100% Container Scanning: Security Policy Implications for Global Supply Chains

by

Allison C. Bennett
B.S. Logistics and Intermodal Transportation
United States Merchant Marine Academy, 2003

and

Yi Zhuan Chin
B.S. Civil and Environmental Engineering
Cornell University, 2007

Submitted to the Engineering Systems Division in partial fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

June 2008

Signature of Author……………………………………………………………………………………
Allison C. Bennett, Engineering Systems Division
May 9, 2008

Signature of Author……………………………………………………………………………………
Yi Zhuan Chin, Engineering Systems Division
May, 9 2008

Certified by………………………………………………………………………………………………
James B. Rice, Jr.
Deputy Director, Center for Transportation and Logistics
Thesis Supervisor

Accepted by………………………………………………………………………………………………
Prof. Yossi Sheffi
Professor, Engineering Systems Division
Professor, Civil and Environmental Engineering Department
Director, Center for Transportation and Logistics
Director, Engineering Systems Division

ABSTRACT

On August 3, 2007, President George Bush signed into law HR1 the "Implementing Recommendations of the 9/11 Commission Act of 2007." The 9/11 Act requires 100% scanning of US-bound containers at foreign seaports by 2012 through the use of non-intrusive (NII) and radiation detection equipment. Maritime stakeholders and the government community have actively debated the feasibility of this plan, citing economic impacts, barriers to global trade and insufficient technology and physical space.

This thesis focuses on importer concerns relating to potential shipment delays, financial burdens, sourcing issues and contingency planning concerns in global supply chain operations. Using port statistics, field study data as well as industry insights, frameworks are developed to identify major stakeholder issues and quantify the financial costs and delay risks bourn across the entire supply chain.

Cost and delay analyses are based on 2 prototypical ports – a small/low-volume export port and a large/high-volume export port. Cost analysis is performed for a consolidated (port authority) level installation and a segmented (terminal operator) level installation to calculate a per-box scanning fee. Queuing models and Monte-Carlo simulations are also developed to quantify truck congestion due to primary scanning and the risk of containers missing vessels due to secondary inspections.

Results of the cost analysis indicate that scanning configurations, particularly related to NII, greatly affect the-per box scanning cost. It is not economically feasible to scan only US-bound containers at half of the 600 ports with direct connections to the US. Analysis of truck congestion suggests that the ramp metering effect of the entry gate can help to abate congestion at the scanning area. Analysis on secondary inspection delays revealed that under a set of assumptions that reflect current operations, the risk of containers missing sailings could potentially increase to 1.5%, which may in turn require a 0.5% to 5% increase in safety stock.

Our study shows that cost and delay implications of 100% export US-bound container scanning may be less severe than industry anticipated. Supply chain disruptions due to scanning is best mitigated through earlier container dispatch, increased safety stock or increased scanning infrastructure and personnel at ports.

# ACKNOWLEDGEMENTS

We are pleased to have worked under the guidance of Jim Rice, our thesis advisor. His thoughtfulness and enthusiasm for supply chain security made our research a pleasure. We also want to thank David Gonsalves, our thesis sponsor from General Motors, who took an active role in ensuring the success of our research goals.

We would like to express our gratitude to members of the maritime industry and government sector, whose practical inputs shaped the scope of our research. We have endeavored to return the favor with practical outputs. Some of the key stakeholders include:

Earl Agron
Vice President, Security
American President Line

Cleiton Alves dos Santos João Simões
Alfândega da Receita Federal do Brasil
Porto de Santos

Anthony Barone
Pfizer Inc.

Ben Cook
Kimberly-Clark

Nilson Datoguia
American President Lines
Santos, Brazil

Michael Dreher
Vice President
Global Transport Logistics & Customs
Adidas Group

Emil Fiorantis
Director, Special Projects
Dominion Customs Consulting Inc.

Jon Gold
National Retail Federation

Alan Lear
Director of Logistics
Libra Terminais, Porto de Santos (Libra Terminals, Port of Santos)
Strategy Consultores Associados

Mohand Merzkani
Dean
Universidad Tecnologica de Honduras, Campus Puerto Cortes

Allen Thompson
Retail Industry Leaders Association

David Spaeth
Wal-Mart Stores, Inc.

We want to voice special appreciation to everyone that made our field study visits to Puerto Cortes, Honduras and Port of Santos, Brazil possible. These hands-on learning experiences greatly contributed to the quality and breadth of our thesis.

Lastly, we are grateful to have worked as a team to tackle this difficult subject. We were able to merge cross-cultural ideas to create an exciting project, whose sum total was far greater than its individual parts could have been.

Table of Contents

Table of Figures

Table of Tables

List of Acronyms

μrem	Microrem
^3He	Helium-3
ASP	Advanced Spectroscopic Portal
ATS	Automated Targeting System
CAS	Central Alarm Station
CBO	Congressional Budget Office
CBP	Customs and Border Protection
CONOPS	Concept of Operations
CSI	Container Security Initiative
C-TPAT	Customs-Trade Partnership Against Terrorism
DHS	Department of Homeland Security
DOE	Department of Energy
DNDO	Domestic Nuclear Detection Office
EDI	Electronic Data Interchange
EU	European Union
FEU	Forty-foot Equivalent Unit
FROB	Freight Remaining Onboard
FTE	Full-Time Equivalent
FY	Fiscal Year
GAO	Government Accounting Office
HPGe	High-Purity Germanium
IMO	International Maritime Organization
ISPS	International Ship and Port Security Code
LPOL	Last Port of Loading
MARAD	Maritime Administration
mrem	Millirem
MTSA	Maritime Transportation Security Act
NaI	Sodium Iodide
NII	Non-Intrusive Inspection
NORM	Naturally Occurring Radioactive Material
NNSA	National Nuclear Security Administration
NVOCC	Non-Vessel Operating Common Carriers
OCR	Optical Character Recognition
POE	Port of Entry
PVT	Polyvinyl Toluene Scintillator
RDD	Radiological Dispersal Device
RFID	Radio Frequency Identification
RIID	Radioactive Isotope Identification Device
RPM	Radiation Portal Monitor
SAFE Port Act	Security and Accountability for Every Port Act

SFI	Secure Freight Initiative
SLD	Second Line of Defense
SPP	Security and Prosperity Partnership
TEU	Twenty-foot Equivilant Unit
WMD	Weapon of Mass Destruction
WSC	World Shipping Council

1 INTRODUCTION

Economic vitality hinges upon global trade. Over 90% of the economic value of global commerce is transported through the maritime domain via containerized cargo. In terms of speed, cost and security, containers are the preferred transportation option. The global standardization of shipping containers allows cargo to efficiently move through the intermodal transportation system of truck, rail and vessel services without requiring the repackaging of cargo.

In the post-9/11 trade environment, the global reach of terrorist organizations lends credence that terrorists or states of proliferation concern may exploit containerized cargo. Utilizing maritime shipping networks, terrorist could launch an attack using special nuclear or other radioactive materials in a weapon of mass destruction (WMD) or radiological dispersal device (RDD). The anonymity of containerization requires containers to be opened or examined with specialized equipment to determine contents with any level of certainty.

Based on the threat imposed by seaborne containers, the United States government used regulatory measures to increase maritime security by extending the inspection frontier to require the scanning of US-bound containers abroad. On August 3, 2007, President George W. Bush signed into law HR 1, the "Implementing Recommendations of the 9/11 Commission Act of 2007," requiring that all US-bound containers be scanned with non-intrusive inspection (NII) equipment to examine cargo density, as well as radiation portal monitors (RPMs) to detect the presence of gamma and neutron radiation (2007). This legislation will be referred to as the 9/11 Act within this document. Our thesis focuses on the container scanning requirements contained in Section 1701 of the 9/11 Act.

This legislation was met with harsh criticism. Stakeholder organizations, ocean carriers and foreign port authorities voiced concerns over responsibilities and costs associated with the scanning process. While concerns over the operational feasibility of scanning (both technological and process-related) and sovereignty have been addressed, little attention has been paid to the impact of the 9/11 Act along the entire supply chain. In particular, businesses are interested in understanding if implementation of the 9/11 Act will cause shipment delays and additional financial costs to their business operations. In order to adjust corporate supply chain strategies and contingency plans, businesses require metrics and tools for advanced planning to avoid taking a reactive posture to the 2012 implementation date. How will non-compliant ports affect sourcing decisions? Whose bottom line is affected by scanning expenses? This study focuses on the impact of 100% scanning of US-bound containers on businesses that depend on global supply chains for their daily operations.

Our analysis is broken down into 2 primary sections addressing potential financial cost and container delays associated with the implementation of the 9/11 Act. We calculate the initialization and operational cost of deployments at small and large ports and examine delays through the probability that a container will miss its scheduled vessel sailing.

1.1 Background

In 2006 over 129 million twenty-foot equivalent units (TEUs) of containerized cargo transited the globe (United Nations, 2007). Approximately 18.5 million TEUs (11 million containers) entered the United States in 2006 from 591 last ports of loading (LPOL), equating to more than 60 vessel calls per day. Approximately 300 of these LPOLs ship 100 or fewer TEUs directly to the United States on an annual basis (Maritime Administration, 2007). The complexity and breadth of the interconnectivity between maritime nodes is depicted in Figure 1.

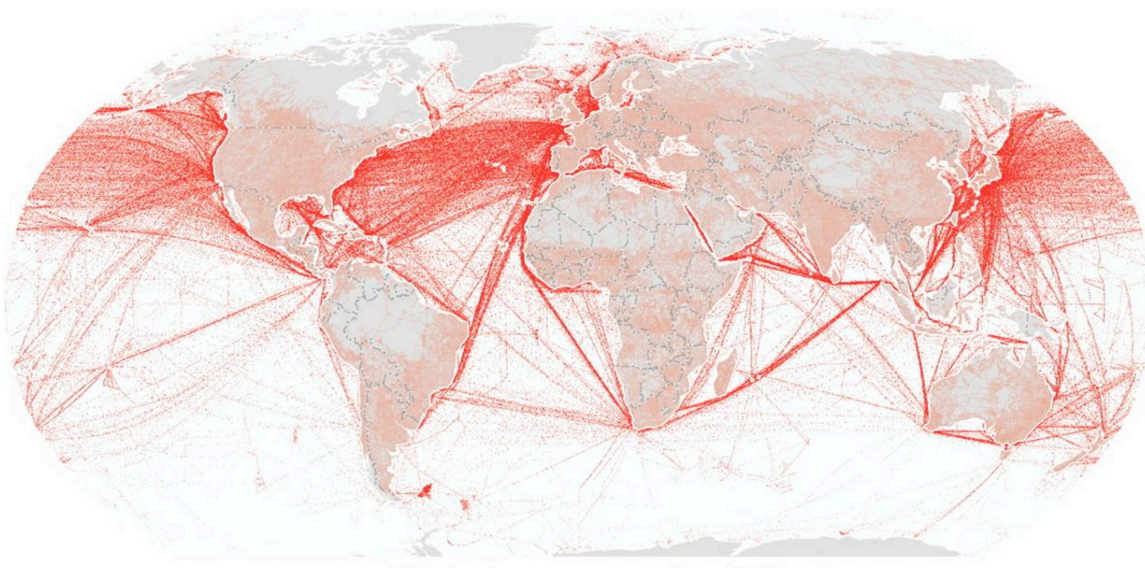


Figure 1. Global Shipping Lanes (Source: Shipping lanes map created from data downloaded at www.aoml.noaa.gov/phod/trinanes/BBXX from the SEAS BBXX database of the Global Ocean Observing System Center from the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration)

This section outlines the relevant US government security initiatives developed during the 6-plus year period since the terrorist attacks of September 11, 2001 and also describes the equipment involved in complying with the 9/11 Act. The list of security programs is not exhaustive, but it highlights major programs focused on inspecting and targeting maritime containers prior to arrival at US ports of entry (POE). It is important to review the progression of US legislation to understand the 9/11 Act in the context of past and current security initiatives. The 9/11 Act requirements are outlined in detail at the end of the section.

1.1.1 Customs-Trade Partnership Against Terrorism (C-TPAT)

The US Customs and Border Protection (CBP) under DHS began the Customs-Trade Partnership Against Terrorism (C-TPAT) in November 2001. C-TPAT is a voluntary program to increase supply chain security. The program requires members to work with their business partners to ensure the integrity of their supply chain and to document this effort. In return, CBP offers reduction of inspections, priority processing, security validation, and involvement in a network of security conscious businesses (United States Customs and Border Protection [CBP], 2007a). At the end of FY2007 DHS reported the involvement of 7,737 certified partners, with 6,003 of these having completed the validation process (Department of Homeland Security [DHS], 2008a).

1.1.2 International Ship and Port Facility Security Code (ISPS Code)

In December of 2002, the International Maritime Organization (IMO) established the International Ship and Port Security Code (ISPS) to enhance maritime security. The ISPS code established standards for security, roles and responsibilities, as well as methodologies for assessing security. It required that by July 1, 2004, all 167 IMO member-states must certify compliance. Contracting governments must set security levels, conduct port facility security assessments, approve security plans for both ships and port facilities, identify ports that need port facility security officers, and test approved security plans. On November 25, 2002, the Maritime Transportation Security Act of 2002 (MTSA) was signed to provide US legislation for the ISPS Code, with the US Coast

Guard in charge of meeting the implementation deadline (International Maritime Organization, 2003).

1.1.3 24-Hour Rule

CBP enforced the 24-Hour Rule on February 2, 2004. The 24-Hour Rule requires ocean carriers and NVOCCs (Non-Vessel Operating Common Carriers) to electronically submit manifest information for US-bound or US-nexus containerized cargo 24 hours prior to loading the container on a vessel bound to the United States. The manifest includes 14 data elements, which provide detailed descriptions on the container's contents. It is important to note that this reporting does not necessarily occur at the first port of departure, but instead the last port prior to a US arrival. This rule must be followed for any container (US-nexus) that is on a vessel bound for the United States, regardless of whether the specific container is destined for or is temporarily off-loaded in the United States. US-nexus also includes freight remaining onboard (FROB), which never actually touches US soil. The security premise is that any container that will be alongside the United States poses a security risk.

Under the 24-Hour Rule, vague cargo descriptions, such as "Freight of All Kind" and "General Merchandise" are no longer permissible. CBP officers utilize the information required by the 24-Hour Rule to identify potential terrorist threats before the container arrives in a US port. CBP will issue "Do Not Load" container messages for violators and will deny access to US ports for those who disregard the instructions (CBP, 2003a).

1.1.4 Automated Targeting System (ATS)

The Trade Act of 2002 authorizes CBP to receive advanced electronic cargo information (including information from the 24-hour Rule for maritime cargo). The Automated Targeting System (ATS) is an internet-based tool, which serves as a basis for all CBP targeting efforts. ATS performs a review of cargo shipments to identify high-risk shipments using a rules-based algorithm to highlight potential risk, patterns, and targets. ATS also assists in identifying which containers should be physically inspected (CBP, 2003b)

1.1.5 Container Security Initiative (CSI)

CBP announced the Container Security Initiative (CSI) in January 2002. CSI is a program that stations US Customs officers at international seaports to work with foreign host government counterparts to screen and potentially inspect US-bound containers. The first port began operations in March 2002. CSI's mission is to target and pre-screen containers abroad and to develop additional investigative leads related to the terrorist threat to US-bound cargo. CSI's container selection data is largely compiled from information provided by the 24-Hour Rule in ATS (CBP, 2008a).

CSI is based on three core pillars:

1) Use of automated targeting algorithms and intelligence to assist in the identification container shipments that pose substantial risk to the United States
2) Evaluation of containers of concern prior to loading the shipment on a vessel bound for the United States
3) Utilization of technology, such as NII technology, to allow for the screening of cargo without hindering the movement of trade

At the end of FY2007 the CSI program consisted of 58 ports, which ship 86% of US-bound maritime cargo (DHS, 2008).

1.1.6 Megaports Initiative

The Department of Energy's (DOE) National Nuclear Security Administration (NNSA) has actively installed nuclear detection equipment in Russia and the former Soviet Union since the mid-1990s through the Second Line of Defense (SLD) Program. The Megaports Initiative, formalized in 2003, is part of the SLD program and focuses on both high-risk and high-volume ports. The Megaports Initiative targets ports based on their attractiveness to nuclear smugglers, including considerations for connectivity between ports of interest.

The Megaports Initiative is unique in its desire to scan the maximum amount of global traffic as possible at each port regardless of origin or destination. Their mission is accomplished by providing or engaging in cost-sharing efforts for radiation detection equipment and through training local entities to operate the equipment and associated communication systems through government-to-government agreements. Maintenance plans are often funded in part by the Megaports Initiative for a finite period. At the end of FY2007 the Megaports Initiative was operational in 12 ports in 12 countries (National Nuclear Security Administration [NNSA], 2008a).

1.1.7 Security and Prosperity Partnership (SPP)

Launched in March of 2005, the Security and Prosperity Partnership (SPP) of North America is a trilateral agreement between the US, Canada and Mexico to increase security through cooperation and information sharing. Although the agreement includes issues for protecting the environment, food supply and public health, a significant focus is on POE security, both physical and through harmonized inspection data and processes. The US agreed to provide Mexico with radiation detection equipment at major commercial and passenger POEs into North America to prevent the smuggling of nuclear/radiological materials. Under this commitment, Mexico's customs agency, Aduana Mexico, expressed a desire to engage with the Department of Energy (DOE) Megaports Initiative to install radiation detection equipment at 4 of their largest container seaports (Security and Prosperity Partnership, 2006).

1.1.8 Security and Accountability for Every (SAFE) Port Act

On September 30, 2006, the Security and Accountability for Every (SAFE) Port Act was signed into law. The Act requires several programs to increase US port security. Some of the programs it codified included CSI and C-TPAT. It required 100% radiation scanning of import containers by December 31, 2007. The SAFE Port Act also established a pilot program for 100% scanning of US-bound cargo overseas. The 9/11 Commission Act amended a SAFE Port Act provision on scanning all United States bound containers at foreign ports (9/11 Act, 2007).

1.1.9 Secure Freight Initiative (SFI)

On December 7, 2006, DOE and DHS jointly developed and deployed the Secure Freight Initiative (SFI), which builds on the concepts of both DHS's Container Security Initiative and DOE's Megaports Initiative. The goal of SFI is to establish an integrated inspection system with the international shipping community to secure the global supply chain against terrorist exploitation. Phase 1 of SFI is separated into 2 categories (CBP, 2007b).

1) 100% Scanning – Full Deployment Pilot
    a. Port Qasim, Pakistan
    b. Puerto Cortes, Honduras
    c. Southampton, United Kingdom
2) Limited Capacity Deployment Pilot
    a. Port Salalah, Oman
    b. Port of Singapore (Brahni Terminal)
    c. Port Busan, Korea (Gamman Terminal)
    d. Port of Hong Kong, China (Modern Terminal)

DHS allocated approximately $30 million to fund NII equipment, while the DOE's National Nuclear Security Administration (NNSA) contributed $30 million to install radiation portal monitors and communications systems, including optical character recognition (OCR) to electronically identify container number (DHS, 2006). The data collected will be assessed by the local customs, US CSI teams at the port, and it will also be transmitted electronically for analysis by the DHS National Targeting Center in Virginia.

The first 3 full deployment ports are part of the SAFE Port Act required pilot project, which aims to inspect 100% of US-bound containers for nuclear and radiological materials prior to departure. The pilot phase ran from October 12, 2007 to April 30, 2008. Under Section 232(c) of the SAFE Port Act, DHS is required to write a report to Congress by April 2008 to discuss the obstacles, feasibility, and recommendations for further deployments. This document, which describes the costs of deployment and lessons learned from the technology, communication systems, logistics and operations, was not released to the public at the time this thesis was written.

The US government will attempt to screen the highest percentage possible at the last 4 ports to assess the challenges presented by ports with high percentages of transshipment containers and high-volume ports. The pilot phase for SFI ends April 30, 2008 for these ports as well. The high-level inspection and information process for SFI is illustrated in Figure 2.

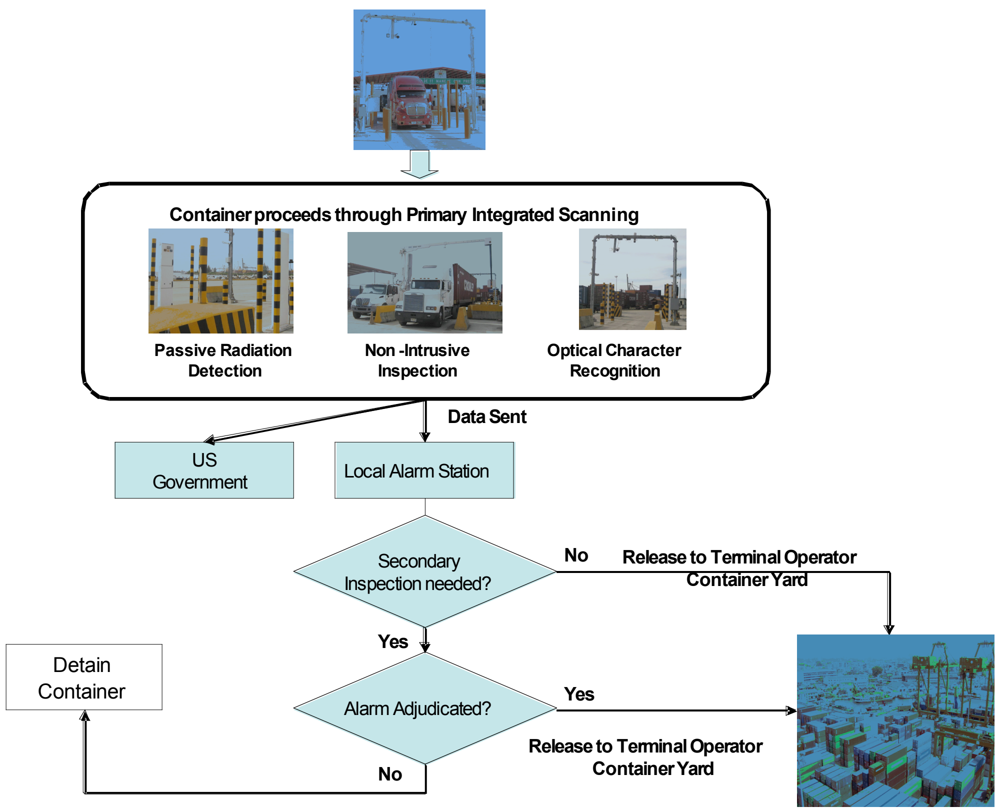


Figure 2. SFI Operations

1.1.10 "10 + 2" Initiative

US Customs and Border Protection is currently reviewing comments submitted on March 18, 2008 by importers and carriers in regards to additional data requirements for US-bound cargo. The currently proposed "10+2" regulation would require importers and carriers to submit data via a CBP-approved electronic data interchange (EDI) system. The Initiative aims to increase the accuracy and breadth of data for the ATS system in adherence to the SAFE Port Act of 2006.

