		
A4.4 Security officer at command center	Select specific footage to be displayed, monitor and maintain oversight of footage on display.		
A4.2 Video Management System	Select specific footage as requested by operator and pipe it to display monitor(s).		
A4.5 Display Monitor(s)	Display live streamed footage piped by Video Management System.		
A4.4 Security Officer at command center	Select a specific segment of footage from a specific surveillance camera to be play back for analysis, assessment, etc.		
A4.2 Video Management System	Process play back request to connect to Video Storage System to retrieve footage.		
A4.5 Display Monitor(s)	Display retrieved footage from Video Storage System in play back request.		

From the analysis of the interactions between the CCTV surveillance system and the passenger, it can be seen that there is an avenue to monitor and track the passenger, his activities and interactions continuously from the moment he enters the airport system boundaries, which are being constantly surveyed by security sensors and surveillance cameras. His progress through the different phases as he approaches the departure gates could be tracked through a suite of surveillance cameras within the airport system providing coverage of his physical progression within the system. The coverage on a particular passenger captured by the various surveillance cameras could be stitched together to provide a pattern on the passenger's behavior, interactions and activities that he had undertaken across the different phases. Thus, a profile could be assembled and used for security assessment. Coupled with video analytics capabilities, this assembled footage could then be assessed and analyzed for anomalies that would otherwise be flagged for additional security verification.

V. INTEGRATED RISK MANAGEMENT

The concept of risks, uncertainties and the associated risk assessment of potentially defective goods as they flow through the supply chain are discussed in this chapter.

A. OVERVIEW

Risk is a structural property of the interactions between objects (Langford, 2012), an important result from interactions and processes within a system or SoS. Risk assessment and analysis form an integral part of the analysis of the airport passenger security system, providing context to the uncertainties and risks associated with the goods as they flow through the supply chain. There are two commonly implemented approaches to risk assessment based on the perspective of risk, either as a structure of objects (methodology) or as a process. Within the methodology-based perspective of risk, risk assessment can be temporal- or event-based depending on the set of pre-identified conditions; for example, risk assessments could be performed as part of a procedure when a specific event (such as foiled terrorist attempt) occurs. Process-based risk assessment occurs in the context of decision making (Langford, 2012). Additionally, a third approach to risk assessment is used in systems thinking. That is, risk is viewed as a consequence of actions and interactions between objects and processes (*nexus*). This approach is used in conjunction with structural objects and processes resulting in a system and an SoS perspective, combined (Langford, 2013).

- The SoS view promotes separation of the systems, implying a process-based approach. In the SoS view the objective is interoperability with high coupling and high cohesion.
- The systems view promotes integration of the systems at a meta-systems level, implying *objects*. In the systems view, the objective is interoperability with low coupling and low cohesion.

B. RISK INDEX (RI)

There are many ways to qualify risk assessment, and one of them is in the form of a risk index. From an SoS perspective, different systems making up the system would each have an RI that is additive in nature for the system compared to the system perspective of having a multiplicative RI. In the context of the airport passenger security system, the discussion on RI in the following segments focuses on the system perspective, assuming that the existing security system is a perfect one without any flaws (i.e., all entities and processes function as they were designed and intended).

1. Risk Index of Passenger Flow in Supply Chain

The concept of the RI in the passenger flow within the supply chain is that every passenger bound for air travel possesses a certain RI that would be computed as part of the risk assessment of the passenger as he/she flows through the various phases of the supply chain. According to the risk-based approach taken by TSA at all U.S. airports, the majority of passengers is deemed to be of low risk (TSA, 2013, March 14) and this translates to a low initial RI that is assigned to all passengers. In the flow toward the aircraft, the RI increases[24] as the passenger physically passes through each phase of the supply chain and progresses nearer to the aircraft, thereby increasing the assessed risk associated with the passenger on board the aircraft.

a. Risk Assessment Scenario

An individual (known as Andrew[25]) with a hand-held sized bag boarded a train traveling in the direction toward the airport at one of the stations along the transportation line. Like all other commuters on board the train, Andrew was assigned an initial (low) RI so as to initiate the tracking and monitoring of the individual's risk index. Andrew behaved like other commuters, settling in a seat. While his boarding location and direction were known, his intentions and final destination were unknown as he could potentially disembark at any station along the way. At one of the other stations, another individual (known as Billy) boarded the train with a hand-held sized bag and two check-in sized bags. Billy found a seat beside Andrew and sat down. Like Andrew, Billy was

[24] The assumptions taken in this increasing RI approach is that all passengers possess some form of risk and the fact that they have progress nearer to the aircraft would translate into a higher risk for the aircraft.

[25] For the purpose of ease of reference, arbitrary names have been given to individual passengers in the scenario.

also assigned a low RI except that his intentions and final destination were clearer compared to Andrew; Billy seemed bound for the airport. Andrew and Billy did not talk to each other throughout the journey. Andrew's final destination became clear as the train pulled out of the last station before the airport. With him on board the train which terminated at the airport, he would be exiting with all remaining commuters bound for the airport. As the train pulled into the airport perimeter, Andrew stood up and picked up one of Billy's check-in bags and went to the door, waiting for the train to stop at the airport. At the terminating station, both Andrew and Billy left in different directions, each with a hand-held bag and a check-in sized bag. Andrew has clearly taken one of Billy's check-in bags along with him.

At the airport, Billy went straight to a "Food & Beverage" counter, grabbed a coffee and sat down while Andrew visited the restroom. Thereafter, Andrew used one of the airport kiosks to process his check-in. He answered "Yes" to one of the system assigned questions asking if he had packed his check-in bag himself. In another question, he answered "No" when asked if his bag had ever left his possession. When Billy checked in at the airline counter, he gave similar answers to the same set of questions. In addition, he answered "No" when quizzed if he was traveling with someone else and if he knew anyone on board the same flight. Thereafter, both proceeded separately to the passenger security screening checkpoint to gain access into the concourse area. After verifying the authenticity of their travel documents and boarding pass details at the document checking station, the document checker arbitrarily waved them to separate security checks and inspection lines. Both Andrew and Billy were scheduled for the same outbound flight and have seats diagonally across the aisle. Like all other passengers, Andrew whisked through the physical inspections via X-ray machines and metal detectors without triggering any security violations. Although Billy had lots of sharp office materials such as geometry sets, t-pins and letter openers, he too was waved through the security checkpoint as none of them were items on the TSA's prohibited items that could not be brought onto airplanes in carry-on baggage (TSA, 2013, June 11). In the concourse area, Andrew met up with Charles who had earlier cleared the security though he was stopped briefly for having a couple of screwdrivers and scissors[26] in his carry-on bag that were within TSA allowable limits. Charles was slated to be seated beside Billy. David was seated at the gate area waiting for boarding. Earlier, he had his set of pocketknives surrendered at the security checkpoint while his set of knitting needles was allowed through (TSA, 2013, January 21).

b. Risk Index Discussion

This section focuses on the risk index allocated to an individual passenger and how it would change as a result of interactions and flow toward the aircraft, a mechanism for risk assessment of passengers.

(1) Airport Boundary Phase:

In the physical movement of a passenger in the airport system as shown in Figure 4, the passenger enters the airport boundary well before reaching the airport domain. The goal in this phase is to identify behavior or activities by individual commuters on board the train that would not be normally observed and differentiate them from the usual observations of train commuters. Once within the behavioral and functional boundaries of the airport, the focus switches to behavior or activities associated with commuters traveling to the airport now that it is confirmed that all remaining commuters on board are destined for the airport. The review of surveillance footage for the April 15 Boston Marathon bombings showed that the suspects "acted differently than everyone else. When the bombs blow up, when most people are running away and victims were lying on the ground, the two suspects walk away pretty casually" (Smith & Patterson, 2013).

Similar to the Boston suspects, individuals with suspected defects would likely act or behave differently from the rest of the normal passengers. Both Andrew and Billy were assigned an initial RI like all other commuters on board the train. During the journey on board the train, they did not exhibit any behavior that would have singled them out from the other commuters. As the train pulled into the airport station, however, Andrew took a check-in bag brought on board by Billy. That was an unusual

[26] Screwdriver less than seven inches and scissors less than four inches are allowed to be carried on board all flights (TSA, 2013, June 11).

event within the behavioral boundary of the airport, and it increased Andrew's RI to a level that warrants some attention from the security authorities. Similarly, Billy allowed this bag to be taken off the train by someone with whom he did not speak throughout the journey; this was not a normally observed act and it also increased his RI.

(2) Airport Domain and Check-in: Within the airport domain, tests and checks would be conducted to verify the presence of defects. Generally, there are two types of tests, Type 1 and Type 2. Type 1 tests are defined as being conducted to verify suspicion based on knowledge and information about passengers, while Type 2 tests are conducted to identify or detect new or known defects. The increased RIs of both Andrew and Billy as a result of their actions on board the train were indicative of the presence of potential flaws in the goods along the supply chain. Once the RI exceeded the pre-defined additional testing[27] threshold, suspected flaws would be tested for deficiencies. The goods would be subjected to a series of Type 1 tests, and depending on the outcome of these tests and checks, the RIs could increase, decrease or remain the same. Besides the outcome of tests and checks, RI could also be affected by other sightings of indifferent behavior and activities that continued to be monitored and tracked during the phase. Type 2 tests and checks are also conducted arbitrarily in this phase to identify or detect defects. Tests and checks could be incorporated as part of the mainstream supply chain process flow within the phase, such as a static built-in test in the form of questions and answers during check-in at airport kiosks or over the airline counters. Alternatively, tests and checks could be triggered dynamically whenever necessary and could be in support of both types of testing. Tests and checks could be activated anytime along the entire supply chain to verify the presence of defects or identify new or known defects within the goods. This could be in the form of interactions between security personnel and the respective passenger within the domain, be it standing in the line or moving around. These could entail simple conversational questions, such as asking where are the passengers traveling to, where did they buy their nice luggage, etc., and observing their responses including factual replies and non-verbal cues.

[27] These are tests conducted in addition to those done at the security checkpoints.

> While facial expression can provide meaningful insights into what a person is thinking and feeling, individuals can possibly put on a false face when they are lying, conniving, or trying to influence the perception of others through false smiles, fake tears, or deceiving looks. Observers would have to be mindful that these signals can be faked, so the best evidence of true sentiment is derived from clusters of behaviors, including facial and body cues, that buttress or complement each other. By assessing facial behaviors in context and comparing them to other nonverbal behaviors, one can use them to help reveal what the brain is processing, feeling, and/or intending (Navarro, 2008).