The "10" portion of the requirement refers to the "Importer Security Filing" that must be filed 24 hours prior to the lading of containers. It contains the following importer elements:

1.) Manufacturer/Supplier's full name and address
2.) Seller/Owner's full name and address
3.) Buyer/Owner's full name and address
4.) Ship-to name and address
5.) Container stuffing location
6.) Consolidator/Stuffer's full name and address
7.) Importer of record number/foreign trade zone applicant identification number
8.) Consignee number(s)
9.) Country of origin
10.) Commodity harmonized tariff schedule number, which provides detailed information on the contents of the container (6-digit tariff schedule number)

The "+2" portion requires the carrier to provide a vessel stowage plan (10 elements) 48 hours before vessel departure from the last foreign port and a container status message (6 elements). The stowage plan physically identifies the location of a container on the vessel. The status message provides an update as the box changes state from being full (loaded with cargo) or empty (CBP, 2008b).

1.1.11 HR 1, the "Implementing Recommendations of the 9/11 Commission Act of 2007" – Section 1701 (9/11 Act)

The 9/11 Act was signed on August 3, 2007 by US President George W. Bush. Appendix A includes the full text of Section 1701. The 9/11 Act amends Section 232(b) of the SAFE Port Act. It states that a container loaded on a vessel in a foreign port shall not enter the United States (either directly or via a foreign port) unless the container was scanned by non-intrusive imaging (NII) equipment and radiation detection equipment. The implementation deadline is July 1, 2012, with a 2 year renewable extension available for ports that have any 2 of the following existing conditions:

1) Systems for container scanning are not available for purchase and installation
2) Systems for container scanning do not have sufficiently low false alarm rates for use in the supply chain
3) Systems for container scanning cannot be deployed or operated because a port does not have the physical characteristics to install such systems
4) Systems for container scanning cannot be integrated with existing systems

5) Use of systems that are available to scan containers will significantly impact trade capacity and the flow of cargo

6) Systems for container scanning do not adequately provide an automated notification of questionable or high-risk cargo to signify the need for secondary inspection by appropriately trained personnel

1.2 9/11 Act Compliance Equipment

This section supplies a basic level of understanding of the equipment necessary to carry out the required scanning by radiation detection equipment and non-intrusive imaging. It also discusses equipment safety concerns and throughput volumes.

Equipment includes radiation portal monitors (RPMs), also called radiation scanners, non-intrusive inspection (NII) equipment, also called X-ray or radiography equipment, and secondary inspection equipment. RPMs are passive systems, which detect the presence of gamma and neutron radiation. Thus, no safety concerns exist during regular equipment operations. DHS and DOE programs, including the Megaports Initiative, Secure Freight Initiative and the domestic seaport deployments all utilize "plastic" polyvinyl toluene scintillator (PVT) RPMs.

Figure 3 illustrates RPM equipment viewed by our thesis team during a site visit in January 2008 at the operational SFI port of Puerto Cortes, Honduras, which is 1 of the original 3 ports selected for the SAFE Port Act and SFI pilot project. Typically the RPM pillars (master and slave pillars) are positioned between 4.5 to 5 meters (14.5 to 19.5 feet) apart. Additionally, bollards are necessary to prevent vehicles from damaging the equipment.

Figure 3. Sample RPM Equipment at SFI location

Equipment specifications are unique to individual vendors. TSA Systems, which is the vendor utilized in Puerto Cortes, Honduras, quotes an ideal operating speed of 5 mph (8 km/hr) for their RPM. The RPM provides immediate alarm identification, allowing continuous flow of vehicles through the portals. TSA Systems (2008) quotes a false alarm rate of “typically less than 1 in 1000”. Often, false alarm rates are confused with innocent alarm rates. Innocent alarms refer to cargo containing radioactive material, which are correctly identified by the RPM, but the content does not pose a security threat. This naturally occurring radioactive material (NORM) is seen in commonly shipped goods such as fertilizer, kitty litter, or foods containing potassium (i.e. bananas or avocados).

NII imaging systems emits x-rays or gamma rays to produce an image of a container’s content. Gamma-ray radiography uses a radioactive source, such as Cobalt-60 or Cesium-137. The x-ray systems typically use a energy spectrum ranging from 2.5 to 9 MeV. These units can be fixed, semi-fixed or mobile. Some operate by the driver passing through the equipment, while others require the driver to exit the vehicle while the unit passes over the container or the conveyance is pulled through the NII system. Caution must be exercised when utilizing NII equipment, as healthy safety concerns associated with radiation emissions need to be addressed in accordance with national, local and union regulations.

In the US, CBP officers must stay within the radiation dose limits of the general public, which are 100 millirems (mrem) per year and 50 microrem (µrem) per hour (note: 1 mrem = 1000 µrem). US radiation workers can receive 2,000 mrem in any year, and no more than 5,000 mrem within 1 year during a 5 year period (DHS, 2007). The SAIC P7500, which is utilized in some of the SFI pilot projects, is a 7.5 MeV drive-through NII system. Its safety features include an emergency stop button and an access control area of 8 m by 5m, which receive a radiation dosage of 2 mrem/hr (SAIC, 2007). Based on the standards for US non-radiation workers, equipment operators and truck drivers would only be allowed in this area 50 hours per year (DHS, 2007). The radiation dose to the cargo is 411 µrem at 5mph (8 km per hour). The P7500 also advertises a throughput rate of 150 vehicles an hour, assuming that 40 foot containers are passing through at 8 to 13 km/hr (5 to 8 mph) (SAIC, 2007). Some non-drive through NII allow for approximately 20 containers per hour. It is important to note that NII equipment currently does not produce any alarm type notification for inspectors, thus container release is dependent on the review time. The throughput rates quoted assume that no hold/release decision is being made.

Examples of NII imaging equipment utilized at the same SFI installation are shown in below in Figure 4, with sample imaging capabilities in Figure 5.

Figure 4. Sample NII Equipment at SFI location

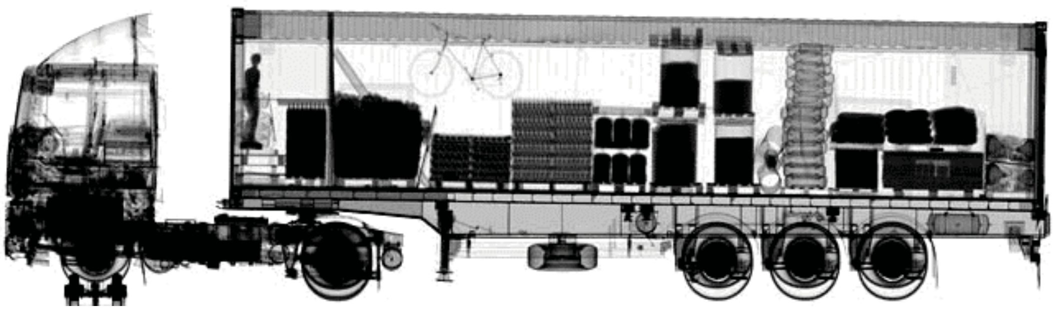


Figure 5. Sample NII Image (Source: CBP, 2007)

Secondary inspection equipment is utilized to isolate the location of a radioactive source and to perform isotopic identification of the container's contents. This secondary equipment assists the operator in differentiating between NORM and weapons grade materials of concern. Identification equipment ranges from hand-held radioactive isotope identification devices (RIIDs) to large-scale advanced spectroscopic portals (ASP). ASPs provide a means of "automating" secondary inspection, in exchange for a high capital investment in new technology. Due to the expense and experimental stage of ASP, they are not included in our cost-analysis. However, high-volume ports or ports with limited or expensive personnel resources should carefully consider utilizing ASP technology. Popular hand-held RIIDs include lightweight (5.5 lbs) sodium iodide (NaI) units and high-resolution germanium detectors (40 lbs).

Several vendors offer secondary inspection equipment. The equipment in Figure 6 provides a sample used at international sites under DOE's Megaports Initiative NNSA, 2007). The TSA gamma detector survey meter locates radioactive sources and measure their intensities. The personal radiation pager is worn by inspectors to assist in identifying a safe working distance from a radioactive source. The Thermo IdentiFINDER unit is an example of a sodium-iodide RIID and the Ortec is a high-purity Germanium (HPGe) based RIID. Figure 7 illustrates an ASP portal, which is an example of the type of technology that is currently deployed at the SFI port of Southampton, United Kingdom (Rutherford, 2008).

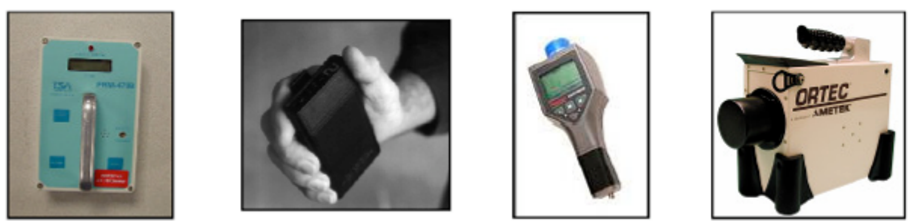


Figure 6. Sample Hand-held Equipment for SFI Ports

Figure 7. Advanced Spectroscopic Portal (ASP)
(Source: *Defense Dept. Doubles Spending on Systems that Don't Deliver*, from http://www.cnet.com/military-tech/?keyword=GAO ed)

2 REVIEW OF LITERATURE

This review of literature focuses first on investigating the current landscape of industry opinions regarding the 9/11 Act published in periodicals and trade press. Next, this section examines academic, governmental and industry research and analyses on quantifying delays and costs associated with the 9/11 Act and other scanning-related security measures. In summary, fervent industry opposition exists for the 9/11 Act, with the inclusion of cost and delay estimates; however, calculations to support and substantiate these claims were not found.

2.1 Documented Industry Opinions

Implications on Ports

The 100% scanning requirements of the 9/11 Act was met with industry criticism. The World Shipping Council (WSC) estimated that US$500 billion of commerce will be affected by the legislation and had even expressed the possibility of discontinuing the carriage of American imports to minimize costs. “We just won’t carry American imports,” said Christopher Koch, President of the WSC (Zin, 2007, para. 15). Port operations in Asia are predicted to suffer the largest impact of the new law, since over 50% of US imports are loaded in China (World Shipping Council, 2007, para. 23). John Lu, Chairman of the Asian Shipper’s Council commented that the legislation will “slow down cargo and cause a gridlock at ports” (Zin, 2007, para. 13).

Critics of the legislation also contend that the technology to scan the 11 million US-bound containers at foreign ports is currently not sufficient to satisfy the requirement. During a hearing in March 2007 by the House Homeland Security Appropriations Subcommittee on the screening of containerized cargo, CBP Assistant Commissioner for

Field Operations Jayson Ahern said that due to the limits of technology and the investment and maintenance costs required, it is “an impossible task… It’s unrealistic at this point in time” (Kimery, 2007, para. 22).

An article in the Wall Street Journal by John Miller (2007) highlighted several port concerns. According to Miller, analysts believed that each port would have to buy 1 to 10 scanners to comply with the new legislation. The European Union (EU) estimated the average initialization cost for a port to be around US$100 million, a cost too large to be justifiable for some of the smaller ports with very few US-bound containers. Even if ports are financially capable of purchasing the scanning equipment, they are faced with other problems such as space constraints. Lieven Muylaert, a Belgian customs official commented, “We’re looking at billions [of euros] in extra spending” (Miller, 2007, para. 5).

Miller believes that the 9/11 Act might even change the dynamics of port competition. Larger ports might strive to gain new business from smaller and older ports that are financially strained to meet the requirements of 100% scanning. The EU has expressed concerns that Asian ports, being newer and more compact, would have an advantage in meeting the requirements. Smaller ports might have to stop shipping to the US altogether if they are unable to bear the financial costs of installation. “The law will force us to stop shipping to the US, unless we can attract a lot more customers, which would justify investment in the equipment,” says Philippe Revel, manager for the shipping terminal at Dunkirk, France (Miller, 2007, para. 14). The EU has also threatened to impose reciprocity and require US to scan all European-bound containers if the 100% scanning legislation is not altered.

It is important to note that none of these hypotheses for port implications included calculations to validate the claims.

Cost and Delay Concerns

Industry had expressed concerns over how the 9/11 Act can potentially cause delays in supply chains and increase the costs of maritime logistics. Nicolette van der Jagt, Secretary General of the European Shippers' Council said, "Business will be paying the lion's share of providing the equipment, but I suspect the biggest cost to shippers will be the cost of delays" (Zin, 2007, para. 3). The Global Shippers' Forum also commented that the legislation will result in "enormous costs to users, suppliers and ultimately consumers" (Zin, 2007, para. 12).

Some feared that the 9/11 Act would result in container bottlenecks and would place a tremendous burden on ports that have limited space or capital to install the scanning equipment. Supply Chain Digest Editor, Dan Gilmore, commented, "Imagine your worst line to get through security at an airport. Now imagine the luggage scanners aren't working quite right, and they have to keep running bags through repeated times. Can you imagine the delays? That's a real possibility for cargo with the law and the current technology for this as it stands" (Supply Chain Digest, 2007, para. 10). Van der Jagt also commented, "We already have the prospect of worsening congestion in many of the world's container ports as volumes grow year on year… One can only imagine the huge queues that will form when every container has to run through radiation and image scanners" (Zin, 2007, para. 4).

There are also concerns about innocent alarms. Gerald Epstein, a homeland security expert for the Center for Strategic and International Studies, commented, "There are an awful lot of things that are radioactive out there… If all you're doing is looking [at the] total amount of radiation, you are going to be opening up a lot of boxes and finding kitty litter" (Zin, 2007, para. 10).

Regarding the cost of scanning, the port of Hong Kong estimated in 2005, a cost of $6.50 per container, which will be passed down to shippers (Supply Chain Digest, 2005, para. 7). Dr. Stephen Flynn, in the Far Eastern Economic Review, provided another estimate that 100% scanning can be "put in place in every major container port in the world at a cost of [US]$1.5 billion, or approximately [US]$15 per container" (Flynn, 2006, para. 40). Flynn went on to say that the total cost of 100% scanning, including containers with tamper-proof seals are "likely to reach [US]$50 to [US]$100 per container depending on the number of containers an importer has and the complexity of its supply chain." He further contends that even if it ends up being an additional US$100 per container, it would only "raise the average price of cargo moved by… only 0.06% (Flynn, 2006, para. 41)."

It is interesting to note that even though many parties give estimates for the delays and costs associated with the 9/11 Act, none of them have officially released their approach for quantifying the numbers that they have presented.

2.2 Delay Estimates

No academic literature was found that directly addressed delay issues associated with the implementation of the 9/11 Act. Literature addressing delay concerns due to security scanning mainly focused on transshipment ports or US ports of entry. This section discusses some of the literature and their relevance in the context of the 9/11 Act.

Scanning at US Ports of Entry

Martonosi, Ortiz and Willis (2005) from RAND Corporation conducted a cost-benefit analysis of 100% scanning of all incoming sea containers using X-ray cargo density imaging (NII) equipment at US ports. This scenario differs from the 9/11 Act since scanning is performed on incoming containers at US ports of entry whereas the 9/11 Act requires containers to be scanned at foreign ports prior to loading. The 9/11 Act also requires radiation scanning (RPM) in addition to X-ray imaging (NII). The difference between these scenarios is important to note because the results from their analysis have often been misquoted by industry to oppose the 9/11 Act. Nonetheless, their analysis serves as a useful reference for the development of an approach to quantify delays associated with the 9/11 Act.

As part of the cost-benefit analysis, Martonosi et al created a queuing model to estimate delays associated with conducting 100% scanning of import containers. Their queuing model assumed that containers arrive at a US port of entry according to a Poisson process. The Poisson process is typically used to model independent random events, in this case – container arrivals, occurring over a period of time. The containers that arrive are then selected for scanning according to a Bernoulli random process with a probability p. For the base case, p is assumed to be 5% and for the case of 100% scanning, p is 100%. Out of the scanned containers, a certain percentage will fail the scanning and be sent for secondary inspection. This process follows another Bernoulli random process with probability *f*, representing the alarm rate.

According to Martonosi et al, the average container arrival rate of 157 US ports of entry is 1,474 TEU/hr with arrival rates for a prototypical large port being 365 TEU/hr and that for a small port being 50 TEU/hr. For their analysis of scanning delays, Martonosi et al divided the 157 ports into 2 groups – top 30 ports and remaining 127 ports. The average container arrival rate within each group is calculated and replicated across the number of ports in the group. Scanning and secondary inspection times were assumed to be exponentially distributed with means of 3 minutes/TEU and 5 hours/container respectively. The number of scanners and inspection teams deployed at each port were assumed to be the minimum required to ensure a stable queue.

Averaging all delay results across the 157 ports, Martonosi et al estimated that the expected delay would increase from 0.5 hour per TEU under current operations to 5.5 hours per TEU under a regime of 100% scanning of import containers. Their estimate of a 5.5 hour delay associated with 100% scanning has been widely misquoted by industry to oppose the 9/11 Act (Zin, 2008, para. 12).

It is important to note that the results presented by Martonosi et al are based on all US imports being scanned on arrival whereas the 9/11 Act requires only US-bound containers, which represent a subset of a foreign port's total exports, to be scanned before departure. Due to difference in scanning volumes, the estimated delay of 5.5 hours may be overstated and inappropriate to estimate potential delays caused by the 9/11 Act.

Additionally, the Martonosi et al model assigned the number of scanners and inspection stations to be the minimum required to guarantee a stable queue, which might have contributed to an inflated delay estimate. Their assumption of a 3 minute/TEU scanning rate may also be too long under the current state-of-the art equipment. Today, vendors of scanning equipment affirm that containers can pass through scanning at a rate as low as 60 seconds/TEU.

Scanning at Transshipment Ports

Erera, Lewis and White (2003) proposed a methodology to estimate the delays associated with the scanning of transshipment containers. Their study defines scanning as the use of both RPMs and NII equipment. Erera et al made use of a best-first heuristic search method to optimize the movement of containers between the inbound ships, the container yards, the inspection areas and outbound ships. The results of their model are shown below in Figure 8. Erera et al estimated that the expected departure delay for an outbound vessel increases exponentially with inspection level. At 10% inspection of transshipment containers, departure delay is approximately 110 minutes.

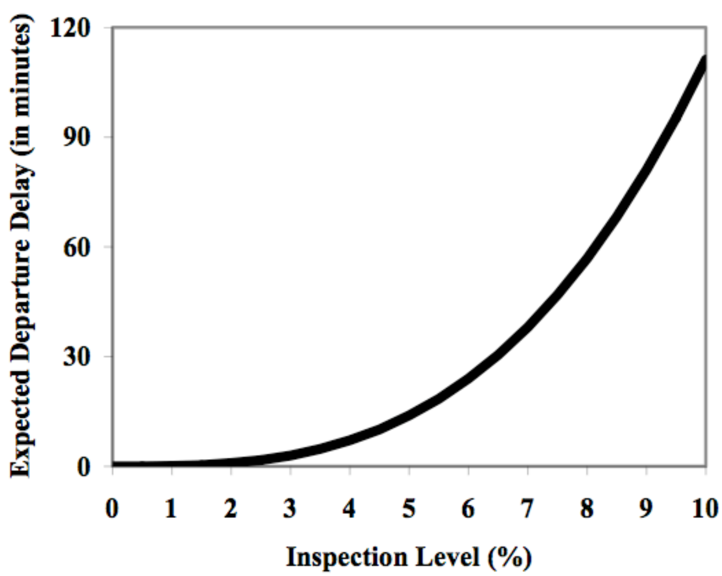


Figure 8. Departure Delays Based on Inspection Level (Source: “Optimization approaches for efficient container security operations at transshipment seaports” by Erera, Lewis and White, 2003)

In their analysis, Erera et al made several model assumptions. First, they assumed that all containers pass through security scanning with no alarms, and no containers are sent for secondary inspection. This is highly unlikely. In practice, approximately 5% of containers that go through primary scanning will trigger an alarm. In many of these alarm cases, the containers' contents include NORM, such as porcelain and kitty litter. These legitimate "innocent" alarms will be confirmed using proper training and manifest details, resulting in some delays. In other cases where the alarms cannot be adjudicated, the containers will be sent for tertiary inspection.

Second, they assumed that the container stowage plan could not be changed. In reality, containers delayed by inspections can typically be stowed in a newly designated location. A container that is delayed significantly will simply miss its sailings since the vessel will most likely not wait for delayed containers.

Due to these assumptions, Erera et al clarified that their presented results do not represent what is likely to happen at a given port, but simply an example of the type of information their methodology can provide.