In this instance, Andrew's RI has further increased as his check-in reply did not match the activities that happened earlier on board the train; clearly he had lied. While Billy had not lied about his luggage, his RI had also increased by virtue of the fact that he is nearer to the aircraft. With each test being used as a basis to determine the RI of the individual of concern, tests and checks could be conducted throughout the remaining phases until such a point where the RI goes down to an acceptable risk index region or when the result of a particular test clearly indicates the presence of defects in the form of security violations that warrant the goods be removed from the product process and out of the supply chain (i.e., ban or stop from boarding the scheduled flight through arrests or assistance in further investigations).

(3) Security Checkpoints: In this phase, passengers are checked and inspected against known defects, such as having the matching (passenger matches the ID that was presented) travel documents (including passport/government issued ID, valid boarding pass, etc. that are authentic); passenger and respective carry-on bags being x-rayed and inspected for the presence of TSA prohibited items. These are generally Type 2 tests aimed at detecting known defects though they could be used to supplement Type 1 testing in certain scenarios. The outcomes of these tests and checks for known defects would be conclusive with either a pass or a failure. Any inconclusive outcome would be tested repeatedly until a conclusion is made. The assumptions taken in this phase would be that all security checks and tests administered are effective and competent in the detection and identification of known security defects or observations. At the end of the phase, all individuals passing the security tests and checks against known defects would have their RI increased given that everyone have progressed nearer to the aircraft.

However, an individual's RI would increase more if the security tests and checks fail. These variations of the RI would be based on one of the following possible outcomes.

- Passed through security checkpoint without any security defect or observation. Passenger clears and passes through the checks without the detection of any prohibited item. RI would be maintained since most passengers were assumed to enter the phase with a low RI, so not having any security violation would maintain that low RI. There would be no unintentional reduction of RI of a suspected passenger because no new defects were identified in this phase as opposed to the observations of his behavior and activities that were dubious in the earlier phases. However, the cumulative effect on the RI is such that it would increase at the end of the phase as passenger moved nearer to the aircraft.
- Stopped at security checks with security defect(s) or observation. Passenger subsequently clears and passes through with the rectification of the defect or observation, possibly through the removal of the offending item(s) (i.e., thrown away or confiscated). With the rectification of the defect, the RI would be maintained though the type and nature of the security observations would be noted for subsequent reference. Similarly, the cumulative effect at the end of the phase constitutes an increased RI.
- Stopped at security checks with security defect(s) or observation. Passenger physically arrested and removed from flight with the offending item(s) being detained. RI would increase beyond the defect threshold following the arrest. Type and nature of security observations would be noted for future reference.

Both Andrew and Billy cleared the security checks without any security defect and had their RI increased like all other passengers at the end of the phase, though an observation was made on Billy's possession of a large quantity of sharp office materials. Charles who did not have any prior observation from the earlier phases cleared the security check also with an RI within the acceptable region. However, observation was made on his possession of screwdrivers and scissors. David had been stopped at the security checks for a brief clarification after pocketknives were found in his carry-on bag. The quick rectification of the detected security defect[28] did not increase his RI though his RI went up at the end of the phase as a result of his progress toward the aircraft.

[28] Defect rectified through the surrendering of the detected pocketknives.

(4) Concourse and Departure Gates: As the goods flow through this last phase of the supply chain, tests and checks continue to be conducted on the suspected goods that have yet to be verified as defect free or within the acceptable risk index. Dynamic Type 1 tests would continue to be conducted on these suspicious goods until the RI reaches an acceptable risk index level, exceeds the defect threshold that would result in an arrest or when boarding commences, whichever occurs first. At the same time, goods would also continue to be monitored and tracked for behavior or activities that could affect RI. Exhibited behavior could be mapped against earlier exhibited behavior for consistency matching. Any significant deviation from the earlier exhibited behaviors or any variation from behaviors exhibited by passengers bound for the same flight[29] at the gate area could result in a further increase of RI. Consistency in behavior against earlier behaviors and behaviors of passengers bound for same flight would maintain the same RI level. RI could be reduced if the observed activities are conclusive that the goods are defect free. An example would be the voluntary check-in of all carry-on bags by a suspected individual who now no longer has access to his carry-on bags.

c. Analysis of Risk Index

An example of the risk index profile plot for the respective passengers as they progress through the various phases toward the aircraft is shown in Figure 14.

[29] Behaviors of passengers from the same flight could be further categorized into same gender passengers who have similar profiles in terms of age, marital status, etc.

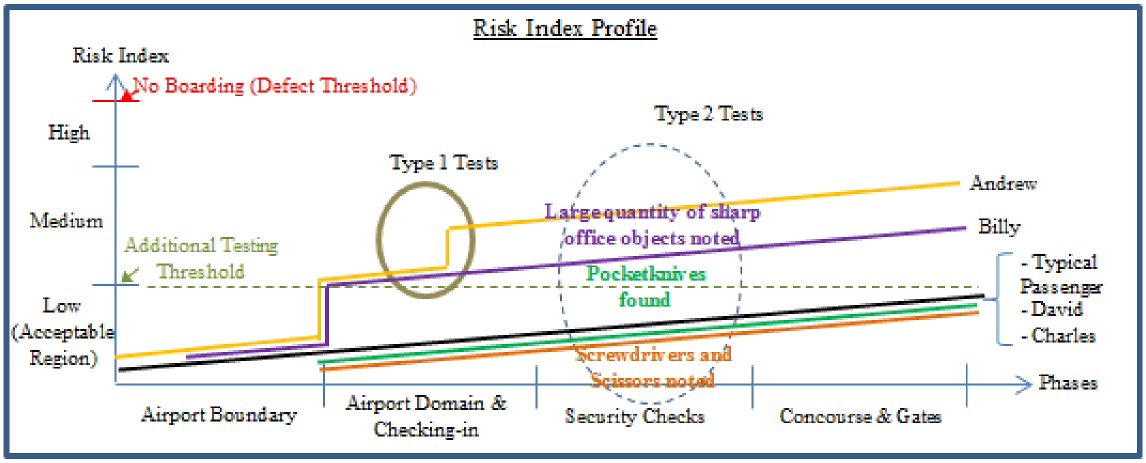

Figure 14. Passenger Risk Index Profile.[30]

The initial phases of the supply chain flow would focus on identifying goods suspected of being potentially defective. Once a particular good is suspected to be defective, it would undergo a series of Type 1 tests to verify the presence of defects. Besides the Type 1 test, a Type 2 test would also be conducted to identify new or known defects. Depending on the outcome of the tests and checks, this entire process could well stretch over the different phases until boarding with a lowered RI or a breached RI (one that had exceeded the RI defect threshold).

None of the tracked individuals' RI has breached the defect threshold though Andrew and Billy had RIs above the acceptable region. These two passengers have a higher risk index profile than the normal passenger. However, on its own, the RI within the medium risk sector may not be a concern. In a similar fashion, two similar tests conducted separately may seem not to have any intrinsic meaning. However, the co-relation of RIs with their associated events could actually point to some useful information, especially when tests results are correlated with an earlier observed activity that required further scrutiny. In this instance, tracing the monitored activities, behaviors and observations of the individual passenger the moment he enters the boundaries of the airport system and then mapping them alongside each other for analysis and comparison to identify *commonalities or differences* provides insights to the observed situation.

[30] Gaps have been intentionally created in the risk index profile to delineate the respective passenger's risk profile plot across the different phases.

The Type 1 tests[31] administered separately on Andrew and Billy at different locations and test stations have linked them together based on what had happened earlier on board the train when Andrew took Billy's check-in bag. This observation was a result of the interaction of information between the test system and the monitoring system and the ability to synthesize both pieces of information to produce the conclusion of suspected defect. It would appear that there was something *unusual* about the four passengers. From the observed activities and interactions (Andrew linking up with Charles at the concourse, Andrew picking up Billy's check-in bag, Charles seated beside Billy) they appeared to be linked and to know each other though this is not explicitly displayed or shown. David likewise has a common link with Billy and Charles in the form of less common observations noted during security screening checks in terms of possession of sharp objects.[32].

These *connections and linkages* of observed activities and behaviors, coupled with the details of security screening of the corresponding check-in bags and other associated information[33] available to the airport security system, provided a systems perspective in the analysis of the collective risk index profile associated with all passengers on board the same flight. This collective picture for a particular flight provided a basis for the decision on the type of security measures or safeguards that could be implemented in preparation for any uncertainties onboard the aircraft subsequently. In this instance, the collective risk index for the flight has exceeded the individual risk index, entering the medium-high risk sector, given the dubious relationships amongst the four passengers and the pattern that they collectively exhibit (in the form of bringing unusual sharp objects on board the flight). The fact that it was inconclusive to dismiss the presence of suspected defect(s) in the passengers further prompted the need for additional safeguards on board the flight.

[31] These are questions on packing of check-in bag and if the bag had ever left the individual's possession.

[32] Sharp objects such as knitting needles and screwdrivers could be used as a weapon on people ("Scotland's courts seize thousands of knives," 2011) (Shupe, 2013; Kaplan, 1993).

[33] Refers to information that serves as inputs into the airport system. For example, information on the manner in which the flight tickets were booked (tickets booked together, bought using the same credit card, etc.)

d. Application of Real-time Monitoring and Tracking of Risk Index Profile

According to Fernandez and Jones (2013), a disgruntled man was hurt after detonating a home-made explosive in the Beijing airport on 20 July 2013. As reported by FlorCruz (2013), the wheelchair-bound man was stopped by airport security when he began distributing leaflets to publicize his cause. "Shortly after his standoff with airport security, the disgruntled petitioner detonated his devices" (FlorCruz, 2013). Airport security had seen the wheelchair-bound man distributing pamphlets earlier and stopped him without further actions. While the wheelchair-bound man was not a passenger scheduled for any flight, the concept of risk index would probably have made a difference in this case. Had the man's movements within the airport boundaries been tracked with his risk index being profiled and monitored, there could been tell-tale signs that would have possibly flagged him for earlier security intervention.

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VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

A systems perspective was taken to investigate the airport passenger security system with the intention of identifying new perspectives on security and ways to enhance aviation security. In the analysis of the airport passenger security system, a supply chain approach was adopted to detect defects in passenger for security. Passengers were viewed as goods moving along the supply chain with each phase being a means to check for security conformance, to be defect-free and ready for boarding. The supply chain approach coupled with the methodological analysis of interactions between airport objects and passengers (as objects) as the later flow toward the aircraft provided insights and new perspectives on the passenger security system. Through this process, new security measures and processes were identified.

Numerous data acquisition opportunities exist within the supply chain to allow security to assess and profile individual passengers. Based on the possible use of hyper-spectral analysis of passenger shoe to identify materials and compositions underneath shoes, security authorities could have a clearer picture of the possible places the individual could have been to or particular activity that he could be involved with prior to the travel to the airport. The analysis of the interactions between the X-ray system and the passenger revealed a trade space between the elements of the X-ray technology, the competency of X-ray operator, the rate at which trays flow through the system, and the processes governing the screening of carry-on and belongings. While there are means to optimize this trade space for a more efficient throughput of passenger during screening, the elements are fundamentally dependent on the defined rule set for security screening.