Lee, Song and Raguramam (2004) expanded on Erera, Lewis and White's paper by including vessel arrivals and departures, size-related weight, risk-index of containers, multi-layered security inspection system and queuing analysis for inspection servers. They proposed mathematical formulations to characterize container operations at a combined transshipment and import-export port. To solve the mathematical problem, they made use of a genetic algorithm to minimize the cost of delays for outbound vessels by varying the percentage of container scanning and the sequence of container movements from yard to outbound vessels. The results are shown below in Figure 9.

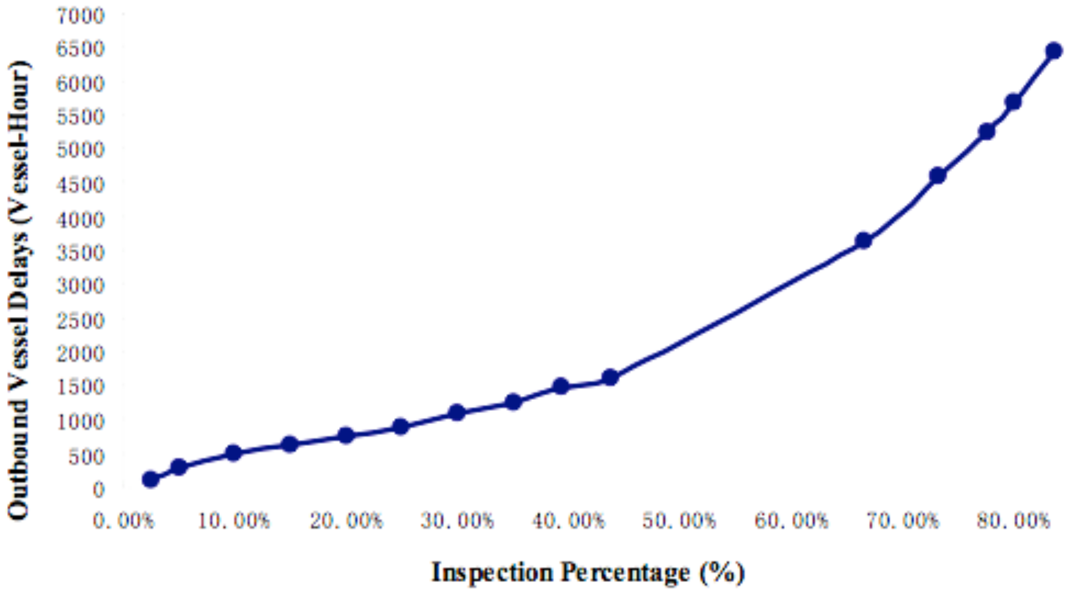


Figure 9. Vessel Delays Based on Inspection Percentages (Source: "An optimization approach to security operations toward sustainable seaport" by Lee, Raguraman and Song, 2004)

Lee et al's results show that delays increase exponentially with increasing inspection percentage. At an inspection percentage of 80%, outbound vessel delay is up to 7000 vessel-hours. Note that the difference in magnitude of the delays measured by Lee et al and Erera et al is due to the difference in measurement units. Lee et al used "vessel-hours" as a measure of delay whereas Erera et al measured delay in terms of "minutes delayed per vessel." Although Lee, Song and Raguramam relaxed some of the assumptions in Lewis, Erera and White's paper, they maintained the assumption that outbound vessels will wait for delayed containers, leading to delayed departures.

2.3 Cost Estimates

Government Budgets

Estimating the cost of port security is a difficult task. Ports vary based on physical layouts, jurisdictional controls, cargo operations (imports, exports and transshipments) and container yard configurations driven by equipment-based storage requirements. It is often said that if you have seen one port, then you have seen one port – warning not to assume that concepts are easily transferable from one port to another.

The Congressional Budget Office (CBO) estimates that the 9/11 Act will cost US$21 billion to implement over the first five-year period. Additionally, the private sector will be impacted by over US$131 million per year; however, none of the assumptions or calculations for these estimates are included. These cost are likely to exceed the annual threshold allowed for private sector mandated expenses from a single policy, which is US$131 million for 2007 (9/11 Act, 2007). Several groups have attempted to estimate the cost of installing, maintaining and responding to port security related equipment.

As reported by the US Government Accountability Office (2005), DOE estimated that each port costs on average US$15 million for the Megaports Initiative in 2003, which includes the installation of radiation detection equipment, associated communication systems, personnel training and a finite maintenance plan. In 2005, DHS projected that the installation of 3,034 domestic RPMs across land and seaport POEs by 2009 would cost US$1.9 billion (GAO, 2006). The GAO has consistently questioned the approach used by both DOE and DHS in their estimations. GAO found that the DOE estimates were heavily based on DOE's experience in Russian land-border, airport, and seaport security installations that began in 1995. GAO contended that the cost of installation varies by the port location, size, physical layout and the level of port infrastructure and cannot be benchmarked against a single country (GAO, 2007a).

In 2007, DOE re-evaluated their costing approach and separated cost estimates by port size, resulting in a new range of US$2.6 million to US$30.4 million per port. DOE and DHS each contributed US$15 million for the 3 pilot installations under the SAFE Port Act, which represents 3 ports of varying sizes (GAO, 2007a). These SAFE Port Act ports began operational testing on October 12, 2007 and a report is due to Congress on their observations by April 2008 (GAO, 2007b). This report; however, is not currently available to the public.

GAO also broached the issue of the lack of specificity in the 9/11 Act, which does not identify the party(s) that will pay for scanning equipment, communications equipment, infrastructure investments, or manning requirements. CBO's cost analysis assumed that this cost would be born by the United States (GAO, 2007a).

Academic Research

Erera, Kwek, Nandini, White and Zhang (2003) proposed a framework to categorize all costs that may be incurred along the entire supply chain as a result of new security measures at seaports. They identified 5 major maritime stakeholders – ports, shippers, freight forwarders, truckers and ocean carriers – and listed the potential costs that these stakeholders may have to incur to comply with new security measures.

Erera et al's categorization of costs serves as a good checklist to help industry to consider the costs associated with port security measures like the 9/11 Act. However, some of the indirect costs are difficult to quantify. For example, no straightforward method exists to estimate how insurance costs and security taxes would increase. Other costs, such reduced flexibility in business operations are difficult to assign a financial value.

Table 1. List of Maritime Stakeholders and Potential Costs (Compiled from "Cost of security for sea cargo transport" by Erera, Kwek, Nandini, White and Zhang, 2003)

Party	**Costs**
Ports	Cost of conducting a Port Vulnerability Assessment (PVA) Cost of establishing restricted areas and security barriers Cost of protecting the waterfront Cost of security lighting. Cost of security alarm and surveillance systems Cost of inspection technology Cost of port employee background checks and credentialing Cost of personnel and material access control and identification Cost of hiring additional security and inspection personnel Cost of changing operational procedures Cost of increased communication Cost of new security system maintenance Cost of technology for consequence mitigation
Shippers	Cost of portal enhancement for timely document transactions Cost of information system revision and increased communication Cost of reduced flexibility in business operations Cost of personnel training
Freight Forwarders	Cost of portal enhancement for timely document transactions Cost of information system adjustment and increased communication Cost of personnel training
Trucker	Cost of communication system and increased communication Cost of driver background checks and credentialing Cost of inspection time delay at port terminals
Ocean Carriers	Cost of portal enhancement for timely document transactions Cost of increased communication Cost of personnel training Cost of increased labor Cost of using standard devices and security-related technology
Entire Supply Chain	Cost of throughput delays in the system Cost of providing more detailed manifest data Cost of security tax Cost of higher insurance costs

2.4 Case Study of Port of Rotterdam

In April 2004, under the Megaports Initiative, the US government funded the deployment of 4 RPMs at the ECT Delta terminal at the port of Rotterdam (NNSA, 2006). Following the success of the pilot project, the GAO reported in 2005 that the Dutch Environment Ministry decided to self-fund full deployment for RPMs at the port's remaining terminals (GAO, 2005). The Dutch government installed 40 RPMs, which began operations in April 2007, covering a reported 100% scanning of road and rail import and export traffic at the port and occasionally transshipment cargo. They utilized NII equipment only for high-risk containers at a centralized location since the port finds NII to be "expensive haulage and time-consuming" (Mollema, 2007). The duration of time from pilot testing to full operation is important to note when considering the timeline for implementing the 9/11 Act, which is approximately 4 years from the publishing of this thesis.

The proposal and tendering process of the full RPM implementation project at the port of Rotterdam began in the summer of 2004. Installation of the 40 RPMs, 3 mobile RPM units and a second central alarm station spanned April 2005 to 2006. The scanning system became fully operational in April 2007. The entire installation process took nearly 3 years, not including the pilot project, which began with the signing of a Declaration of Principles in August of 2003 (Bonewit, 2007).

The port of Rotterdam is currently conducting a study on automated container inspection lanes, which will employ the following technologies:

1) RPM
2) NII

3) Radio-Frequency Identification (RFID)

4) Optical Character Recognition(OCR) cameras

The automated container inspection lane aims to maintain a continuous speed of 13 km/hour. The physical layout of the RPM and NII is similar to the proposal within this thesis. The Rotterdam project is a joint study by the port authority, customs and port businesses. Figure 10 illustrates their conceptual design for the automated container inspection lane.

Figure 10. Port of Rotterdam Conceptual Scanning (Source: http://www.iaph2007.com/Presentations/IAPH2007-Mollema.pdf

The port of Rotterdam anticipates that 2 inspection lanes could serve the entire port. The proposed areas where the lanes will be located are marked in Figure 11. In 2006 the port of Rotterdam was the last port of loading for 433,955 US-bound TEUs, with a total throughput of 9.7 million TEUs (MARAD, 2007).

Figure 11. Port of Rotterdam Conceptual Scanning Locations (Source: http://www.iaph2007.com/Presentations/IAPH2007-Mollema.pdf

The port of Rotterdam serves as an example of a large port that takes a proactive posture on security. It also proves that RPM scanning can be achieved on a large-scale import/export operation utilizing existing technology, with adequate physical space and full port coordination. The Rotterdam automated scanning case study highlights the importance of all the port stakeholders' involvement early in the planning stage of security projects.

3 TAXONOMY

This section first discusses the opinions of several of the top US importers regarding the 9/11 Act. Interviews revealed 2 primary concerns among industry:

1) How is the 9/11 Act going to affect supply chains and operations?
2) Who will pay for the implementation and how much will it cost?

Based on interviews, port visits and our own research, a framework was developed to analyze these 2 concerns. Section 3.2 explores the first concern by identifying potential delays along the supply chain and how the delays will affect the players along the chain. Section 3.3 discusses the second concern by laying out the stakeholders and their willingness to bear or pass down the costs of implementation.

3.1 Interviews with Top 10 Importers

Interviews were conducted with several of the top 10 importers in the US to get a better understanding of their opinions on current security programs and how the newly passed 9/11 Act can potentially affect their operations in the future. Several security initiatives have been implemented in the wake of the terrorist attacks of September 11, 2001. The majority of the importers stated that delays are not currently an issue in the maritime transportation mode even with these addition new initiatives. Sporadic delays have occurred due to increased scanning and inspection but not of great concern.

C-TPAT

Many companies have committed to C-TPAT with high expectations, investing substantial time and capital to fulfill the requirements. However, reactions to C-TPAT participation have been mixed. Some companies assert that they have seen tangible decreases in delays and inspections while others observe that their inspection rates are unchanged. One importer conjectured that only companies that ship out of high-risk countries or carry high-risk cargo would receive tangible benefits from C-TPAT compliance since their inspection levels would be significantly reduced. For other companies shipping common cargo from low-risk countries, their inspection levels were low to begin with and thus, C-TPAT compliance had not resulted in reduced inspections. Another importer had an opposing view, believing that companies with a good cross-section of cargo origins would probably benefit the most from C-TPAT compliance whereas those that consistently source from high-risk locations, such as Colombia or the Indian subcontinent will continue to face scanning and inspections. None of the importers interviewed had performed a cost-benefit analysis to determine whether a tangible or financial benefit was realized by their company in direct association to their investments in the C-TPAT program. However, some importers are finding it increasingly difficult to justify the costs of C-TPAT compliance.

Opinions and Analysis of 9/11 Act

Most of the companies interviewed had a good understanding of the requirements in the 9/11 Act. They knew that the legislation requires both RPM and NII scanning and identified several of the key caveats and ambiguities in the legislation as mentioned in Section 1.1.11.

All of the companies interviewed were opposed to the 100% scanning legislation, citing increased delays and costs as 2 of the major problems with the 9/11 Act. Additionally, they supported the traditional risk-based layered approach of scanning only high-risk containers as opposed to a blanket approach of 100% scanning. One importer even claimed that the legislation would cost “hundreds of billions of dollars globally” and “the world is not ready for such an undertaking.”

Some of the companies were confounded that the 9/11 Act was passed even before preliminary results from the SAFE Port and SFI pilots was submitted. Some importers felt that this was a sign that Congress had its own objective, regardless of the outcome of the pilot project. Companies also voiced potential long-term problems with the 9/11 Act. In particular, many feared that the European Union or China might call for reciprocity, requiring US exports to be scanned prior to being shipped to these countries.

None of the companies interviewed had performed a robust cost or delay analysis to substantiate their opposition to the 9/11 Act. Several stated that the additional delays and costs were so great that no analysis could accurately capture the extent of the consequences. Others felt that the current legislation is so ambiguous and uncertain that any analysis at this point in time is premature.

3.2 Potential Delays and Implications

Our discussion with these importers yielded a list of potential delay impacts that the 9/11 Act could have on their supply chains. This section integrates the opinions from the interviews with our own analysis and research into a framework that presents the potential risks and implications along the supply chain. Figure 12 lists major nodes and links on a typical supply chain from an overseas exporter to a US importer, and the potential delay risks at each point. Figure 13 shows the implications these delays might have on major stakeholders in the supply chain.

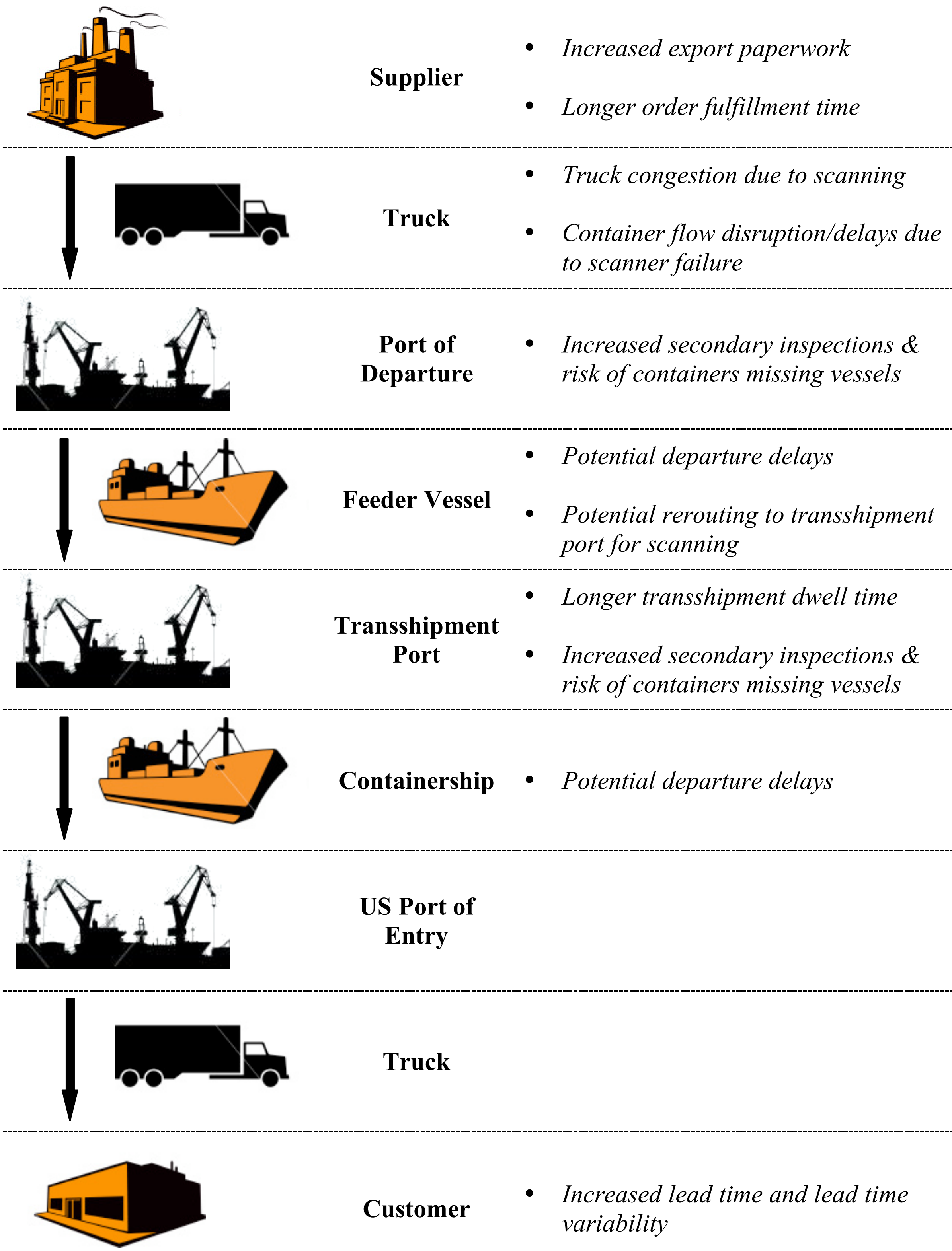


Figure 12. Possible Delays due to 9/11 Act on International Supply Chains

Suppliers	• *Earlier container dispatching* • *Increased holding fees for early arrival and longer dwell time* • *Need for expedited order processing/production* • *Reduced flexibility in business operations* • *Cost of increased documentation*
Truckers	• *Reduced driver productivity* • *Compensation for drivers' unproductive hours in queue* • *Reduced truck asset utilization*
Ports	• *Capacity pressure due to longer container dwell times* • *Capacity constraints due to equipment footprint* • *Financial burden of installing and operating scanners* • *Increased manpower requirement for scanning and secondary inspections* • *Reduced port throughput* • *Potential administrative and routing confusion to identify and divert US-bound containers*
Ocean Carriers	• *Need to re-route and re-schedule vessels* • *Greater container stowage confusion*
Importers	• *Increased risk of out-of-stock and lost sales* • *Increased risk of spoilage and obsolescence* • *Higher safety stock and inventory* • *Potential production disruption due to delays of critical parts* • *Higher costs of international shipping* • *Complicates sourcing and transportation decisions*

Figure 13. Delay Implications

Suppliers

From the perspective of suppliers, the 9/11 Act can potentially result in a longer transit time from the origin to the destination, lengthening their order fulfillment time. Suppliers usually ship containers in just enough time to get through the port and paperwork processes without excess buffer time built in. With the expectation of delays from 100% scanning, exporters might be forced to stuff and send out their containers earlier, which in turn require more expedient production and order processing, and reduced operational flexibility. Furthermore, early container arrivals at ports will incur greater holding fees, which will ultimately be borne by either the supplier or the importer. One importer commented, "You cannot change the time on water – your manufacturing [cycle] time, your time in production runs, and order cycles and time at the port prior to loading is where changes will happen."

Overseas ports might also increase the paperwork required for exportation or place more stringent protocols on existing documentation. Theoretically, export documentation can be compiled in parallel with container stuffing. Some ports have imposed harsh penalties for inaccurate documentation, forcing many companies to compile documents only after their containers are stuffed, thereby further increasing the time for export. Many of the interviewed companies have already expressed concerns over the proposed "10+2" requirements, explicating that the extra documentation will require an expensive adjustment to IT systems to consolidate data at a single point. Many also believed that the amount of time taken to collect and verify data may require inventory to be held longer while the data is being collected. Additionally, some importers voiced a concern over privacy issues associated with providing proprietary data to a single source, particularly if that logical entity was not the parent company. If foreign ports mandate increased documentation in response to the 9/11 Act, documentation costs could further escalate. However, it should be noted that the vast majority of the importers believed “10+2” was achievable and supported in the context of DHS utilizing a layered security approach, as opposed to the 9/11 Act – scan everything anyways approach.

Truckers

The 9/11 Act will likely also affect truckers. Truckers are concerned that the 100% scanning of US-bound export containers will increase truck congestion at ports. The longer a truck spends in queuing, the fewer hauls it can make and therefore the less productive it is. Despite the unproductive hours, the trucking company will still have to compensate truck drivers for the time they spend in queues. From an asset utilization viewpoint, the longer the truck queuing time, the fewer trips the truck can make in a day. For example, if a truck can originally make 3 round trips a day but as a result of congestion (or queuing) due to 100% scanning, can only make 2 round trips daily, the trucking company would have lost 33% of the truck’s utilization.

Current 100% US-bound scanning regimes carried out at the SAFE Port Act pilot port of Puerto Cortes, Honduras, shows no significant truck delays. However, industry contends that given the small size of all 3 of the SAFE Port Act pilot ports and the financial support from the US government, it makes sense that congestion is minimal, making these pilot port lessons not transferable to other larger ports. Therefore, they doubt high-volume ports will be able to achieve the same level of efficiency.

Another problem is the potential disruption of container/truck flow due to failure of scanning equipment. Since the 9/11 Act implies that containers that have not been scanned may be prohibited from being loaded on a US-bound vessel, the failure of scanning equipment can potentially shut down or severely limit ship loading. If no redundancy is built in, i.e. only 1 set of scanning equipment, the flow of US-bound export containers may be significantly constrained. A large backlog of containers/trucks would likely accumulate while awaiting repairs to be completed, potentially impacting the port's entire operation. Even after repairs are completed, it would probably certainly take some time to clear the backlog of container scans. Even if ports have more than 1 set of scanning equipment, the failure of 1 set could place intense pressure on the remaining scanners, further exacerbating congestion.