The current security concept of batch screening of passengers through a centralized passenger security screening model could be further improved. Correlation between passengers and their scheduled flights and between passengers on the same flight could be achieved through decentralized screenings at the respective departure gates or groups of departure gates. This decentralized security screening model would provide a more refined baseline in terms of behavioral traits and activities of a common group of passengers bound for the same aircraft, thereby increasing the granularity of the security assessment. Compared to a centralized security screening model, the decentralized security screening at departure gates also minimized the set space for any possible change of passenger status to defective.

The existing surveillance capabilities within and around the airport boundaries could be used to piece together a real-time profile of every passenger based on the pattern of behavior, interactions and activities undertaken across the different phases toward the aircraft. Coupled with the concept of RI profiling of every passenger, this monitoring and tracking of individual profiles and status could improve the probability of identifying potentially defective passengers before they board any aircraft.

While improvements to the identified security measures and processes could enhance aviation security, the airport passenger security system can only be as effective as the individuals operating and running these processes, as human beings remain a vulnerable inside link that is susceptible to exploitation by terrorists.

B. RECOMMENDATIONS

In the interest of similar area of studies, future research could consider expanding the scope of analysis beyond the airport passenger security system to involve other objects within the airport that have interactions with the aircraft or with any other objects. These other objects may include passengers and flight crew onboard the aircraft.

Arising from the thesis research, the existing airport infrastructure was identified as one of the key limitations of the current system. This was an inherent limitation given that the post 9/11 security measures were "quickly" incorporated into existing airports at that time, working around constraints posed by the airport infrastructure. Trade-offs were made within the system, maximizing one aspect while using the remaining variables to trade-off security. From a cost-effectiveness perspective, aviation travel was "secured" without regard for cost within a short timeframe after 9/11. While the cost-effectiveness of the airport security system has improved over time, as depicted in Figure 15, it has a fixed baseline, possibly constrained by the inherent infrastructure, something that can be resolved if the limitation was changed.

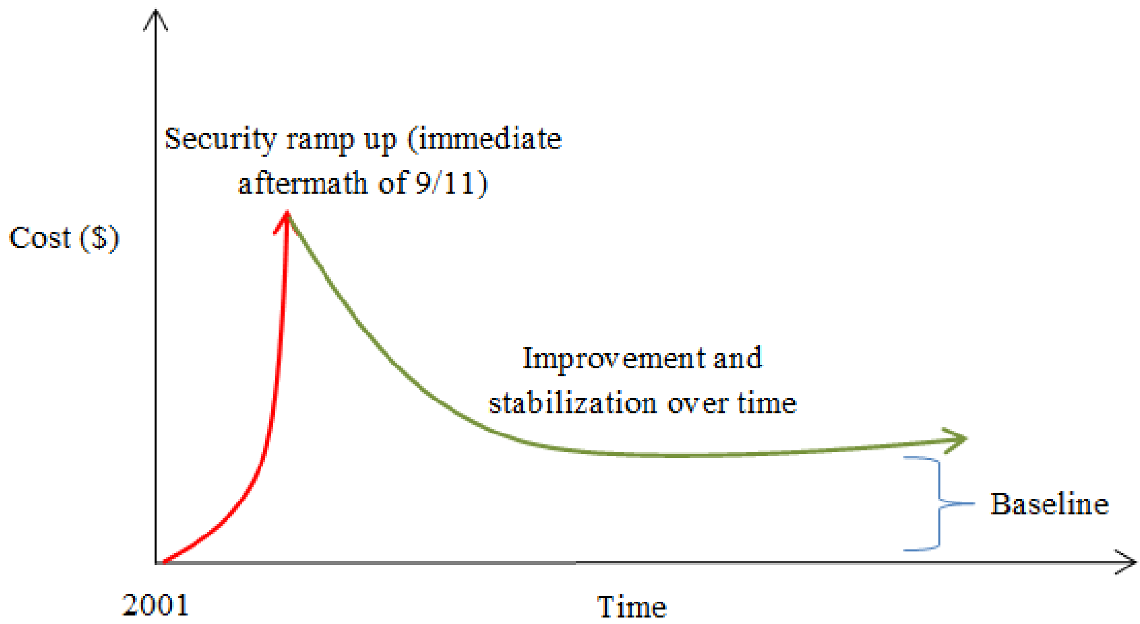

Figure 15. Cost-effectiveness of Airport.

A hypothetical model for the airport passenger security system of the future was envisaged (without the fundamental infrastructure as a constraint), and this model can be further researched subsequently. The hypothetical model for airport passenger security system of the future is shown in Figure 16.