Ports

The purchase and operations of scanning equipment are significant financial investments, which some ports might not be able to or choose to afford. To alleviate the costs, ports might charge higher handling fees or impose security taxes, which would probably ultimately cascade down to importers. For a large importer like Wal-Mart that imported 695,000 TEUs in 2005 (Colliers International, 2005), a US$10 charge per TEU would cost the importer almost US$7 million annually.

Physical space is another major concern for ports. As mentioned in Section 1.2, scanning equipment requires substantive space, which may not be readily available at crowded ports. Scanning of all US-bound containers can also increase the number of physical inspections at the port. Ports with limited capacities might have to expand secondary inspection areas to accommodate the additional containers. To make matters worse, suppliers might respond to the increased delays by sending their containers to ports earlier, further increasing dwell time and exacerbating the space problem. Expansion is also not just a matter of financial investment either; some ports have already reached physical capacity with no more room for expansion. There are also potential economic losses associated with using physical space in ports for security purposes that could be used for handling additional cargo volume.

Ports with transshipment cargo present another set of problems. Typically, the process of transshipment is expedient. Feeder vessels arrive at the transshipment port; containers are off-loaded and moved to the container yard to await the mother vessel; when the mother vessel arrives, the containers are reloaded and sent to their final destination. Typical transshipment container dwell times average a couple of days. Sometimes, dynamic shipments occur where containers off-loaded from feeder vessels are immediately reloaded onto mother vessels, bypassing container yard storage.

Scanning at transshipment ports would add cycle time to the transshipment process. Containers will now have to be off-loaded and sent for scanning before going to the container stacks or being reloaded on a mother vessel. With dwell times typically shorter than export containers, the probability of these transshipped containers missing their sailings due to inspection is higher. Scanning transshipment containers may require that the container be stowed in the container yard immediately after scanning to mitigate the effects of scanning on the cargo operations, requiring a second driver to move the container to and from secondary inspection, which adds complexity and cost. The risk of missing a vessel sailing due to inspection would likely be high for dynamic transshipment process.

There may also be resistance from port labor unions. In a truck operation a gang of stevedores transfers containers from the gantry crane near the vessel to a rubber-tire or rail-mounted crane within the container yard. In a straddle carrier operation these pieces of equipment cannot drive through current RPM and NII technology, which causes its own unique issues. The port's efficiency is measured by the number of containers each of these large vessel gantry cranes move per hour. The gang of stevedores is dedicated to a single crane and their pay is often directly related to the crane's efficiency, thus any delay incurred by routing the vehicle or waiting for results associated with scanning equipment would directly relate to reduced efficiency. Furthermore, there are health and safety concerns regarding the radioactive emission from NII scanners.

To allow time for transshipment scanning, transshipment ports might mandate a minimum transshipment dwell time between feeder arrival and mother vessel departure. This might force ocean carriers to adjust their shipping schedules. From the port perspective, this will also decrease port throughput.

According to our interviewees, the greatest threat of the 9/11 Act is the increased risk of containers missing their vessel sailing due to secondary inspections. A container that misses its vessel will have to be held at the port for the next available vessel to US, which can take up to a week to arrive. Even then, there is no guarantee that there is sufficient room on the next vessel to accommodate the delayed containers. For companies carrying time-sensitive goods, a delayed container can potentially mean the spoilage or obsolescence of the contents. For retailers, a delayed container can lead to missed sales, promotions and potentially subsequent price markdowns. For manufacturers, especially those running on Just-in-Time operations, a delayed container of a critical part can mean production shutdown.

Ocean Carriers

Terminal operator and ocean carrier interviews refuted the claim that vessel departures would be delayed to wait for delayed containers. Due to the high docking and vessel operating fees, the chance of a vessel's sailing time being adjusted to accommodate delayed containers is a remote possibility. They suggested that the vessels would depart and any delayed cargo would have to wait for the next sailing.

Ocean carriers are concerned over the potential need to re-route and re-schedule vessels in response to changes in port policies. In 2006, out of the 591 last ports-of-loading that ships directly to the US, 295 ports (50%) ship less than 100 TEUs directly to the US annually (MARAD, 2007). It is logical to believe that these low-volume ports would not be willing to invest in scanning equipment and would redirect US-bound containers to transshipment ports instead. Ocean carriers shipping from these ports would then have to re-route their vessels to transshipment ports, increasing the transit time of goods and costs due to increased container handling fees. Additionally, fewer vessels might be able to be dedicated to a single service, due to increased voyage time. These increases could effect the ocean carrier's entire operation. Similarly, if transshipment ports increase their minimum transshipment dwell time, vessels that currently operate under tight transshipment times might have to be re-scheduled or containers might have to wait longer in the container yard for a later sailing date.

Importers

Delays that occur upstream in the supply chain will likely affect importers ultimately. If the delay or the response to a delay results in higher costs, these costs would probably be passed down through the chain to the consignee. For example, if truckers have to pay their drivers more, they will likely attempt to charge shippers more. Shippers would then include these additional costs into their costs of goods sold and markup the prices charged to importers. Similarly, if ports charge shippers higher holding fees, shippers would likely increase the prices charged to importers to recoup the cost.

Costs aside, the accumulation of all the delays along the entire supply chain would result in longer lead-times and greater lead-time variability for importers. If companies are not fully prepared, this can lead to decreased service levels, increased out-of-stock, increased lost sales, increased spoilage and even production disruptions. To protect against these increased uncertainties, importers would likely carry more inventory. Some of the importers who were interviewed believed that inventory levels would skyrocket and make it less attractive to import from overseas.

Sourcing and transportation decisions would probably become more complex. Companies choose their suppliers based on 3 main criteria: 1) price, 2) reliability and 3) speed. The 9/11 Act can potentially reduce the attractiveness of overseas sourcing in all 3 factors by increasing costs, reducing reliability and decreasing speed in international supply chains. Businesses would likely consider these factors as they make sourcing decisions. Depending on the severity of the costs and delays, these may lead organiations to revisit their offshore sources, potentially in favor of a portfolio of supply options that may include domestic supply.

3.3 Burden of Cost

Many companies have expressed concerns over which parties along the supply chain will have to bear the cost of implementation of the 9/11 Act. Although companies generally feel that the costs will ultimately cascade down to importers, there may be other political or strategic factors that could cause stakeholders to absorb some of the costs themselves.

US Government

The US government is currently subsidizing 7 SFI pilot ports to test how the implementation of the 9/11 Act will affect port operations. Although it is unlikely that the US government would extend its subsidies to over 600 other ports that ship directly to the US, industry leaders wonder whether the US government is willing to share the cost of implementation with some overseas ports.

Foreign ports and terminal operators interviewed have expressed discontent with the US for forcing the requirements upon them and expressed concern that the US is merely pushing the cost of security – something that they are not willing to pay themselves – to foreign governments and ports.

Overseas Governments

Overseas governments may have incentives to bear or partially absorb the cost of implementation for 3 main reasons.

1) Politically, foreign governments might want to foster better trade relations with the US and show that they are committed to security. They might also want to provide some subsidies to appease ports and terminal operators.

2) Economically, they might want to remain attractive to foreign direct investments and continue exporting their domestic produce to the US. This is especially true for transshipment ports, which can lose their clients overnight due to cost increases. If a foreign country chooses not to comply with the legislation, export businesses (agricultural or manufacturing) would have to redirect their products to another country for export to the US. This would increase the cost of exports and could reduce the attractiveness of production in the aforementioned country.

3) Operationally, they might view the 9/11 Act as a customs responsibility and want to maintain control over its implementation and potentially utilize the equipment to scan import cargo and exports bound to nations other than the US.

An example of a foreign government volunteering to bear the cost of scanning is the Dutch government with their investments at the Port of Rotterdam as mentioned in the case study in Literature Review.

At the same time, there may be other reasons for foreign governments to choose not to bear any of the implementation costs. If a country is too poor or the government is highly corrupt, the possibility of a government subsidy would be low. For example, terminal operators in the port of Santos, Brazil have expressed doubts that the Brazilian government will help absorb some of the implementation costs and believed that the burden will ultimately fall upon terminal operators.

Port Authority (Government or Privately Owned)

Port authorities might end up partially or completely paying for the cost of implementation if they are mandated by their local governments to do so. Terminal operators might also exert pressure on port authorities to share the cost of implementation. Port authorities might also volunteer cost sharing with terminal operators in order to attract terminal operators to their ports. Port authorities can contribute to the implementation by providing the power grid and fiber optic infrastructure to scanning sites and expanding capacity both within and beyond the port perimeter.

Terminal Operators

If overseas local governments are unwilling to bear the cost of compliance, the onus might be placed on individual terminal operators. Also, if port authorities shoulder the cost, they will likely cascade it down to terminal operators. If terminal operators fail to ensure that containers are scanned prior to loading, they may lose customers since they are unable to offer direct service to the US. On the other hand, if terminal operators were to invest in scanning equipment, they may have to pass down the installation and operating costs to importers. Some terminal operators might see this as a business opportunity to charge exporters an additional security fee that covers the cost of scanning and includes a marginal profit. Large terminal operators with global operations may be able to adjust scanning charges to be competitive on particular routes or in specific regions, while still recovering their investments. Large terminal operator Hutchison Whampoa Limited, for example, is currently being paid around US$6.5 million by the US government to conduct scanning at the port of Freeport, Bahamas (Bridis and Solomon, 2006).

On the other hand, other terminal operators are hesitant to be the first to invest in scanning equipment. This phenomenon is especially pertinent in ports with more than 1 container terminal operator. The port of Santos in Brazil, for example, has 3 container terminal operators. An interview with one of the terminal operators revealed that investment in scanning equipment is a huge gamble due to the multiple extension clauses in the 9/11 Act. In fact, there is a prisoner's dilemma (game theory) between the terminal operators. If one operator decides to invest in scanning equipment, the huge capital requirement will force the operator to charge higher fees to recoup its investments. The increased fees might drive exporters away to other cheaper terminals. The existence of the extension clauses further increases the incentives for terminal operators to delay their investments. If one of the operators invests in scanning while another operator receives an extension, the operator who invested would have spent additional capital without receiving much competitive advantage.

Terminal operators also have to consider how they are going to recover the initial installation costs. Are they going to charge a standard fee for all the terminals they run around the world or should they charge fees according to the regional competitive landscape? In an ideal situation, if all ports were to charge the same fee for scanning, there will be no room for price modifications. However, in reality, different ports and terminal operators might use different pricing strategies to gain competitiveness. If the port of Freeport, Bahamas charges an additional US$20 per container and the neighboring port in Jamaica undercuts at a fee of only US$5, exporters might move their transshipment operations from Freeport to Jamaica. These are all issues that terminal operators have to consider when deciding whether to invest in scanning and how to pass down the costs.

4 RESEARCH SCOPE

This section serves to clarify key assumptions regarding the implementation of the 9/11 Act. It also defines the scope of this research in terms of a framework for quantifying costs and delays, laying out a road map to address the industry dynamics and issues identified in the Taxonomy.

4.1 Assumptions and Interpretation of 9/11 Act

Section 1.1.11 summarizes the requirements of the 9/11 Act as pertaining to the 100% scanning requirement. This research does not address the container seal requirements also defined in Section 1701 of the 9/11 Act. Our thesis does not address the feasibility or effectiveness of the implementation of the 9/11 Act. Our research attempts to simulate a scenario of 100% scanning of US-bound containers using currently available technology, although developments in technology may change the scenario. This section covers key assumptions for scanning definitions, responsible parties, the types of containers scanned and the methods required for data processing.

The 9/11 Act calls for the DHS Secretary to establish “technological and operational standards for systems to scan containers” (2007, §1701, para 8). To date, these standards have not been released to the general public. Thus, we must define our assumptions to place our research in a proper context. Operationally, the 9/11 Act requires that a US-bound container be scanned “at a foreign port before it was loaded on a vessel” (9/11 Act, 2007, §1701, para 8). This provides ambiguity as to whether this scanning can occur at any point within the supply chain after the shipment is stuffed into a container, or whether the spirit of the law requires this scanning to occur at the last port of loading. This research takes a conservative security stance and assumes that the 9/11 Act scanning should occur at the last port of loading prior to being shipped to the US.

In this research, we assume an alarm rate of 5%. This is defined as the average number of containers that will cause RPM alarms during primary scanning. The alarm rate is directly related to the type of commodities shipped through a port, due to NORM, which causes innocent alarms. This is based on available data on worldwide RPM alarm rates. Bethann Rooney, the Port Security manager at the Port Authority of New York and New Jersey reported an alarm rate of 2.5% on import containers (Detecting Nuclear Weapons and Radiological Materials, 2005). During a Canadian Border Service Agency sponsored limited pilot project at the port of Halifax, a radiation alarm rate of 5% was observed for import container cargo (Canada Border Service Agency, 2006). The Belgian Federal Public Service Finance anticipates a primary inspection alarm rate of 5% to 10% for import and export container cargo (Belgian Federal Public Service Finance, 2006).

This thesis assumes an average alarm rate of 5% based on these actual alarm rates, with the consideration that in practice, alarm rates could be higher or lower than 5%. RPM false alarm rates, which are typically .1%, are negligible, and assumed to be absorbed into the average alarm rate estimate. All alarms do not occur by TEU, which is the typical measurement of a port volume. Instead they occur by container load carried by on a chassis or bomb cart pulled by a truck. This could be a single 20 foot container (1 TEU), a single 40 foot container (2 TEUs), a 45 foot container or 2 separate 20 foot containers on the same flat bed. This is worth noting, because using a port's TEU volume to estimate alarm rates or scanning efficiencies is inaccurate. The majority of international containers are 40 foot equivalent units (FEU), thus an industry "rule of thumb" was developed to estimate the actual number of container represented by a TEU port volume. Typically the number of actual shipping containers is 2/3 of the total TEU volume. Additionally, the NII equipment does not provide alarm notification, thus we are unable to quantify the rate of secondary inspections due to suspicion that arises from NII images. This was a factor when deciding to establish an alarm rate at 5% instead of the 2.5% observed at the Port of New York and New Jersey.

The 9/11 Act also fails to define what entities are responsible for conducting the scanning or incurring the financial burden. The legislation mentions further inspection by "appropriately trained personnel" (9/11 Act, 2007, §1701, para 4). This gives rise to the notion that alarm review, inspection decisions and actual inspections could be a function of any trained person. Based on the information in the 9/11 Act, this could be a national government, port operator, terminal operator (such as Dubai Ports World) or a third-party inside or outside the port perimeter. Although this research does not directly address the source manpower, it does make the assumption that the cost of necessary personnel is similar to the cost of US customs personnel currently operating RPM and NII scanning systems. This thesis also assumes that no costs are absorbed by the US or foreign government and that all costs are passed directly to the importer.

This thesis focuses on the scanning of US-bound containers as exports at the last port of loading. US-bound containers can depart a last port of loading as either an export or as a transshipment container. Transshipment containers are offloaded from one ship, stored within a container yard, and then loaded onto another vessel for shipment to the final destination. This concept is similar to the airline hub-and-spoke system. These containers do not arrive at the port through a physical processing gate, but instead the port serves as a waypoint in the container's voyage to its ultimate destination.

Based on the complexity of estimating equipment quantities and delays involved with scanning transshipment containers, this research does not address this type of scanning. Transshipment container scanning would most likely occur within individual container yards during container discharge operations, between being offloaded from a vessel and container yard storage. If technology, container flow, and physical constraints are too difficult for a port to hurdle, these transshipment boxes may be redirected through the types of inspection gates described within this thesis.

Additionally, data analysis and transferring assumptions were made in this thesis. The 9/11 Act does not specifically require assessment of information produced by the radiation and NII equipment. This thesis assumes that all data generated from the scanning equipment must be reviewed. All RPM alarm data is assessed and a decision is rendered to inspect or not inspect the container. NII equipment does not currently produce an alarm, thus all NII images are reviewed for any inconsistencies, which may trigger an inspection. Currently, this would provide grounds for an exemption based on the NII's inability to "adequately provide an automated notification of questionable or high-risk cargo as a trigger for further inspection by appropriately trained personnel" (9/11 Act, 2007, §1701, para 4). In the SFI and SAFE Port Act, pilot operations data on US-bound containers is sent electronically in near-real time to US customs. This feature is not a requirement of the 9/11 Act; therefore, it is not included in the cost consideration.

4.2 Research Approach

The literature review and stakeholder interviews revealed the prevalence of opinions on the perceived negative impacts of implementing this legislation. However, we identified a dearth of quantitative measures to substantiate these claims. The objective of this thesis is to identify major stakeholder issues and provide a framework for quantifying the financial costs and delay risks bourn across the entire supply chain in association with implementing the 9/11Act.

Cost and delay analyses in this thesis are based on 2 prototypical ports – a low volume export port, referencing Puerto Cortes, Honduras and a high volume export port, referencing Antwerp, Belgium. Cost analysis was performed for a consolidated (port authority) level installation and a segmented (terminal operator) level installation. Cost estimates were created for initialization and operational costs, with consideration to the entities that may bear these expenses. Costs are then assessed based on past domestic installations within the US, along with estimates provided by vendors and international seaports. These costs are then broken down to an expected per box fee. This thesis will not attempt to quantify indirect costs, such as loss of business flexibility, faced by other major stakeholders due to the uncertainty surrounding how the legislation will affect the operations of these stakeholders. An attempt at quantification is premature at this time.

Delay analysis was performed to quantify 2 delay risks of the greatest concern to businesses – truck congestion and secondary inspection. Truck congestion is explored through a queuing model to assess delays at the port main gate and at the primary scanning area. For secondary inspections, a Monte Carlo simulation was developed to estimate the probability of a container missing its vessel due to secondary inspection delays. The 2 models are deliberately kept generic to be applicable to different ports. As such, specific port layouts and internal operations at terminals, such as container stacking and crane moves are not included. The models were also developed to be easily reproducible to allow businesses to make quick estimates on potential delays without the need for port-specific attributes other than the number of gate-in booths, export volumes and the average secondary inspection time.

5 COST OVERVIEW

This section aims to provide US importers with a framework for understanding the costs associated with implementing the 9/11 Act. The purpose is not to provide a specific dollar amount for compliance with the 9/11 Act, as each port varies in physical lay-out and the level of investment in power and fiber infrastructure. This section discusses initialization and operational cost, and provides analysis on the progress and lessons learned from existing scanning programs. We discuss potential entities that may bear specific costs and how these costs can be divided; however, the structure of cost division will likely change on a per port basis. Figure 14 below shows the broad categorization of the stakeholders.

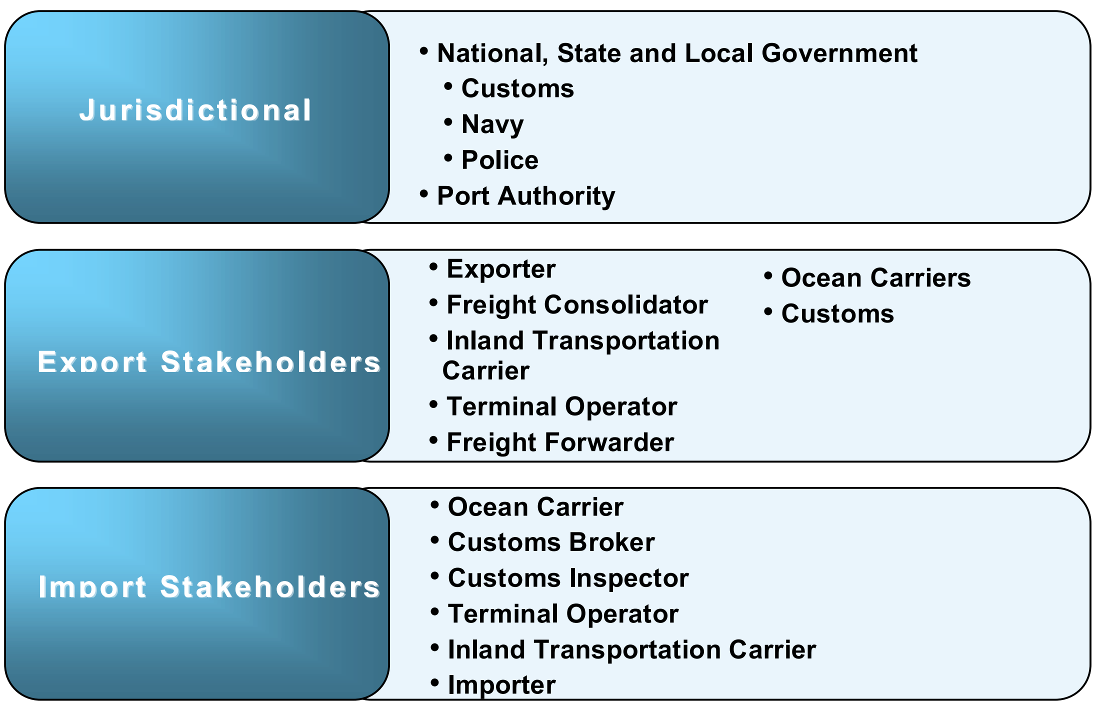


Figure 14. Stakeholder Breakdown

The entire physical grounds of the port are referred to as port authority, in reference to the jurisdictional control of the port. Within the port authority, individual terminal operators have separate perimeters. Although some terminal operators are government owned or owned by the port authority entity, this section assumes that terminal operators are private and separate business enterprises.

For cost analysis calculations, we identified 2 types of container ports:

(1) Small/low-volume container port – defined as a container port with a single port authority main gate and 2 distinct terminal operator facilities.

(2) Large/high-volume container port – defined as a container port with 2 port authority main gates and 10 distinct terminal operator facilities.

In each of these ports, we defined 2 implementation plans:

(1) Port authority level installation – export containers are scanned within the perimeter of the port authority's jurisdiction prior to arriving at individual container terminals. This option would require a minimal amount of equipment and personnel by capitalizing on an existing centralized customs inspection area located en route between the port authority main gate and the individual terminals.

(2) Terminal operator level installation – each individual container terminal at the port would be equipped with its own set of equipment to scan export containers. Each individual terminal's inspection capability would be self-sufficient, and no assets are shared.

Each individual installation location is required to have more than 1 set of RPM and NII equipment installed. This decision for equipment redundancy is necessary to compensate for scheduled and unscheduled maintenance downtime.

5.1 Initialization Costs

Initialization costs are defined as the purchase price for equipment, installation, operational testing, civil engineering works, initial training and communication package. Based on our discussions with jurisdictional and expert stakeholders, an array of potential entities may bear the initial initialization costs. In many cases the national government, through customs or an appropriate agency, will purchase equipment and pay associated set-up costs in a manner similar to the US government's installation of RPM equipment at domestic import gates. In other situations, the port authority, terminal operator or even a private third-party may pay for these expenses.

5.1.1 Equipment and Installation Costs

Equipment costs were quantified and analyzed utilizing US government domestic import installation prices. Next, equipment vendor data was utilized to adjust or confirm the relevance of the US domestic prices to foreign 9/11 Act compliant installations. Then a cost analysis was created for a small and large port. Our field study visit to Puerto Cortes, Honduras, serves as the baseline for the small port estimates. Antwerp, Belgium, which has released some cost information from its RPM experience with the DOE Megaports Initiative, serves as the basis of estimate for the large port example.

5.1.2 Domestic Equipment and Installation Costs

Initially, DHS anticipated installing 3,034 RPMs across all US POEs by September 2009 at a cost of US$1.3 billion. Figure 15 indicates the percentage of deployment in the maritime domain, as well as a rough budget estimate if costs are equally allocated across all POEs. Based on the complexity of seaport deployments, equal allocation provides a low basis of estimate for seaport installation expenses. The poor correlation between land-border and seaport installation estimates was further enumerated in the GAO report on DOE's Megaport cost estimates discussed in the Review of Literature Section.

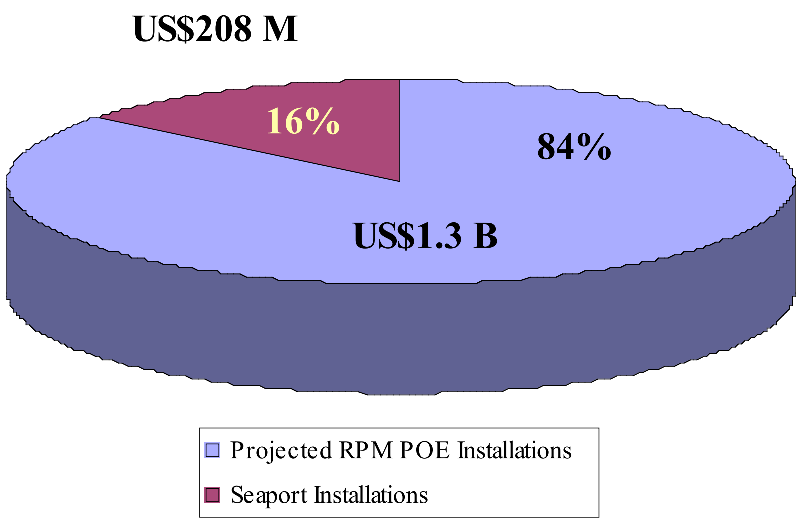


Figure 15. Percentage of Seaport RPMs in DHS Domestic Deployment

According to the GAO (2006) this DHS cost estimate is overly optimistic. This is partially because the estimate fails to include any budget for advanced spectroscopic portals (ASPs). Based on the experience of DHS in procuring RPMs for domestic deployment the average cost per RPM is US$55,000 uninstalled (GAO, 2007c), with the highest manufacturer's price in 2006 for US government purchases being US$130,959 (Domestic Nuclear Detection Organization, 2006). These costs are based on a bulk purchase of RPMs. A separate initiative was launched in July 2006 by DNDO with a US$1.2 billion budget to develop and deploy ASP domestically over a 5 year period (GAO, 2007d).

By December 2005, DHS had deployed 143 of the initially estimated 495 RPMs at domestic seaports, scanning 32% of US container imports. As of October 11, 2007, Vayl Oxford, Director of the Domestic Nuclear Detection Office (DNDO) reported that a total of 358 RPMs have been installed at the 22 busiest US seaports; scanning 93% of US import container traffic (SAFE Port Act, 2007). On April 2, 2008, CBP Deputy Commissioner Jayson Ahern testified in a hearing before the Subcommittee on Homeland Security that 398 RPMs were domestically installed to date, scanning 98% of US seaborne imports. An additional 94 RPMs will be installed at seaports by the end of FY 2009 for a total of 492 RPMs installed at US seaports (Secure Freight Initiative, 2008). Table 2 illustrates the installation progress. Currently, DHS believes at least 200 additional RPMs will be necessary to complete 100% scanning of US container imports, increasing the total RPMs required at US seaports to 695 units.

Table 2. DHS Installation of RPMs at the 22 Busiest US Seaports

Date	***Quantity of RPMs***	***Percentage of US Seagoing Imports Scanned***
1 Dec 05	143	32%
11 Oct 07	358	93%
2 Apr 08	398	98%
?	695	100%

Based on DHS's FY2008 budget submission for large scale NII units, the US government estimated a total cost per NII unit of US$3.23 million (DHS, 2007b). Based on the wide range in prices and capabilities of NII equipment, it is uncertain what the cost break-down is between equipment purchase and installation. DHS's schedule for future deployment of NII's domestically is indicated in Table 3.

Table 3. DHS Domestic NII Deployment Schedule

Year	***Quantity of NIIs***
FY2008	15
FY2009	17
FY2010	10

Cost estimates for installing RPMs domestically average US$200,000 (GAO, 2007c). These estimates obtained in a GAO report reference their analysis of a DNDO cost-benefit analysis, which is not available to the public, limiting our ability to assess many of DNDO's assumptions. However, installation inferences can be made based on US seaport standards, which represent highly integrated and technically forward operations. Some of these installation assumptions include:

1. Electrical power already exists at the site of installation
2. The port has an existing fiber backbone and allows the use of dark fiber within the conduit run or the port permits additional fiber to be pulled through existing conduit
3. Civil works installations are minimized based on existing workspace and inspection areas for US Customs officers on site

These assumptions should be considered when calculating the cost of implementation at international seaports.

Domestically, sodium iodine (NaI) hand-held RIIDs are utilized for secondary inspections. Approximately 900 units are deployed at a cost of US$10,300 per RIID. Additionally, personal safety pagers and radiation intensity search units are also utilized. DHS radiation pagers cost an average US$1000 per unit. (DHS, 2006b). Table 4 outlines the basic costs associated with domestic scanning equipment.

Table 4: US Domestic RPM Installation Costs Per Unit

Equipment Type	***Average Equipment Cost***	***Installation Cost***	***Installation Total***
Radiation Portal Monitor (RPM)	$55,000	$200,000	$255,000
Radioactive isotope identification devices (RIID)	$10,300	$0	$10,300
Advanced Spectroscopic Portal (ASP)	$377,000	$200,000	$577,000
Personal Radiation Detectors (Pagers)	$1,000	$0	$1,000
Non-Intrusive Inspection (NII)	Not Available	Not Available	$3,226,667

5.1.3 Vendor Estimates

Vendor estimates are included to provide a point of comparison using commercial data to validate or raise concerns with the applicability of US government domestic cost estimates for international 9/11 Act compliance. To date, a number of vendors have installed scanning equipment at international airports, seaports, and border crossings. This section focuses primarily on NII prices due to the lack of available domestic data to identify unit cost. This section includes pricing data from several companies, including Nuctech Company Limited, SAIC and Smith Detection. TSA Systems and Ortec provide pricing data for hand-held equipment not included in the domestic program pricing information.

The price range of NII is based on the type of radiography (gamma or x-ray), the energy range for x-ray based system and equipment configuration. Equipment configurations describe whether the unit is either mobile or stationary. Mobile scanners typically require the driver to exit the vehicle, while the NII itself is driven past the container to perform the inspection. Stationary systems allow the driver to pull the conveyance through NII equipment. Several parameters govern the decision of determining the appropriate equipment selection. First, the health and safety standards and political element associated with unionized labor can be the primary factor that regulates equipment selection. Additionally, the amount of space available for scanning may encourage the use of a fixed unit.

Nuctech

Nuctech Company Limited, which originated out of Tsinghua University China, has exported scanning technology solutions to more than 70 countries. They claims to hold the largest market share in the field of high-energy security inspection systems. Although an international standard has yet to be established for RPMs and NII scanners, US government agencies are currently conducting a comprehensive evaluation of Nuctech's NII scanner and RPMs in Beijing, China. Nuctech's NII prices range from US$1.9 million to $3.5 million.

The average throughput for Nuctech's NII equipment in actual operations is 20-25 vehicles per hour, with a unit that requires the driver to exit the vehicle prior to scanning. Nuctech's Fast Scan System for RPM allows vehicles to drive through the portals at a speed of 5-15 km/hour, with theoretical throughput of 150 vehicles per hour.

Nuctech's mobile scanner is 4 MeVs, with a radiation safety zone requirement of 43 meters long and 38 meters wide. This safety zone is established to reduce the amount of radiation received by personnel in the area. Unlike the RPM equipment, NII emits radiation. Nuctech's mobile model requires the driver to exit the vehicle prior to scanning. The drive through scanner is 2.5 MeV, with a radiation safety zone is 20 meters long and 7 meters wide (personal communication March 15, 2008).

SAIC

SAIC, a US-based company is another major supplier of NII equipment. Their P7500 is currently deployed in a number of CBP installations overseas, including the SFI installation in Southampton, United Kingdom. This 7.5 MeV high-energy X-ray also advertises a theoretical scanning capability of 150 containers per hour. The price for this system is US$2.4 million (SAIC, 2007).

Smith Detection

Smith Detection, a United Kingdom based public company, is active in NII equipment sales around the world. According to the authorized federal supply schedule catalogue price, valid through July 31, 2001, the cost for a low throughput Mobile Scan Cab2000 is US$1.33 million, while the high throughput HCV Mobile 2500II NII is

US$2.96 million. Currently the delivery schedule of these 2 units is 8 to 10 months. The warranty consists of 1 year for parts, labor and travel, with additional details outlined in individual proposals. Smith also provides a system-training course for $10,653 per week (General Services Administration, 2006).

TSA

Additionally, TSA Systems, a vendor to DOE international installation, provided their July 2007 standard product price list. The list was referenced to obtain an estimate for survey meters utilized in secondary inspection. Prices vary based on capability, but the approximate single unit purchase price is $3,400 (personal communication, April 10, 2008).

At SFI Ports and under the Megaports Initiative, high-purity germanium (HPGe) (for gamma detection) and moderated ^{3}He tubes (for neutron detection) based RIID systems are used in addition to NaI systems. These HPGe detectors have better resolution when compared to NaI detectors; however, they are not currently being deployed at US ports. We contacted one vendor, Ortec, which provided us single unit pricing for the Ortec Detective-EX, which contains both a gamma and neutron identifier at US$70,000 (personal communication, April 17, 2007). A summary of vendor pricing is included in Table 5.

Table 5. Vendor Pricing Data

Equipment Type	***Equipment Cost***
Nuctech NII	$1,900,000 - $3,500,000
SAIC P7500 NII	$2,400,000
Smith Detection Cab2000	$1,330,000
Smith Detection HCV Mobile 2500II NII	$2,960,000
TSA Survey Meter	$3,400
Ortec Detective-EX HPGe	$70,000

5.1.4 Other Initialization Elements

This section identifies additional items and services necessary in the initialization period. DHS identified an average of an additional US$180,000 per RPM, above the US$200,000 installation costs based on land-border installations. This expense is divided between hardware and personnel. Hardware accounts for between US$60,000 and US$80,000, which includes primarily communication equipment, as well necessary traffic control measures. Personnel expenses include travel for the oversight of the installation, training of personnel, as well as some licensing fees for software and building permits. It should be noted that this expense is separate from personnel manning requirements, which will be discussed in the operational section. This constitutes the remaining US$100,000 to US$120,000 (personal communication, April 7, 2008).

Within a container port, inspections are typically tracked by container numbers. The process of identifying the container number ranges from manual input using approximately 4 mounted video or still image cameras to automated Optical Character Recognition (OCR). These cameras are positioned in close proximity of the scanning equipment. OCR is utilized in all current SFI deployments to facilitate the speed and accuracy of data transmission. Under the pilot project, CBP collects records on all US-bound containers regardless of alarming condition. Without OCR, manually inputting the container numbers for all non-alarming containers could potentially become a full-time job. The 9/11 Act currently does not provide any requirement to send data back to the US; however, this added expense should be considered a possibility.

Installation expenses are a function of regional labor, licensing and tax costs, as well as power and fiber infrastructure. Complementary civil works projects are often needed to provide office space for RPM alarm and NII image review, as well as server space for the communication equipment. Additionally, traffic controls may be required to direct vehicle movement, control speed or prevent conveyances from parking inside the pillars of the RPMs. This can include the addition of speed bumps, drop bars, signage, traffic lights and lane re-configuration.

Costs can escalate substantially if power and fiber must be laid for the project. Additionally, it may be necessary to make alterations to the terminal operating and customs software packages in order to track containers through the system, provide container destination and commodity information to those responsible for adjudicating alarms, as well as placing inspection holds and releases on containers.

One vendor estimated that a software package for a simple 4 lane RPM design typically cost US$30,000 (personal communication, April 10, 2008). Prices quickly escalate when modifications are necessary to meet the needs of the port's concept of operations. In order to reduce disruption within the port, scanning systems and software typically have to adapt to the existing flow of goods and information in place at the port. These elements are mentioned to provide a frame of reference when considering the substantial variance in cost estimates based on the level of customization required at the port.

5.2 Operational Costs

Operational costs are defined as ongoing expenses incurred for the purpose of operating the container scanning equipment. Significant contributors to this cost include:

1) Wages for additional personnel

2) Cost associated with additional container movements

3) Ongoing training

4) Data transfer costs

5) Equipment maintenance, repair and replacement

The costs associated with performing the actual secondary inspection are absorbed by the port at the personnel level. The 9/11 Act does not currently place restrictions on parties that have permission to operate the scanning equipment, review the data, or adjudicate alarms. Based on our interviews and port field research, the following entities may shoulder some of the operational cost:

1) Government (National, State and/or Local)

2) Port Authority (potentially also government operated)

3) Terminal Operators

4) Third Party

In the US and the SFI Port pilot model the secondary container inspections and review process is a customs function. Typically, the labor costs associated with performing current inspections is not passed directly on to the customer; however, the fees associated with additional movements of the container to achieve the inspection are passed on. In Puerto Cortes, Honduras, a $40 equipment handling fee is levied for the provision of a driver and vehicle chassis to move a container for secondary inspection. Based on our interviews and site visits, operational costs vary based on the number of containers scanned, often both US and non-US bound shipments, alarm rate experienced at the port, equipment quantity and configuration. Additionally, opinions on the methodology for passing scanning costs varied from the government absorbing all of the cost outside of equipment moves to passing all scanning costs to the importer.

5.2.1 Domestic Operational Costs

The expense associated with scanning is substantial. According to the April 2008 Ahern testimony, an additional US$27.3 M has been requested to hire new CBP officers and support to preserve the flow of legitimate cargo through smaller US seaports. Table 6 displays the staffing matrix.

Table 6. New DHS Staff for FY 2009 RPM Seaport Installation

Quantity of RPMs	***CBP Officers***	***Scientist***	***IT Specialist***	***Mission Support***	***FTE***
94	238	20	25	12	137

This cost is directly associated with the installation of 94 RPMs in FY 2009, which will scan approximately 230,000 containers, representing 2% of the 11.5 M annual container imports (Secure Freight Initiative, 2008). This equates to a burdened yearly expense of US$114,706 per new hire, costing US$119 per container annually in labor charges alone to scan containers at smaller US ports. This expense should raise a red flag to lawmakers who have long supported a threat-based, layered approach to port security. This level of expense also underscores the importance of evaluating incremental program costs.

Based on the FY2008 DHS budget, the US employs 9 customs personnel per NII unit. This is budgeted at a burdened rate of US$137,803 per person and thus US$1.24 million per unit (DHS, 2007d). The budget information did not differentiate between employees required for oversight versus those integral to equipment operations.

Additionally, US ports typically operate 24 hours per day, but it is uncertain whether NII scanning occur over 3 daily shifts. We will not attempt to make assumptions on the number of equipment operators in the cost estimate; however, we will utilize the 9-person employment per NII for staffing estimates.

Average maintenance costs for RPMs are US$5,500 per year per unit based on a US$55,000 purchase price, while ASP maintenance costs are approximately US$38,000 per year per unit based on a US$377,000 purchase price (GAO, 2007c).

5.2.2 Vendor Operational Cost Data

Several of the vendors we interviewed were reluctant to commit to a specific number of operators necessary for each piece of equipment. The NII equipment requires a minimum of 1 dedicated person to review alarms. An intelligent interface has not been developed to review these images. Since NII equipment does not automatically trigger an "alarm" status, each individual image would have to be reviewed to identify anomalies. The number of NII operators is a function of the number of containers scanned, number of containers reviewed, desired speed of container review and release, as well as operating hours and safety standards for active scanning equipment in a country. Some NII equipment requires an additional person to be located within line of site of the equipment to be able to perform immediate shutdown due to radiation safety zone violations.

The RPM is a passive system, thus there are no safety personnel required for operation. RPM data is typically consolidated in alarm reviewing station(s), thus the addition of a RPM in a deployment does not necessarily indicate that additional staffing is required. One computer workstation can review and process alarms for several RPMs.

RPM reviewing staffing depends on the number of container passing through the equipment, port alarm rate and the concept of operations. Typically less than 5% of the containers will alarm and require operator review. It is important to note that most ports operate 24 hours a day, while many customs authorities operate on standard working hours. This requires personnel for 3 additional shifts for alarm review, or potential additional delays and cost may be associated with only staffing the alarm station 8 hours per day. Both DHS and DOE existing port programs urge their partners to review and process alarms throughout port operational hours.

Our discussion with vendors brought to light an industry rule of thumb that annual maintenance for equipment is approximately 10% of the purchase price of the unit. This concept was either also used by DHS in the domestic calculations, or the domestic program average reinforces the validity of the industry observation.

5.3 Cost Calculations

As previously noted, the sentiment in the industry is that if you have seen one port, you have seen one port. This concept essentially highlights the uniqueness associated with each port based on physical layout, jurisdiction, types of container handling equipment, number of terminal operators, number of gates within the port authority and terminal operators, union representation and the breakdown between import, export and transshipment cargo operations. The first portion of this section attempts to lay-out the fundamental considerations necessary to formulate a budget for the installation of equipment in compliance with the 9/11 Act. These considerations hinge on initialization and operational costs.

Although it is difficult to quantify costs in a dynamic environment we will lay-out baseline assumptions to create a 9/11 Act compliance estimate. The true value of this study is not in the dollar figure, but instead in the process necessary to consider those costs, particularly weighing the additional trade-offs discussed in the delay section of this thesis.

Table 7 outlines the cost estimates from the previous section that are utilized in this cost estimate. These cost fail to address the escalating expenses associated with software modifications necessary to conform to individual port operations. As previously discussed, these assumptions are based largely on US estimates across all ports of entry, thus the installed unit cost for RPM and NII is potentially low.

Table 7. Baseline Cost Estimates (US$)

	Description	Unit Price	Physical Installation Per Unit
Primary Inspection	RPM	$ 55,000	$ 200,000
	NII	N/A	N/A
Secondary Inspection	HPGe	$ 70,000	$ -
	NaI RIID	$ 10,300	$ -
	Survey Meter	$ 3,400	$ -
	Pager	$ 1,000	$ -
	ASP	$ 377,000	$ 200,000
Stations	RPM Alarm Station	$ -	$ -
	Secondary Inspection Team	$ -	$ -
Fiber Optic Lease	Port Fiber Network	$ -	$ -

	Description	Hardware/Software Installation Per Unit	Training and Oversight Per Unit
Primary Inspection	RPM	$ 70,000	$ 110,000
	NII	N/A	N/A
Secondary Inspection	HPGe	$ -	$ -
	NaI RIID	$ -	$ -
	Survey Meter	$ -	$ -
	Pager	$ -	$ -
	ASP	$ 70,000	$ 110,000
Stations	RPM Alarm Station	$ -	$ -
	Secondary Inspection Team	$ -	$ -
Fiber Optic Lease	Port Fiber Network	$ -	$ -

	Description	Initialization Unit Cost
Primary Inspection	RPM	***$ 435,000***
	NII	***$ 3,226,667***
Secondary Inspection	HPGe	***$ 70,000***
	NaI RIID	***$ 10,300***
	Survey Meter	***$ 3,400***
	Pager	***$ 1,000***
	ASP	***$ 757,000***
Stations	RPM Alarm Station	$ -
	Secondary Inspection Team	$ -
Fiber Optic Lease	Port Fiber Network	$ -

Operational estimates are divided into personnel expenses and maintenance, shown in Table 8 and 9. The inspector wages are calculated from domestic US burdened rates. The secondary inspection rate was obtained by averaging the NII and RPM operator salaries. All maintenance estimates are based on 10% of the equipment purchase price. The NII has a wide price range so the maintenance amount was obtained using the average domestic installed cost with the same amount deducted for installation, hardware and personnel as the domestic RPM.