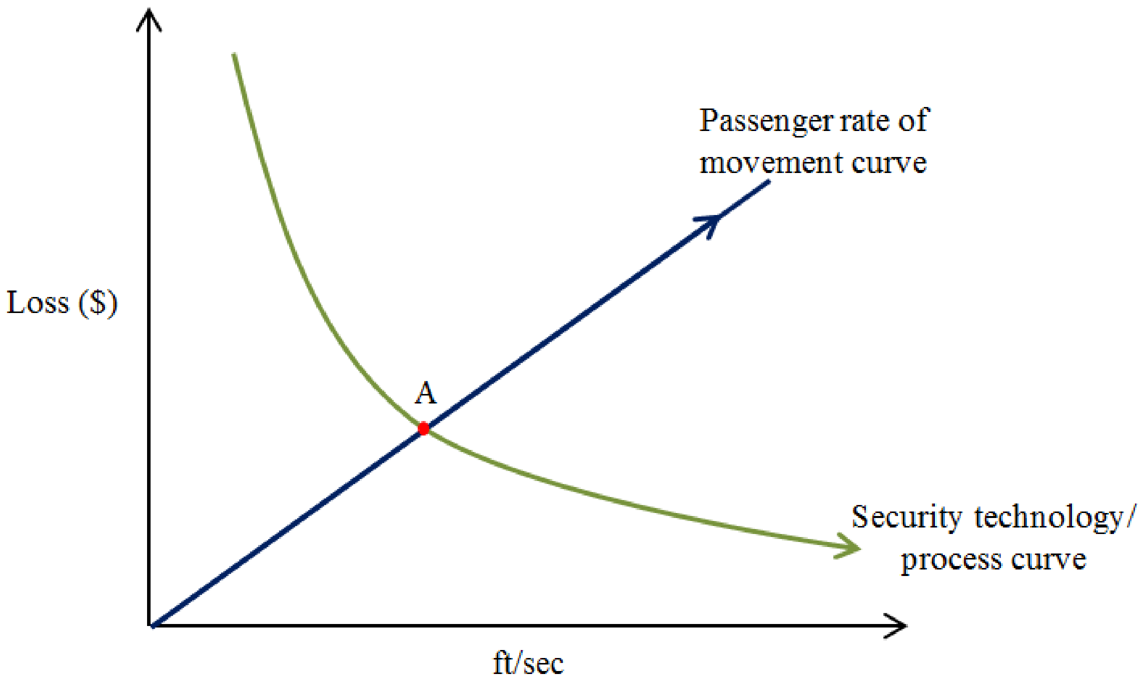

Figure 16. Hypothetical Model for Airport Passenger Security System of the Future.

This model shows the relationship between the passenger and the deployed security technology and process. Figure 16 is a plot of loss (in terms of cost) versus performance (in terms of throughput or otherwise known as security efficiency in the form of feet moved per second) of passengers through the airport passenger security system. From the passenger perspective, an increase in throughput with a faster rate of movement across the airport domain, clearing security in a shorter period of time would come at a higher loss (i.e., more costly) to the individual. Conversely, a slower throughput would correspondingly lower the cost incurred by each individual. In the deployment of advanced security technologies and improved security processes, security authorities strive toward improving security efficiency with a lower cost (i.e., improved security would lower the loss associated with the loss of life, damage to aircraft and infrastructure, and economical loss resulting from terrorist(s) hijacking an aircraft). At the end toward zero throughput, the loss to security is infinite (as security technologies and processes are inadequate to detect and identify terrorists boarding aircrafts) as the passengers never make it to their destination.

The intersection of both the passenger and the security technology and process curve as shown at Point A reflects the current state of security technologies and processes, and the corresponding level of loss that is "acceptable," the corresponding cost of security to the passenger and the resulting rate of flow through the airport.

The aim is to move down the security technology and process curve to reduce loss resulting from the hijacking of aircraft while maintaining or lower the cost of security to each passenger. This can be achieved through improving the "gradient" of the passenger curve, shifting point A toward point B as shown in Figure 17.

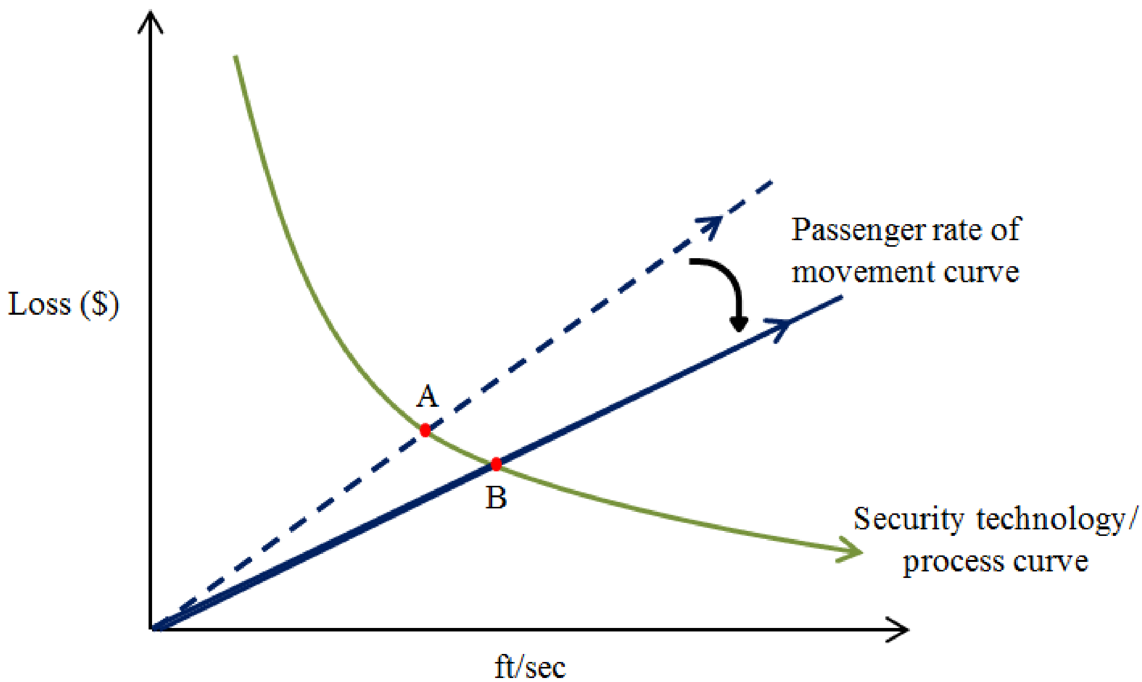

Figure 17. Long Term Model Improvement.