Table 8. Baseline Operational Cost Estimates – Personnel (US$)

	NII	RPM Alarm Station	Secondary Inspection
Personnel Per Unit (FTE)	9	5	5
Burdened Cost of Personnel	$ 137,803	$ 114,706	$ 126,255
Annual Personnel Unit Cost	***$ 1,240,227***	***$ 573,530***	***$ 631,273***

Table 9. Baseline Operational Cost Estimates – Maintenance (US$)

Equipment Type	***Per Unit Maintenance (Annual)***
RPM	$ 5,500
NII*	$ 284,667
HPGe	$ 7,000
NaI RIID	$ 1,030
Survey Meter	$ 340
Pager	$ 100
ASP	$ 37,700

Each gate regardless of whether it is a port authority or terminal operator gate is assumed to have:

1) 4 Inbound (Gate-in or Import Lanes)
2) 4 Outbound (Gate-out or Export Lanes)

An example of this generic gate is shown below.

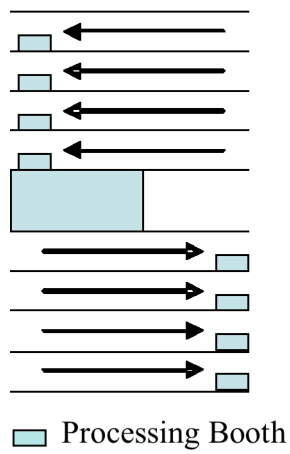


Figure 16. Generic Port Gate

Primary inspection consists of 2 RPMs and 2 NIIs installed in 2 inspection lanes. Each inspection team, whether at the port authority or at the terminal operator level will be equipped with the following inspection tools:

1) 1 High Purity Germanium (HPGe) RIID
2) 2 Search Instruments – Survey Meters
3) 2 Radioisotope identification devices – NaI RIID
4) 10 Personal Safety Pagers

An example of an inspection area is shown in Figure 17.

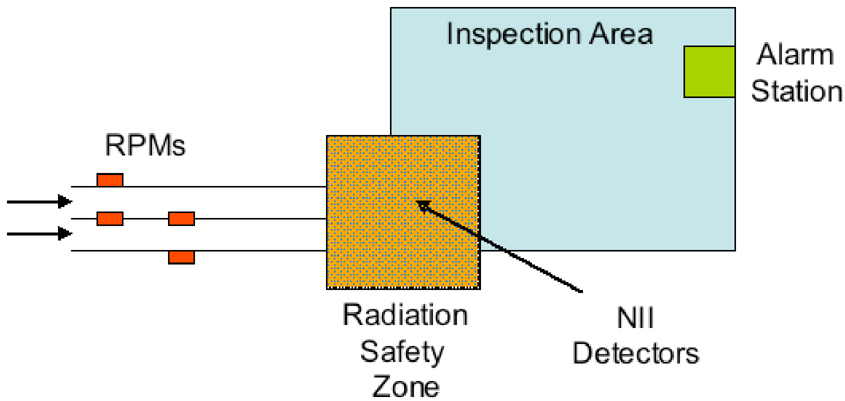


Figure 17. RPM and NII Inspection Area

5.3.1 Port Authority Level Installation Assumptions

The following assumptions are made for port authority installations for both the small and large port sample calculations:

1) Customs has taken on the responsibility for scanning equipment and alarm adjudication tasks
    a. No union rules prohibit drivers from remaining inside the vehicle during active NII scanning
    b. Customs officers are allowed to operate active NII systems
    c. Customs must hire additional staff for all scanning related tasks
    d. Customs has sufficient space and jurisdiction to have an inspection facility on the Port Authority premise
    e. This space includes office space for additional personnel and equipment necessary to operate the system

    f. Adequate space is available in computer server room for 1 to 2 server racks associated with the system

2) Electrical power is available to the equipment location at a negligible fee
3) The port has a fiber optic backbone with additional dark fiber available at installation site
    a. A fee must be paid for use of bandwidth (US$400,000 per year)
4) Data is reviewed and stored in country and is not sent back to the United States
5) Minimal alterations must be made to the site
    a. Additional signage
    b. Speed bumps
    c. Traffic lights and associated ground loops
    d. Bollards to protect equipment
6) The port is capable of identifying destination of container at the port authority main gate (i.e. US-bound)
7) Commodity information on the container is available electronically in a timely manner without alterations to current computer systems
8) Adequate space is available for equipment and safety zone footprint
9) Assumed that all US-bound cargo are export cargo that passes through gate, not transshipped between vessels

These assumptions indicate a "best case" scenario for a highly technical port, with an efficiency focus for the 9/11 Act installation. The basic concept of operations for this model is that all containers pass through the port authority main gate(s). At the main gate the export container is identified as a US-bound container. Instead of receiving clearance to proceed to the terminal operator facilities, the driver is directed to pass through a scanning station en route to the facilities. This station would include 2 inspection lanes. These lanes would be outfitted with both RPM and NII ports in a tandem set-up. This requires adequate spacing to prevent the active NII equipment from causing an alarm on the passive RPM equipment. The next step is highly dependant on data reviewing decisions that are not required under the 9/11 Act. A substantial amount of queuing space would be necessary if every NII image is analyzed by a customs officer prior to determining whether to release a container that did not cause a radiation alarm.

5.3.2 Terminal Operator Level Installation Assumptions

The following assumptions are made for terminal operator installations for both the small and large port sample calculations:

1) US-bound containers are equally likely to depart from any terminal at the port, meaning that all terminals need to be equipped with scanning devices
2) Customs has not taken on the responsibility for scanning equipment and alarm adjudication tasks
3) Each individual terminal operator is responsible for installing its own equipment
4) Secondary inspection occurs on the premises of each individual terminal operator, and space is adequate to perform this function
5) No union rules prohibit drivers from remaining inside the vehicle during active NII scanning

6) Terminal personnel are only able to meet 0% of the personnel requirements for the scanning operation and must hire additional staff for the remaining tasks
7) The terminal includes office space for additional personnel and equipment necessary to operate the system
8) Adequate space is available in computer server room for 1 to 2 server racks associated with the system
9) Power is available to the equipment location at a negligible fee
10) The port has a fiber optic backbone with additional dark fiber available at installation site

    a. A fee must be paid for use of bandwidth

11) Data is reviewed and stored in country and is not sent back to the United States
12) Minimal alterations must be made to the site

    b. Additional signage
    c. Speed bumps
    d. Traffic lights and associated ground loops
    e. Bollards to protect equipment

13) The terminal is capable of identifying destination of container at the terminal operator gate (i.e. US-bound)

14) Commodity information on the container is available electronically in a timely manner
15) Adequate space is available for equipment and safety zone footprint
16) Assumed that all US-bound cargo are export cargo that passes through gate, not transshipped between vessels

These assumptions assume that a single authority at the port does not take an active oversight role. This prevents the use of shared assets between the terminals, which could include mobile NII equipment for redundancy across several terminals; instead this capability is necessary for each individual terminal. Another example would be a mobile secondary inspection team that could travel to the terminal to perform inspections, reducing the manpower needs. A centralized secondary inspection area could also be utilized, requiring terminals to send containers to this location to perform secondary inspections. The terminal operator level installation assumes the worst-case, particularly in the area of manpower.

5.3.3 Small Container Port

The SFI Port of Puerto Cortes, Honduras, described throughout this thesis serves as a general baseline for the physical lay-out for the small container port model. According to US Customs statistics, this small port shipped 162,741 TEUs directly to the United States in 2006, ranking 20th out of the 591 ports with direct shipments to the US (MARAD, 2007). The port's total reported throughput for 2006 was 507,946 TEUs, with no transshipment operations. Puerto Cortes has a high percentage of US-bound cargo when compared to its total volume. We have calculated our cost estimate utilizing Puerto

Cortes's container traffic statistics; however, it should be noted that 50% of the ports with direct shipments to the US in 2006 shipped less than 100 TEUs each.

The port operates 24 hours per day, 7 days per week. The average container dwell time for imports is 5 days, with exports remaining in the container yard for a maximum of 2 days. Import drivers are able to pass through the NII without regulatory concerns. The port has sufficient space to conduct port authority level inspections, with a holding area that can hold 20 containers at a time. Currently, the port scans 100% of all import and export cargo. They report no decrease in their port efficiency due to scanning, which was a concern for shipping lines prior to the implementation. Additionally, the negative effects of container missing their sailing due to secondary inspection have been negligible.

The port had previously purchased 3 NII scanners starting in 2005. Union concerns led the port to provide private contractors to drive export vehicles through the NII equipment, instead of union drivers. A contractor, Comosa, was hired to perform the NII equipment scanning. Comosa charges US$27.50 per scan, with a reduction in price to US$25.00 when annual scanning exceeds 200,000 containers. During the SFI installation 3 RPMs and associated communications systems were installed. The port estimates that this US investment cost US$4 – 4.5 million. Honduran Customs added 26 staff members to support the RPM and NII scanning operations. The port paid to lay 7 km of fiber optic cable with 25 wires for port-wide usage, including the SFI installation.

Additionally, it is important to note that Puerto Cortes, Honduras, utilizes the DHS "reach back" network to provide technical assistance for alarm adjudication. This consists of 24-hour alarm assessment assistance by technical and scientific experts in the

US. At Puerto Cortes, US-bound alarm data is sent to local US CSI officers as well to the US for review. Under the 9/11 Act, national governments may need to provide their own alarm adjudication assistance. Countries with existing nuclear energy bodies, laboratories and university research partnerships may find this to be a manageable task, while other nations may not have the capabilities for this level of assistance.

The following assumptions are made under the small container port for a port authority level installation:

1) A single port authority main gate is utilized to enter and exit the port facility
2) 2 terminal operators exist
    a. Each terminal has its own perimeter fencing and main gate
3) 1 Primary inspection area is located en route between port authority main gate and individual terminals at a Customs manned inspection facility
4) 1 RPM Alarm Station
5) 1 Secondary Inspection Team

The following assumptions are made under the small container port for a terminal operator level installation:

1) A single port authority main gate is utilized to enter and exit the port facility
2) 2 Terminal operators exist
    a. Each terminal has its own perimeter fencing and main gate
3) Primary inspection occurs at each of the 2 individual terminals
4) 2 RPM alarm station (1 at each individual terminal operator)
5) 2 secondary inspection teams (1 at each individual terminal operator)

The general layout of the small port is illustrated in Figure 18.

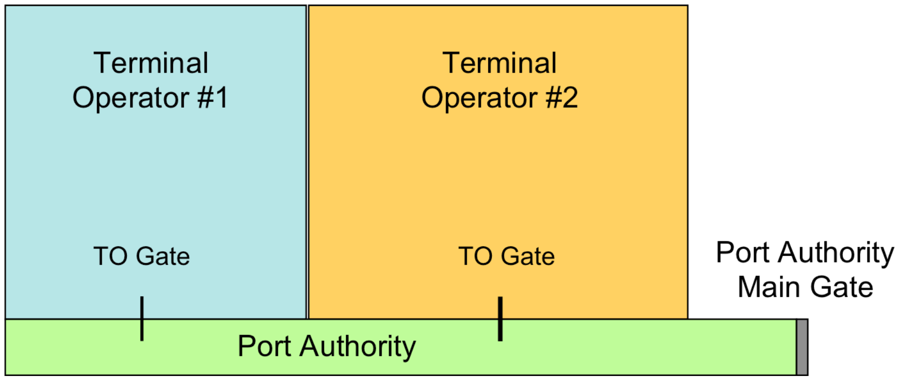


Figure 18. Small Port Lay-out

5.3.4 Large Container Port

The port of Antwerp, Belgium, serves as the basis for the large port estimate within this thesis. An October 2006 statement from the Belgian government described some of the operational expenses associated with deploying RPMs through the DOE Megaports Initiative at the Port of Antwerp. Antwerp's container throughput for 2006 was 7 million TEUs, within its 10 container terminals shown in Figure 19 below. Antwerp shipped 347,848 TEUs directly to the US in 2006, ranking 12th out of the 591 US direct trading ports (MARAD, 2007). Based on the American Association of Port Authorities March 2008 statistics, Table 10 below shows the world port rankings for 2006.

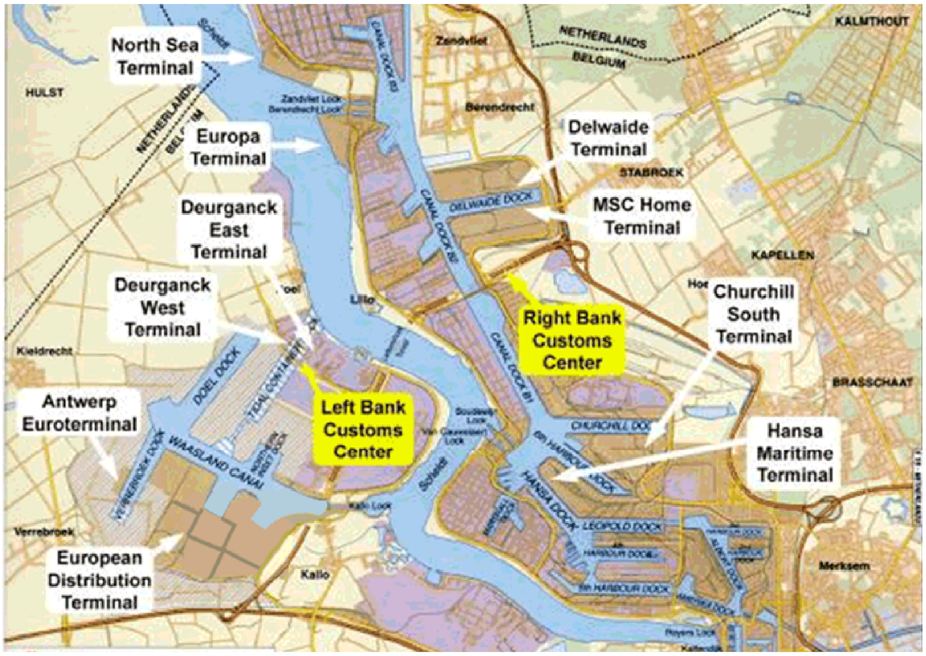


Figure 19: Port of Antwerp Port Lay-out

Table 10. 2006 World Container Port Statistics

WORLD PORT RANKING - 2006							
CONTAINER TRAFFIC (TEUs, 000s)							
RANK	PORT	COUNTRY	TEUs	RANK	PORT	COUNTRY	TEUs
1	Singapore	Singapore	24,792	26	Algeciras	Spain	3,257
2	Hong Kong	China	23,539	27	Dalian	China	3,212
3	Shanghai	China	21,710	28	Yokohama	Japan	3,200
4	Shenzhen	China	18,469	29	Colombo	Sri Lanka	3,079
5	Busan	South Korea	12,039	30	Felixstowe	United Kingdom	3,000
6	Kaohsiung	Taiwan	9,775	31	Jeddah	Saudi Arabia	2,964
7	Rotterdam	Netherlands	9,655	32	Gioia Tauro	Italy	2,900
8	Dubai	United Arab Emirates	8,923	33	Nagoya	Japan	2,752
9	Hamburg	Germany	8,862	34	Manila	Philippines	2,722
10	Los Angeles	United States	8,470	35	Port Said	Egypt	2,680
11	Qingdao	China	7,702	36	Valencia	Spain	2,613
12	Long Beach	United States	7,289	37	Santos	Brazil	2,446
13	Ningbo	China	7,068	38	Kobe	Japan	2,413
14	Antwerp	Belgium	7,019	39	Oakland	United States	2,392
15	Guangzhou	China	6,600	40	Salalah	Oman	2,390
16	Port Klang	Malaysia	6,326	41	Durban	South Africa	2,335
17	Tianjin	China	5,950	42	Ho Chi Minh	Vietnam	2,328
18	New York/New Jersey	United States	5,093	43	Barcelona	Spain	2,318
19	Tanjung Pelepas	Indonesia	4,770	44	Osaka	Japan	2,232
20	Bremen/Bremerhaven	Germany	4,450	45	Vancouver (BC)	Canada	2,208
21	Laem Chabang	Thailand	4,123	46	Savannah	United States	2,160
22	Xiamen	China	4,019	47	Kingston	Jamaica	2,150
23	Tokyo	Japan	3,969	48	Le Havre	France	2,130
24	Jawaharlal Nehru	India	3,298	49	Keelung	Taiwan	2,129
25	Tanjung Priok	Indonesia	3,280	50	Tacoma	United States	2,067

Sources: *Shipping Statistics Yearbook 2007*; Containerisation International Yearbook 2008; U.S. Army Corps of Engineers, *Waterborne Commerce of the United States CY 2006; AAPA Surveys*; various port authority internet sites.

The Belgian's describe that for their 10 container terminals, "all entrance and exits (both for road transport as for rail transport) of these terminals need to be equipped with [radiation] portal monitors" (BFPSF, 2006, para 2). It should be noted that this description is for port-wide deployment of RPMs for all containerized cargo – both imports and exports bound to any destination, not just the United States. "On each terminal the [radiation] portal monitors are connected with a Local Alarm System (LAS) . . . situated at the exit (gate-out) of each terminal"**(** BFPSF, 2006, para 3). "All terminals of the port are (by means of special optical fibre backbone) connected with a Central Alarm Station (CAS) . . . one at the Left Bank. . . and one at the Right Bank." The Belgians describe that "Until now the U.S. Government has invested 40 million dollar[s] in the Antwerp project **(**BFPSF, 2006, para 4**).** The "U.S. Government is responsible for the purchase and installation of material" with 'material' being defined as "the [radiation] portal monitors, all hardware and software, [and] the handheld equipment." The Belgian government spent "a onetime cost of several million euro" for VAT and other taxes on the construction work (BFPSF, 2006, para 4). Approximately "one hundred [Belgian] customs officers will work exclusively on the Megaports Initiative project" (BFPSF, 2006, para 3). The Belgian Finance ministry paid to lease the optical fiber backbone that connects the RPMs and the 2 central alarm stations at an annual cost of €250,000, approximately US$400,000 (BFPSF, 2006, para 3). This information provides a practical insight into actual expenses associated with a scanning project. It is unclear how far along in the installation project the US$40 million represents, as well as how many RPMs are associated with the installation. Additionally, the Belgians' provided insight into their concept of operations defined in 3 phases (BFPSF, 2006, para 5):

“**Phase 1 -** The portal monitor raises an alarm. The technical measuring data and the video images of the containers are immediately transmitted to the CAS through the optical fibre network. The terminal operator is informed electronically of the non-release of the container, awaiting a decision of the CAS. On the basis of a radiation profile and requested information on the consignment, the CAS will either resolve the alarm or proceed to a second inspection. The alarm rates are expected to be 5 to 10% of all trucks in Phase 1. If the alarm is not resolved, Phase 2 becomes effective.

Phase 2 - The container is inspected by CAS personnel from the outside by means of handheld equipment allowing customs authorities to obtain more information on the exact location and the nature of the substances generating radiation. These officials will decide either to release the container, either to call upon the assistance of an approved organisation. Approximately 2 to 5% of the Phase 1 alarms will require a Phase 2 inspection.

Phase 3 - The container is transferred to the CAS. The CAS is equipped with the necessary facilities for unloading and loading of goods. Checks are performed by an acknowledged expert. A container can, in exceptional cases and at the request of the Belgian FANC, be isolated on the spot. The amount of Phase 3 checks is estimated at a couple of dozens a year.”

The following assumptions are made under the large container port for a port authority level installation:

1) 2 port authority main gates are utilized to enter and exit the port facility
2) 10 Terminal operators exist
    a. Each terminal has its own perimeter fencing and main gate
3) 2 Primary inspection areas are located en route between port authority main gate and individual terminals at a Customs manned inspection facility
4) 2 RPM Alarm Station
5) 2 Secondary Inspection Team

The following assumptions are made under the large container port for a terminal operator level installation:

1) 2 port authority main gates are utilized to enter and exit the port facility
2) 10 Terminal operators exist
    a. Each terminal has its own perimeter fencing and main gate
3) Primary inspection occurs at each of the 10 individual terminals
4) 10 RPM alarm station (1 at each individual terminal operator)
5) 10 secondary inspection teams (1 at each individual terminal)

The general layout of the large port is illustrated in the figure below.

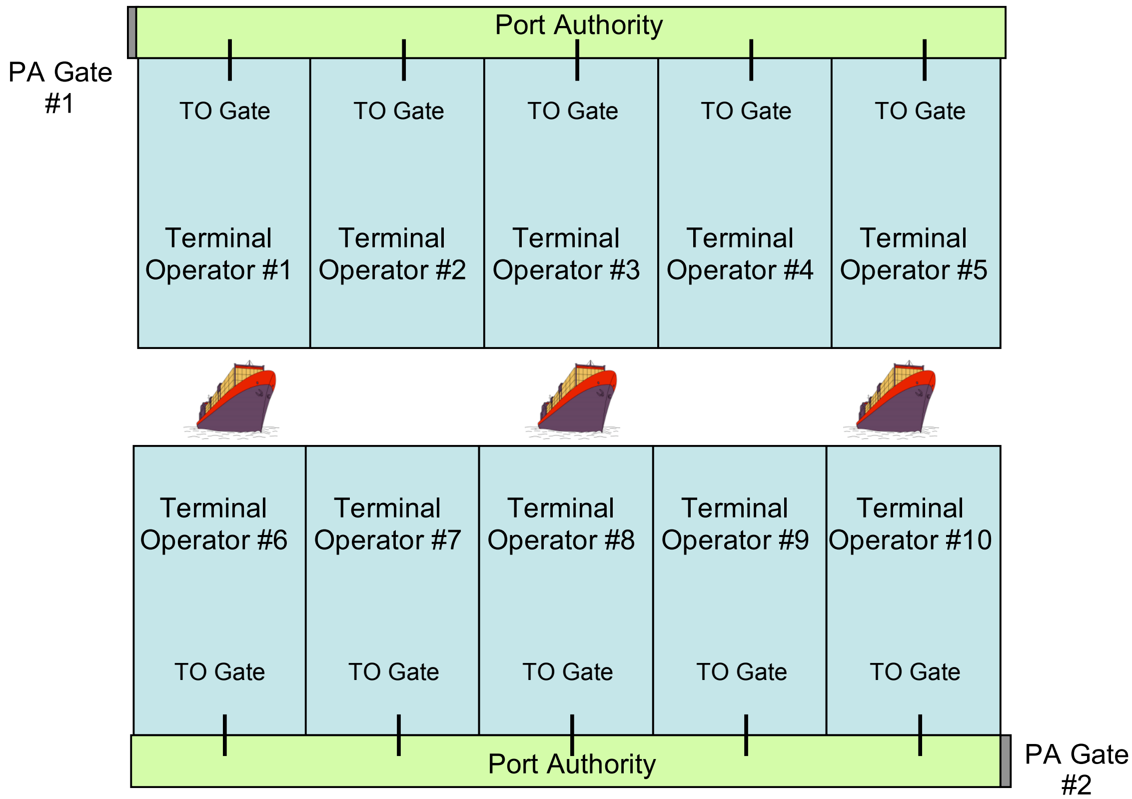


Figure 20. Large Port Lay-out

5.4 Cost Results

Based on the assumptions outlined in Section 5.3 for both small and large port installations, the following cost estimates were created.

5.4.1 Small Container Port – Port Authority Level Installation

Table 11 outlines the initialization cost for the port authority level installation and Table 12 defines the annual operational cost.

Table 11. Small Container Port – Port Authority Initialization Costs (US$)

	Description	Equipment Quantity	Initialization Cost
Primary Inspection	RPM	2	***$870,000***
	NII	2	***$6,453,334***
Secondary Inspection	HPGe	1	***$70,000***
	NaI RIID	2	***$20,600***
	Survey Meter	2	***$6,800***
	Pager	12	***$12,000***
	ASP	0	***$0***
Stations	RPM Alarm Station	1	***$0***
	Secondary Inspection Team	1	***$0***
Fiber Optic Lease	Port Fiber Network	N/A	***$0***
	Total Initialization Cost		***$ 7,432,734***

Table 12. Small Container Port – Port Authority Annual Operational Costs (US$)

	Description	Maintenance Fee	FTE	Personnel Cost
Primary Inspection	RPM	$ 11,000	0	*$0*
	NII	$ 569,333	18	*$2,480,454*
Secondary Inspection	HPGe	$ 7,000	0	*$0*
	NaI RIID	$ 2,060	0	*$0*
	Survey Meter	$ 11,000	0	*$0*
	Pager	$ 4,080	0	*$0*
	ASP	$0	0	*$0*
Stations	RPM Alarm Station	$0	5	*$573,530*
	Secondary Inspection Team	$0	5	*$631,273*
Fiber Optic Lease	Port Fiber Network	$0	0	*$400,000*
	Subtotal Cost	***$ 604,473***	***28***	***$4,085,257***
	Total Operational Cost			***$4,689,730***

Industry experts and product brochures state that expected life-cycle for both the RPM and NII equipment is 10 years. Table 13 identifies an annual scanning expense, which combines the cost of initialization with the cost of operating the equipment (based on current US staffing estimates, with no adjustment for inflation) for 10 years.

Table 13. Small Container Port – Port Authority Annual Costs (US$) Based on 10 Year Equipment Life-Cycle

	Description	Annual Cost
Initialization Cost	RPM	$ 98,000
	NII	$ 3,695,121
Operating Cost	HPGe	$ 14,000
	NaI RIID	$ 4,120
	Survey Meter	$ 11,680
	Pager	$ 5,280
	ASP	$0
Stations	RPM Alarm Station	$ 573,530
	Secondary Inspection Team	$ 631,273
Fiber Optic Lease	Port Fiber Network	$ 400,000
	Total Annual Cost	***$ 5,433,003***

Based on 2006 port statistics for Puerto Cortes, Honduras, Table 14 provides a per container break-down of the 10 year costs for the 9/11 Act compliance with a port authority level installation. The scanning cost assumes that the port passes 100% of the scanning associated cost to its customers. The 9/11 Act only requires the scanning of US-bound containers; however, Table 14 provides fee schedules based on scanning only US-bound containers, as well as amortizing the fee across all export container traffic.

Table 14. Small Container Port - Port Authority Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	162,741	86,007	$ 63
All-Export	265,955	140,554	$ 39
2006 statistics from Puerto Cortes, Honduras, with US-Bound Boxes estimated from Export TEU/Box percentage			
Amortized over 10 year life of equipment, no salvage value			

5.4.2 Small Container Port – Terminal Operator Level Installation

The same assumptions from Section 5.4.1 were utilized to create Table 15 to Table 18.

Table 15. Small Container Port – Terminal Operator Initialization Costs (US$)

	Description	Equipment Quantity	Initialization Cost
Primary Inspection	RPM	4	$1,740,000
	NII	4	$12,906,668
Secondary Inspection	HPGe	2	$140,000
	NaI RIID	4	$41,200
	Survey Meter	4	$13,600
	Pager	24	$24,000
	ASP	0	$0
Stations	RPM Alarm Station	2	$0
	Secondary Inspection Team	2	$0
Fiber Optic Lease	Port Fiber Network	N/A	$0
	Total Initialization Cost		$ 14,865,468

Table 16. Small Container Port – Terminal Operator Annual Operational Costs (US$)

	Description	Maintenance Fee	FTE	Personnel Cost
Primary Inspection	RPM	$ 22,000	0	$0
	NII	$ 1,138,667	36	$ 4,960,908
Secondary Inspection	HPGe	$ 14,000	0	$0
	NaI RIID	$ 4,120	0	$0
	Survey Meter	$ 22,000	0	$0
	Pager	$ 8,160	0	$0
	ASP	$0	0	$0
Stations	RPM Alarm Station	$0	10	$ 1,147,060
	Secondary Inspection Team	$0	10	$ 1,262,545
Fiber Optic Lease	Port Fiber Network	$0	0	$ 400,000
	Subtotal Cost	**$ 1,208,947**	**56**	**$ 7,770,513**
	Total Operational Cost			$ 8,979,460

Table 17. Small Container Port – Terminal Operator Annual Costs (US$) Based on 10 Year Equipment Life-Cycle

	Description	Annual Cost
Initialization Cost	RPM	$ 196,000
	NII	$ 7,390,242
Operating Cost	HPGe	$ 28,000
	NaI RIID	$ 8,240
	Survey Meter	$ 23,360
	Pager	$ 10,560
	ASP	$0
Stations	RPM Alarm Station	$ 1,147,060
	Secondary Inspection Team	$ 1,262,545
Fiber Optic Lease	Port Fiber Network	$ 400,000
	Total Annual Cost	**$ 10,466,007**

Table 18. Small Container Port – Terminal Operator Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	162,741	86,007	$ 122
All-Export	265,955	140,554	$ 74
2006 statistics from Puerto Cortes, Honduras, with US-Bound Boxes estimated from Export TEU/Box percentage			
Amortized over 10 year life of equipment, no salvage value			

5.4.3 Large Container Port – Port Authority Level Installation

Table 19 outlines the initialization cost for the port authority level installation and Table 20 defines the annual operational cost.

Table 19. Large Container Port – Port Authority Initialization Costs (US$)

	Description	Equipment Quantity	Initialization Cost
Primary Inspection	RPM	4	***$1,740,000***
	NII	4	***$12,906,668***
Secondary Inspection	HPGe	2	***$140,000***
	NaI RIID	4	***$41,200***
	Survey Meter	4	***$13,600***
	Pager	24	***$24,000***
	ASP	0	***$0***
Stations	RPM Alarm Station	2	***$0***
	Secondary Inspection Team	2	***$0***
Fiber Optic Lease	Port Fiber Network	N/A	***$0***
	Total Initialization Cost		***$ 14,865,468***

Table 20. Large Container Port – Port Authority Annual Operational Costs (US$)

	Description	Maintenance Fee	FTE	Personnel Cost
Primary Inspection	RPM	$ 22,000	0	*$0*
	NII	$ 1,138,667	36	*$ 4,960,908*
Secondary Inspection	HPGe	$ 14,000	0	*$0*
	NaI RIID	$ 4,120	0	*$0*
	Survey Meter	$ 22,000	0	*$0*
	Pager	$ 8,160	0	*$0*
	ASP	$0	0	*$0*
Stations	RPM Alarm Station	$0	10	*$ 1,147,060*
	Secondary Inspection Team	$0	10	*$ 1,262,545*
Fiber Optic Lease	Port Fiber Network	$0	0	*$ 400,000*
	Subtotal Cost	***$ 1,208,947***	**56**	***$ 7,770,513***
	Total Operational Cost			***$ 8,979,460***

Table 21 identifies an annual scanning expense, which combines the cost of initialization with the cost of operating the equipment (based on current US staffing estimates, with no adjustment for inflation) for 10 years.

Table 21. Large Container Port – Port Authority Annual Costs (US$) Based on 10 Year Equipment Life-Cycle

	Description	Annual Cost
Initialization Cost	RPM	$ 196,000
	NII	$ 7,390,242
Operating Cost	HPGe	$ 28,000
	NaI RIID	$ 8,240
	Survey Meter	$ 23,360
	Pager	$ 10,560
	ASP	$0
Stations	RPM Alarm Station	$ 1,147,060
	Secondary Inspection Team	$ 1,262,545
Fiber Optic Lease	Port Fiber Network	$ 400,000
	Total Annual Cost	***$ 10,466,007***

Based on 2006 port statistics for Antwerp, Belgium, Table 22 provides a per container break-down of the 10 year costs for the 9/11 Act compliance with a port authority level installation.

Table 22. Large Container Port - Port Authority Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	347,848	231,899	$ 45
All-Export	3,583,336	2,388,891	$ 4
2006 statistics from Antwerp, Belgium, with box count estimated using industry 2/3 conversion ratio			
Amortized over 10 year life of equipment, no salvage value			

5.4.4 Large Container Port – Terminal Operator Level Installation

The same assumptions from Section 5.4.1 were utilized to create the following tables.

Table 23. Large Container Port – Terminal Operator Initialization Costs (US$)

	Description	Equipment Quantity	Initialization Cost
Primary Inspection	RPM	20	**$8,700,000**
	NII	20	**$64,533,340**
Secondary Inspection	HPGe	10	**$700,000**
	NaI RIID	20	**$206,000**
	Survey Meter	20	**$68,000**
	Pager	240	**$240,000**
	ASP	0	**$0**
Stations	RPM Alarm Station	10	**$0**
	Secondary Inspection Team	10	**$0**
Fiber Optic Lease	Port Fiber Network	N/A	**$0**
	Total Initialization Cost		**$ 74,447,340**

Table 24. Large Container Port – Terminal Operator Annual Operational Costs (US$)

	Description	Maintenance Fee	FTE	Personnel Cost
Primary Inspection	RPM	$ 110,000	0	*$0*
	NII	$ 5,693,334	180	*$ 24,804,540*
Secondary Inspection	HPGe	$ 70,000	0	*$0*
	NaI RIID	$ 20,600	0	*$0*
	Survey Meter	$ 110,000	0	*$0*
	Pager	$ 81,600	0	*$0*
	ASP	$0	0	*$0*
Stations	RPM Alarm Station	$0	50	*$ 5,735,300*
	Secondary Inspection Team	$0	50	*$ 6,312,725*
Fiber Optic Lease	Port Fiber Network	$0	0	*$ 400,000*
	Subtotal Cost	***$ 6,085,534***	280	***$ 37,252,565***
	Total Operational Cost			**$ 43,338,099**

.

Table 25. Large Container Port – Terminal Operator Annual Costs (US$)
Based on 10 Year Equipment Life-Cycle

	Description	Annual Cost
Initialization Cost	RPM	$ 980,000
	NII	$ 36,951,208
Operating Cost	HPGe	$ 140,000
	NaI RIID	$ 41,200
	Survey Meter	$ 116,800
	Pager	$ 105,600
	ASP	$0
Stations	RPM Alarm Station	$ 5,735,300
	Secondary Inspection Team	$ 6,312,725
Fiber Optic Lease	Port Fiber Network	$ 400,000
	Total Annual Cost	**$ 50,782,833**

Table 26. Large Container Port – Terminal Operator Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	347,848	231,899	$ 219
All-Export	3,583,336	2,388,891	$ 21
2006 statistics from Antwerp, Belgium, with box count estimated using industry 2/3 conversion ratio			
Amortized over 10 year life of equipment, no salvage value			

5.5 Cost Analysis

This analysis addresses observations based on the calculations for compliance with the 9/11 Act by identifying cost drivers of initialization, operational and per box fees. First, both the initialization and operational calculations confirm that a ports' ability to scan containers using a consolidated process within the port authority jurisdiction provides economies of scale for equipment quantities and personnel requirements. Next, it is important to note that while the initialization costs are significant, scanning program costs are driven primarily by operating costs. Manpower for a 24 hour operation is substantial, particularly in areas with high income and burden structures. This is particularly true for the NII operation where a linear relationship exists between the number of equipment units and inspection teams. This relationship results in a US$24.8 million dollar employment expense for large ports when individual container terminal operators are responsible for scanning. The large port example highlights the escalating costs of a fragmented deployment plan.

Puerto Cortes, Honduras hired a third-party to conduct the NII scanning and initial image analysis, which began prior to joining the Secure Freight Initiative. The third party charges US$27.50 to scan loaded containers, regardless of their dimensions. Currently, the port requires this screening for all import and export containerized cargo. It is important to note that a RPM fee is not currently levied during the US government funded pilot project and some government subsidies are in place to reduce the burden of the scanning fee. This fee still serves as a reference point. The ranges of fees estimated in Section 5.4 run from $4 per box to $219 per box. The lowest fee calculated for Honduras within this section was $39 a box, which includes the scanning of all exports with both NII and RPM.

Table 27 indicates the costs associated with amortizing the scanning cost across all container imports and exports (no transshipment at the port), which is consistent with their current operations.

Table 27. Small Container Port – Port Authority Level Full Scanning: Installation Per Box Fee (US$)

Container Type	***TEUs***	***Boxes***	***Per Box Scanning Fee***
US-Bound	162,741	86,007	$ 63
All-Export	265,955	140,554	$ 39
Total Throughput	507,946	266,106	$ 20
2006 statistics from Puerto Cortes, Honduras, with US-Bound Boxes estimated from Export TEU/Box percentage			
Amortized over 10 year life of equipment, no salvage value			

Under this new assumption, the cost of scanning is estimated as low as $20 per box. This does not necessarily indicate that Puerto Cortes should reconsider their current contract, since our basis of cost estimate is not unique to Honduras. However, this underscores the value in considering the cost of installation not just within the physical and jurisdictional constraints of the port, but also to carefully consider the cost of outsourcing the project to a third-party.

Additionally, Puerto Cortes provides an interesting contrast, because it is a small port, when examined by container throughput; however, it represents a substantial volume of direct to the US container shipments. In 2006, 295 of the 591 last ports of loading for direct shipments to the US sent less than 100 TEUs. The use of Puerto Cortes for the small port model fails to capture the financial impacts for small ports that only desire to pass costs to US-bound containers. Table 28 and Table 29 utilize all of the cost assumptions for Puerto Cortes, except that the US-bound volume was set to 100 TEUs.

Table 28. Small Container Port – Port Authority Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	100	67	$ 81,495
All-Export	265,955	140,554	$ 39
US-Bound TEUs set at 100, with box count estimated using industry 2/3 conversion ratio 2006 All-Export statistics from Puerto Cortes, Honduras			
Amortized over 10 year life of equipment, no salvage value			

Table 29. Small Container Port – Terminal Operator Level Installation Per Box Fee (US$)

Container Type	TEUs	Boxes	Per Box Scanning Fee
US-Bound	100	67	$ 156,990
All-Export	265,955	140,554	$ 74
US-Bound TEUs set at 100, with box count estimated using industry 2/3 conversion ratio 2006 All-Export statistics from Puerto Cortes, Honduras			
Amortized over 10 year life of equipment, no salvage value			

5.6 Cost Summary

This cost section highlights the complexities associated with estimating the cost of compliance with the 9/11 Act. Port governance, operations, physical layout weigh heavily in developing an implementation plan. The quantity of US-bound containers plays a significant role in determining how to comply with the 9/11 Act.

We recognize that the DHS domestic program has important differences from the requirements of the 9/11 Act. It is important to underscore that the domestic program scans all US import container cargo with RPMs, but not with NII. NII is only used to inspect high-risk containers. However, concerns voiced today over the mass installation involved in the 9/11 Act are similar to those previously addressed by the US domestic program. The GAO's 2005 report cited concern over the equipment's potential for inhibiting the flow of commerce through the port. DNDO's April 2008 statement allayed these fears with the assertion that the RPM scanning of 98% of the US container import volume resulted in no adverse affects to the flow of commercial goods through US seaports. Additionally, if US trading partners insist upon reciprocal scanning of US export traffic, the domestic import data illustrates the significant expense that additional equipment will have on the US government. Finally, even with the lessons learned from the import installations, the US would already need to start this project to have it completed by the 2012 deadline it has imposed on other sovereign nations.

If a port determines that the individual terminals are the best location for scanning to occur, they should investigate the option to continue to oversee the scanning operation from the port level. This could allow for RPM alarm decisions to be adjudicated at a central alarm station, similar to the actual RPM operations at the port of Antwerp. Additionally, secondary inspection could occur at a consolidated area within the port authority or a mobile secondary scanning team(s) could be deployed to the individual terminals. NII redundancy could potentially be achieved through the purchase of mobile NII scanners, which could be leveraged across several terminals for back-up.

Next, manpower is a costly aspect of our cost scenario. It is important to keep in mind that our estimate assumes that all tasks associated with 9/11 compliance require new hires, and that NII equipment is operated 24 hours a day, and that all RPM alarms are assessed 24 hours per day. In practice, it may be possible to leverage existing personnel to accomplish some of the work. As an example, if secondary inspection occurs at a customs inspection area, some of the existing inspection teams time might be able to be allocated to the 9/11 compliance program. Additionally, the verbiage in the

9/11 Act does not require 24 hour operations, review of data generated from the equipment, or immediate response to alarming conditions. This could potentially allow ports to dramatically reduce staffs and equipment operating periods.

The ASP, which automates secondary inspection, was not included in the basis of estimate because it is not required in the 9/11 Act and due to its recent entry to the market. When a port determines the best method for secondary inspection they should consider the cost associated with hand-held secondary equipment and compare it to the cost of an ASP unit. Redundancy for an ASP could be achieved through back-up hand-held equipment, instead of second unit. The ASP may not completely eliminate the need for a secondary inspection team, thus the facility would need to consider equipment costs, FTEs as well as any potential efficiency gains through automation.

Approximately half of the last ports of loading that shipped TEUs directly to the United States in 2006 comprised of annual shipments of less than 100 TEUs. Based on our cost estimates, it is reasonable to consider that some of these ports with low trade volume to the US may consider discontinuing this direct service. Ocean carriers may need to alter their shipping routes to utilize transshipments hub ports to serve as the last port of loading prior to the US. This has a cascading affect, altering these routes can increase transit time for related and unrelated shipments, as well as reduce the frequency of service or numbers of vessels operating on a particular route.

Finally, this section serves as a tool to quantify costs associated with 9/11 Act compliance for importers as well as governments and ports. Port operations, jurisdictional constraints and physical lay-outs make comparisons between ports difficult. Costs are unique to individual port operations; however, this section highlights the cost related benefits of consolidated scanning operations. The calculations also indicate that if ports anticipate passing the financial burden on their customer, they should carefully consider whether to amortize the costs across US-bound containers or all export container throughput.

6 DELAY ESTIMATION

Section 3.2 identified a list of potential delay risks and implications associated with the 9/11 Act. This section goes into in-depth analyses of the 2 delay risks of greatest concern, highlighted by the importers interviewed – truck congestion and containers missing sailing due secondary inspection delays. Although these 2 delay concerns are related sequentially, i.e. truck congestion occurs at scanning and containers that fail will undergo secondary inspection and risk missing vessels, it is highly complex to model both delays simultaneously. Doing so requires the simulation of vessel arrivals, specific assumptions about port operations and resources, and the ability to track which container is bound for which vessel. Such level of complexity is beyond the scope of this study where the purpose is to provide generic approaches for businesses to quickly estimate delays across different ports. As such, the 2 delay concerns are decoupled to allow for simplified and more widely applicable analysis.

Where applicable, the reference ports used for delay estimation in this section are based off the port of Puerto Cortes, Honduras and the port Antwerp, Belgium. The consistent use of these 2 ports as reference ports allow for easier cross-reference between this section and Section 5 on cost analysis.

6.1 Truck Congestion

Trucks arriving at a port have to undergo gate processing before being allowed access into the port perimeter. Gate processing consists of several procedures, including but not limited to – customs clearance, validation of truck and container identity, verification of company permit, electronic entry of container and chassis number, and truck weighing. Average gate processing times for different ports vary by the level of technology employed, number of procedures conducted, etc, and ranges from as little as 17 seconds in the port of Singapore to as long as several minutes in less advanced ports.

Currently, many ports are facing serious truck congestion at port entry gates. The port of Long Beach, Los Angeles, for example, used to suffer from congestion so bad that it could take a truck several hours to even enter the port. The trucks idling the streets surrounding the port perimeter led to increasing air and noise pollution. In response, California enacted a new law that fined terminals $250 every time a truck is forced to idle outside a terminal for more than 30 minutes.

Other foreign ports in the world today suffer from similar truck congestion problems due to increased freight volumes and limited roadway in the surrounding neighborhood of the port. To alleviate truck congestion at port gates, several ports have extended gate hours or made use of an appointment system to stagger truck arrivals. Extended gate hours allow trucks to arrive and be serviced over more hours in a day, while appointments help to distribute truck traffic more evenly throughout the hours of gate operation instead of having spikes in truck traffic during peak hours. In general most major container ports currently utilize 24-hour gate operations.