Further research could look into areas that could facilitate this movement along the security curve to achieve greater throughput at a lower cost. For example, the concurrent approach of being security screened while moving through airport toward the aircraft as compared to the existing sequential approach through the different phases at the airport domain. Through the deployment of advanced security technology and changes in security processes (paradigm shift from the existing way in which airports are being built and operate), the passenger upon entering the physical boundary, could possibly be transported to the doorsteps of the aircraft and get security screened concurrently while onboard. There will be scope for analysis within this identified trade space and work toward the eventual end state of maximum throughput and lowered security loss. This increased efficiency will eliminate the need to be at the airport well in advance of scheduled departure to accommodate the different phases, including security screening. Instead, travelers will need only to allow sufficient time for the transportation and movement from the physical boundary of the airport to the doorsteps of the aircraft with security screening being performed concurrently.

LIST OF REFERENCES

Ahlers, M. M. (2013, March 5). TSA to allow pocketknives, some sports equipment. CNN. Retrieved Mar 15, 2013, from http://www.cnn.com/2013/03/05/travel/tsa-carry-on-changes

Beamon, B. M. (1998). Supply chain design and analysis: Models and methods. *International Journal of Production Economics*, *55*(3), 281-294.

Blanchard, B. S. & Fabrycky, W. J. (2011). *Systems Engineering and Analysis*. Boston: Prentice Hall.

Bozarth, C. C. & Handfield, R. B. (2006). *Introduction to Operations and Supply Chain Management*. Upper Saddle River, NJ: Pearson Prentice Hall.

Buede, Dennis M. (2009). *The Engineering Design of Systems*. Upper Saddle River, NJ: Wiley.

Centre for Strategy & Evaluation Services. (2011). *Interim evaluation of FP7 research activities in the field of space ans security: Aviation security and detection systems – case study*. Retrieved July 30, 2013, from http://ec.europa.eu/enterprise/policies/security/files/doc/aviation_case_study_cses_en.pdf

Delta Air Lines (DELTA). (2013). Check-in options. Retrieved May 16, 2013, from http://www.delta.com/content/www/en_US/traveling-with-us/check-in/options.html#

Durkin, A. (2013, March 18). TSA allows knives, Michigan airports absolutely don't. *Associated Press*. Retrieved June 15, 2013, from The Huffington Post website: http://www.huffingtonpost.com/2013/03/18/tsa-to-allow-knives-but_n_2897318.html

Fernandez, C. & Jones, G. (2013, July 20). Disgruntled man hurt after detonating explosion in Beijing airport. *Reuters*. Retrieved Aug 1, 2013, from Reuters.com website: http://www.reuters.com/article/2013/07/20/us-china-explosion-beijing-idUSBRE96J04F20130720

Fletcher, Kenneth C. (2011). *Aviation security: a case for risk-based passenger screening* (Master's thesis, Naval Postgraduate School). Retrieved from http://hdl.handle.net/10945/10601

Government Accountability Office (GAO). (2011). *Department of homeland security: Progress made and work remaining in implementing homeland security missions 10 years after 9/11* (GAO-11-881). Washington, DC: Author. Retrieved July 16, 2013, from http://www.gao.gov.new.items/d11881.pdf

Hammer, P. D., Johnson, L. F., Strawa, A.W., Dunagan, S. E., Higgins, R.G., Brass, J., Slye, R. E., Sullivan, D. V., Smith, W. H., Lobitz, B. M., Peterson, D.L. (2001). Surface reflectance mapping using interferometric spectral imagery from a remotely piloted aircraft, *IEEE Transactions in Geoscience and Remote Sensing*, vol.39, no.11, pp.2499-2506.

Hammer, P. D.; Peterson, D. L.; Smith, W. H.; Dunagan, S. E.; Johnson, L. F.; Strawa, A. W.; Zott, J.; Langford, G. (1996). Remote sensing with hyperspectral imagery using DASI-an imaging interferometer, *Geoscience and Remote Sensing Symposium, 1996. IGARSS '96. Remote Sensing for a Sustainable Future, International*, vol.4, no., pp. 2276-2278.

Hawley, K. (2006, January 17). Statement of Kip Hawley (Assistant Secretary) before the United States Senate Committee on Commerce, Science and Transportation. Retrieved Jul 17, 2013, from http://www.tsa.gov/sites/default/files/publications/pdf/testimony/testimony_senate_911commission_101707.pdf

James, A. (n.d.). How to check your luggage at an airport. *USA Today*. Retrieved June 7, 2013, from USA Today website: http://traveltips.usatoday.com/check-luggage-airport-33651.html

Jamshidi, M. (2009). *System of Systems Engineering: Innovations for the 21st Century*. Hoboken, N.J: Wiley.

Jenkins, J. P. (n.d.). *Hijacking*. Retrieved 17 July, 2013, from Britannica Encyclopedia website: http://www.britannica.com/EBchecked/topic/265608/hijacking

Kane, R. (2009). *Electronic baggage screening program: Program specific Recovery Act plan.* Department of Homeland Security: Transportation Security Administration. Retrieved June 7, 2013, from http://www.dhs.gov/xlibrary/assets/recovery/TSA_EBSP_Recovery_Act_Plan_Final_2009-05-15.pdf

Kaplan, T. (1993, October 3). Killings turn screwdriver into unlikely tool of death. *Los Angeles Times*. Retrieved July 11, 2013, from http://articles.latimes.com/1993-10-03/local/me-41993_1_slotted-screwdriver

Ketchen Jr, D. J., Rebarick, W., Hult, G. T. M., & Meyer, D. (2008). Best value supply chains: A key competitive weapon for the 21st century. *Business Horizons*, *51*(3), 235-243.

Kollberg, M., & Dreyer, H. (2006). *Exploring the impact of ICT on integration in supply chain control: A research model.* Department of Production and Quality Engineering, Norwegian University of Science and Technology, Norway.

Langford, Gary O. (2012). *Engineering Systems Integration: Theory, Metrics and Method.* Boca Raton: CRC Press.

Langford, Gary O. (2013). “System of Systems Integration, Qualification, and Lifecycle”, Lead Systems Integrator Certificate Program, Course SE3413, Naval Postgraduate School, 2013.

Lee, H. L. (2000). "Creating value through supply chain integration," *Supply Chain Management Review*, Vol. 4, September/October, No. 4, pp. 30-36.

Lord, S. (2009). *Federal air marshal service: Actions taken to fulfill core mission and address workforce issues* (GAO-09-903T). Washington, DC: Government Accountability Office. Retrieved July 17, 2013, from http://www.gao.gov/new.items/d09903t.pdf

Maier, M. W. and Rechtin, E. (2009). *The art of Systems Architecting*. Boca Raton: CRC Press.

Morrison, B. (2002, April 4). Attendants question ground security. *USA Today*. Retrieved June 7, 2013, from USA Today website: http://usatoday30.usatoday.com/news/nation/2002/04/04/ground-security.htm

Navarro, Joe, & Karlins, Marvin. (2008). *What Every BODY Is Saying: An Ex-FBI Agent's Guide to Speed-Reading People*. New York, NY: Collins Living.

Notis, K. (2005). Airline Travel Since 9/11. Retrieved May 14, 2013, from Research and Innovative Technology Administration, Bureau of Transportation Statistics website: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/special_reports_and_issue_briefs/issue_briefs/number_13/html/entire.html

Pistole, J. S. (2011, September 6). *CSIS: Evolution of aviation security since 9/11*. Washington, DC: Transportation Security Administration. Retrieved May 14, 2013, from http://www.tsa.gov/press/speeches/tsa-administrator-john-s-pistole-csis-evolution-aviation-security-911-washington-dc

Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS). (n.d.). *Passengers: All carriers – all airports*. Retrieved July 17, 2013, from http://www.transtats.bts.gov/Data_Elements.aspx?Data=1

Scotland’s courts seize thousands of knives. (2011, January 11). Retrieved July 11, 2013, from *BBC News* website: http://www.bbc.co.uk/news/uk-scotland-12241827

Shupe, Lilian. (2013, July 8). Prosecutor: Man used screwdriver as weapon in Flemington. *Hunterdon County Democrat*. Retrieved July 11, 2013, from NJ.com website: http://www.nj.com/hunterdon-county-democrat/index.ssf/2013/07/prosecutor_for_the_second_time.html

Smith, M. & Patterson, T. (2013, April 19). FBI: Help us ID Boston bomb suspects. *CNN*. Retrieved April 19, 2013, from http://www.cnn.com/2013/04/18/us/boston-blasts/index.html

Terminal Guide – Richmond International Airport. (n.d.). Retrieved May 16, 2013, from Richmond International Airport website: http://www.flyrichmond.com/index.php/terminal-guide

Transportation Security Administration (TSA). (2013a, July 3). *3-1-1 for carry-ons*. Retrieved July 17, 2013, from http://www.tsa.gov/traveler-information/3-1-1-carry-ons

Transportation Security Administration (TSA). (2013b, May 21). *AIT: Frequently asked questions*. Retrieved July 17, 2013, from http://www.tsa.gov/ait-frequently-asked-questions

Transportation Security Administration (TSA). (2013c, January 26). *Layers of security*. Retrieved July 17, 2013, from http://www.tsa.gov/about-tsa/layers-security

Transportation Security Administration (TSA). (2013d, June 11). *Prohibited items*. Retrieved June 11, 2013, from http://www.tsa.gov/traveler-information/prohibited-items

Transportation Security Administration (TSA). (2013e, March 14). *Risk-based security initiatives*. Retrieved June 11, 2013, from http://www.tsa.gov/traveler-information/risk-based-security-initiatives

Transportation Security Administration. (TSA). (2013f, May 14). *Secure Flight Program*. Retrieved July 17, 2013, from http://www.tsa.gov/stakeholders/secure-flight-program

Transportation Security Administration (TSA). (2013g, January 21). *Transporting knitting needles and needlepoint*. Retrieved June 11, 2013, from http://www.tsa.gov/traveler-information/transporting-knitting-needles-and-needlepoint

Transportation Security Administration (TSA). (2013h, January 7). *Travelers*. Retrieved July 17, 2013, from http://www.tsa.gov/stakeholders/travelers

Transportation Security Administration (TSA). (2012, April 13). *TSA announces testing of document verification technologies*. Retrieved Jul 17, 2013, from http://www.tsa.gov/press/releases/2012/04/13/tsa-announces-testing-document-verification-technologies

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