With the introduction of the new 100% scanning requirement, the fear is that an even greater burden will be placed on ports already facing truck congestion at port gate-in. If the port decides to conduct scanning at gate-in, trucks would be subjected to an additional scanning time on top of the usual gate-in procedures. This may increase entry time per truck and worsen congestion exponentially. For ports implementing the appointment system, increased entry time per truck would potentially mean that fewer trucks can be scheduled within an allocated hour. On the other hand, if the port decides to conduct scanning after truck entry, it is faced with another problem of finding when and where to conduct the scans within the terminal.

The degrees of these delays greatly depend on the port's concept of operations (CONOPS) for the equipment. Ports can respond to alarming containers in 3 ways.

1. They can immediately assess alarming containers in situ to determine whether the container should be sent for secondary inspection.
2. They can direct all alarming containers to secondary inspection without assessing whether the alarm is innocent due to NORM cargo.
3. They can allow the container to continue to its destined terminal without any diversion while the reviewing authority collects the necessary data and performs analysis. A container hold message would need to be generated to ensure that the box is not loaded prior to alarm adjudication. Once a decision is rendered, either the hold would be removed or the container would need to be removed from the container stack to undergo secondary inspection prior to loading.

There are also other issues to be considered, for example: how ports are going to differentiate between US-bound export containers from other export containers to conduct scanning, and whether ports are going to dedicate special gates and lanes just for US-bound containers. Terminal operators in Santos, Brazil, have expressed desires to conduct scans on all exports and not just US exports if they were to purchase the required scanners. This will allow them to amortize equipment costs over greater volumes. Since October 1, 2007 the port authority in Puerto Cortes, Honduras, began scanning 100% of export cargo, regardless of destination. They report no significant delay in processing export containers; however, the port is small, handling only 140,554 export containers (265,955 TEUs) in 2007. Their ability to maintain efficiency may not be scalable to a larger port where additional scanning time can potentially reduce export-processing speed.

On the other end of the spectrum, ports that are more concerned with reducing the number of container scans might choose to scan only US-bound exports, where equipment costs are amortized over smaller volumes. Reducing the number of scans should reduce the negative impact on efficiency; however, the effort needed to separate US-bound from non US-bound containers may actually cause an even greater reduction of the port's efficiency.

6.1.1 Queuing model for Truck Congestion

Although there are many locations that ports can choose to place the export scanners, the most plausible venue is near the entry gates after gate-in processing. This is because the gates present an isolated chokepoint that trucks are already forced to go through. If scanners are placed too far outside of the typical vehicle route from port authority gate-in to individual terminals, the need arises to reroute trucks to the scanning point and this runs a greater risk of delays and routing confusion. If scanners are placed too far away from the port perimeter, e.g., at the highway exit ramp leading to the port, the risk of en route compromise becomes an issue. Terminal operators and port authorities interviewed have also identified the entry gates as the most convenient location to conduct scanning. As such, the queuing simulation model developed in this study will be built based on scanning being conducted immediately after gate-in.

In this study, a port gate is defined as the entire area where trucks can enter the port. The port gate consists of several processing booths that perform all the gate-in procedures. Figure 21 shows a picture of a port gate with 9 booths. After being released from the booths, the trucks move on to a scanning area, which consists of several sets of scanning equipment, to undergo RPM and NII scanning.

Figure 21. Picture of a port gate with 9 booths

The model attempted to simulate queuing at 2 locations: one queue immediately before the entry gate and the second queue immediately before scanning. All trucks that arrive at the port will have to undergo gate-in procedures at the entry gate while only trucks carrying US-bound containers will undergo scanning as required by the 9/11 Act. It is necessary to simulate both queues simultaneously since the arrival rate of trucks at the scanning area is dependent on the release rate of trucks at the entry gate. Doing so will also identify bottleneck locations and how they shift from the entry gate to the scanning area and vice-versa.

6.1.2 M/M/n Queue for Gate Processing

Before proceeding to quantify the increased wait times due to 100% scanning, it is necessary to first understand the gate operations and queuing models at different types of ports. . Queuing models are often represented using the Kendall notation:

A/B/N

where A = distribution of inter-arrival times

B = distribution of service times

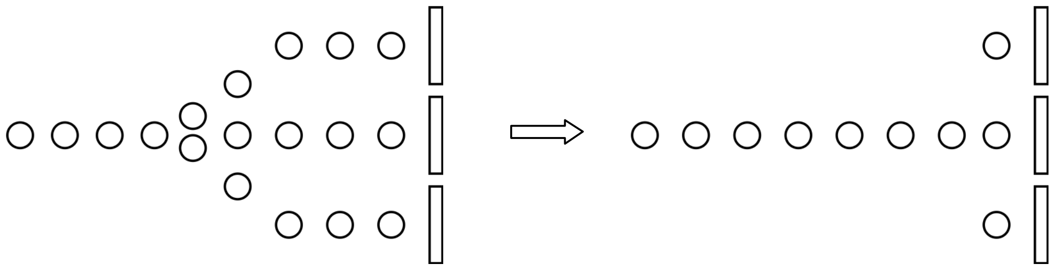
N = number of servers

In general, truck queues at port gates can be classified as M/M/n systems. An M/M/n queuing system represents a multi-server, single-queue system where truck arrivals and service times are both exponentially distributed. This queuing model typically happens in ports with one or more booths located adjacent to each other. Trucks entering the terminal will form one single line and wait for the next available booth to serve them.

It is recognized that there are other ports with different gate operations but many of them can be approximated to an M/M/n system as described below:

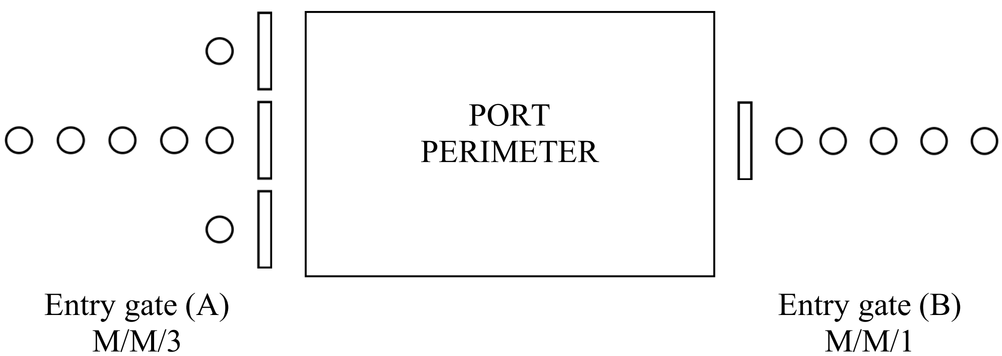
1. *Ports with multiple booths and multiple lanes for multiple queues*

   These ports are in fact multi-server, multi-queue systems. However, in many cases, the entry lanes are usually not long enough to accommodate substantial truck queues. Once the capacity of the lanes is reached, the trucks at the rear will congregate to form a single queue. As such, these terminals can be simplified as multi-server, single queue systems.



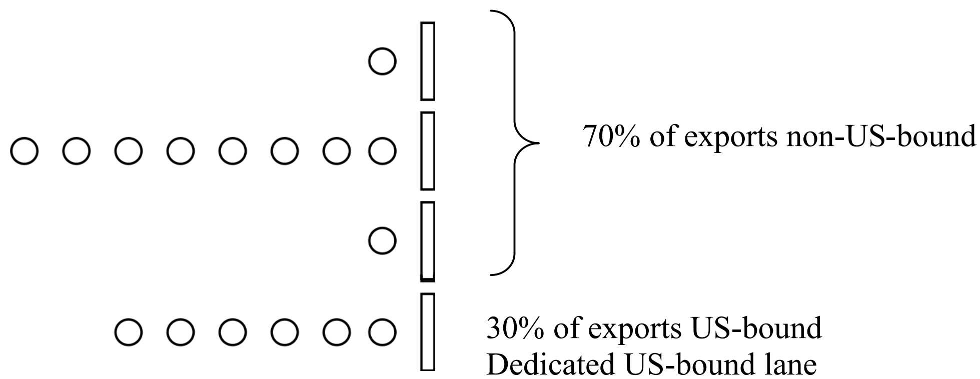
2. *Ports with multiple entry gates that are located far apart*

Some ports have more than 1 entry gate. The port of Antwerp, for example, has 2 entry gates that are located at opposite ends of the port. The gate operation can be modeled as 2 separate M/M/n systems.



3. *Terminals with separate booths for US and other containers*

Some ports might choose to dedicate certain gates to US-bound containers so that the scanning of US containers does not hinder the movement of other containers into the port. For such cases, queues can be approximated to 2 systems of M/M/n queues, one for US containers and one for other containers, where the arrival rate of US-bound containers follow a Poisson distribution weighted by the ratio of US-bound containers to total port volume.



6.1.3 M/M/n Queue for Scanning

Similarly, queues at the scanners can be classified under the Kendall notation as an M/M/n system. Scanning time is assumed exponentially distributed with a mean of 60 seconds. This assumption is based on actual field visit to the SFI port of Puerto Cortes, Honduras.

The port of Puerto Cortes is an SFI port where the US government had financed and installed 2 sets of RPM and NII equipment in 2006. The RPM and NII equipment are highly integrated and all containers that enter the port have to undergo scanning by both devices. As mentioned in Section 1.2, RPM scanning is typically brief but NII imaging can potentially take up to 10 minutes per container if the images have to be meticulously analyzed. Based on observations at Puerto Cortes, the majority of the NII images are only given a perfunctory examination to look for striking anomalies without any time-consuming analysis. As such, the combination of both RPM and NII scanning only takes an average of 60 seconds per container.

The legislation did not clearly state the level of scrutiny required for NII image analysis. As such, we believe the cursory standard observed at Puerto Cortes is sufficiently compliant with the 9/11 Act. One could argue that using a cursory review time as standard represents a misleading system operation but the purpose of this paper is not to discuss the effectiveness of RPM and NII scanning but to analyze the current implementation of the legislation at SFI ports to give realistic estimates of delays and costs when DHS creates further standards for implementing the 9/11 Act.

6.1.4 Parameters and assumptions of Queuing model

A queuing model was built to investigate the impact of the 9/11 Act on truck congestion. Actual export volumes from 2 ports were used to represent the export volumes of a typical small and large port respectively. The port of Puerto Cortes, Honduras was chosen as a basis for a typical small port. In 2006, Puerto Cortes exported 140,554 containers, of which 60% (86,007 containers) were bound for the US. The port of Antwerp, Belgium was chosen to represent a typical large port. In 2006, Antwerp exported a total of 3,583,336 TEUs, of which approximately 10% (347,848 containers) were bound for the US. Using the standard industry conversion ratio of 3 TEUs to 2 containers, it was estimated that Antwerp exported around 2.4 million containers in 2006. Table 30 shows the summary of the export volumes at Puerto Cortes and Antwerp. It is further assumed that each container arrives at the ports on a single truck.

Table 30. Export volumes and percentage of US-bound in Puerto Cortes and Antwerp

Port Category	***Reference Port***	***No. Export Containers***	***% of US-bound***
Low export volume	Puerto Cortes, Honduras	140,554	60%
High export volume	Antwerp, Belgium	2,388,891	10%

The gate-processing rate is assumed exponentially distributed with a mean of 60 seconds per truck. This rate is realistic for a generic export port. To prevent the case of infinite queue at the entry gate, the number of operational booths is constrained to be sufficient to avoid infinite growth of the queue. This is based on the criteria that truck arrival rate has to be strictly less than the total service rate at the booths:

$$n\mu \geq \lambda$$

Where n = number of booths

λ= mean arrival rate of trucks (trucks/hour)

μ = mean booth service rate (trucks/hour)

The mean arrival rate of trucks is determined by dividing the total truck arrivals in a year by the total number of hours in a year. For Puerto Cortes, arrival rate is 16 trucks/hour; for Antwerp, arrival rate is 273 trucks/hour. Note that these values are only used to determine the minimum number of booths required at each port and are not used to generate truck arrivals. The mean arrival rates used to randomly generate truck arrivals will be discussed in the next section. The minimum number of booths required for each reference port is shown in Table 31 below.

Table 31. Minimum booths required for different export volumes

Reference Port	***Trucks/hr***	***Minimum number of booths***
Puerto Cortes, Honduras	16	1
Antwerp, Belgium	273	8

Scanning times are assumed exponentially distributed with a mean of 60 seconds. This value is based on actual field visit to the port of Puerto Cortes, Honduras, where the scanning systems are already operational and reflects current available scanning technologies.

For the purpose of the simulation, it is assumed that trucks that trigger RPM alarms or NII image concerns at primary scanning will either be moved to a separate secondary inspection area or to a yard stack to await further instructions, such that the flow of trucks through the scanners remain undisrupted. This is believed to be a realistic assumption – if a container fails primary scanning and requires a more time-intensive secondary inspection, it is highly unlikely that the inspection will be conducted in situ with other containers waiting in line. Ports will not risk such unnecessary disruptions to deal with alarms. As such, this queuing model will not include the probability of triggering alarms or secondary inspection. Delays due to secondary inspection will be analyzed in another model in Section 6.2.

6.1.5 Model Development

Simulation begins at 6:00am on the first day and lasts for 10 days. Trucks arrive at the port according to a Poisson process. To better capture reality, each day is divided into 2 segments, one segment runs from 6:00am to 5:59pm and the second from 6:00pm to 5:59am the next day. This is because truck arrival throughout the day is usually not constant. For a port with 24-hour gate operations, up to 85% of the truck traffic arrives in the day and only 15% arrives at night. The average arrival rate at any point in the day is determined by the daily arrival rate weighted by the percentage of arrivals corresponding to the time segment in the day. The inter-arrival times between trucks are then randomly generated following an exponential distribution with means corresponding to the time of day and export volumes shown in Table 32 below.

Table 32. Mean arrival rates by reference port and time of day

Reference Port	***Daily arrival rate (trucks/day)***	***85% day arrival rate***		***15% night arrival rate***	
		trucks/hr	***Sec/truck***	***trucks/hr***	***sec/truck***
Puerto Cortes	384	27.2	132.4	4.8	750
Antwerp	6552	464.1	7.8	81.9	44

Upon arrival, trucks have to undergo gate processing at the entry booths with gate-in time exponentially distributed with a mean of 1 minute per truck. Upon release from the entry gate, containers on the trucks will be determined if they are US-bound based on a Bernoulli random process with a probability *x* corresponding to the percentage of US-bound containers to total export volume. To model Puerto Cortes, *x* is chosen to be 60%; to model Antwerp, *x* is chosen to be 10%. If the containers are bound for US, they will have to undergo scanning by RPM and NII.

If a container is selected for scanning, it will arrive at the scanners at the same time it is released from the entry booths. Driving time from the entry gate to the scanning area is assumed to be constant and thus excluded from the model since it theoretically has no effect on queuing. Figure 22 shows the logic behind the queuing model.

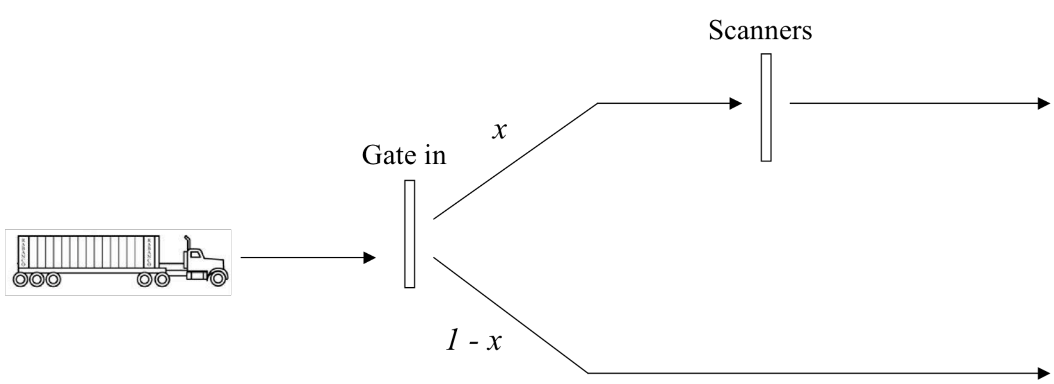


Figure 22. Truck Congestion Process

6.1.6 Results from Queuing Model

The levels of truck congestion estimated by the queuing model are shown in Figure 23 and Figure 24. Note the difference in the scale of the vertical axes between the two figures. The vertical axis of Figure 23 is in seconds whereas the vertical axis of Figure 24 is in minutes and hours.

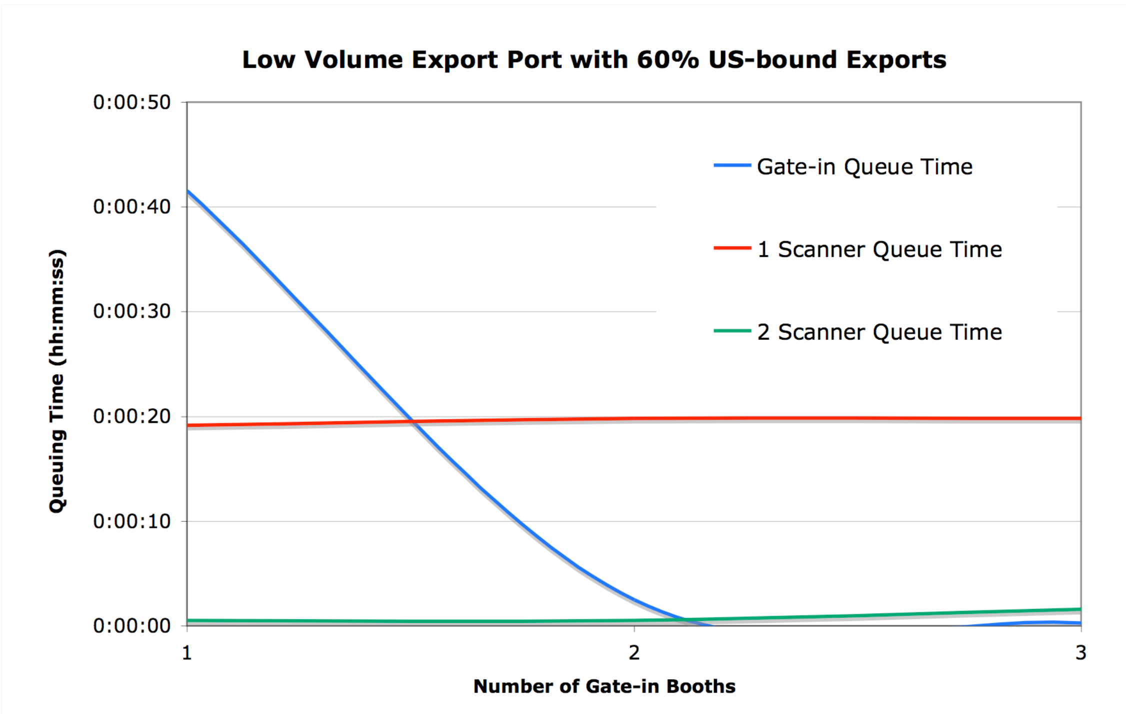


Figure 23. Queue Times for Low Volume Export Port with 60% US-bound Exports

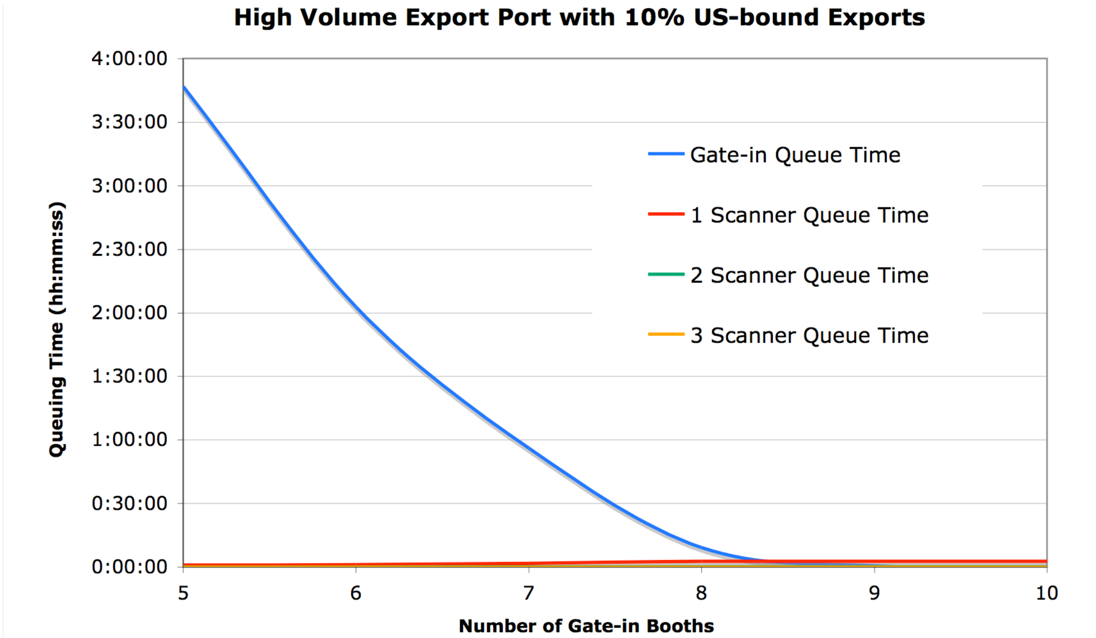


Figure 24. Queue Times for High Volume Export Port with 10% US-bound Exports

Figure 23 shows that for a low volume export port with 60% US-bound cargo similar to Puerto Cortes, Honduras, the average queuing time associated with the gate-in process is no more than 42 seconds regardless of the number of booths. The average scanning queue time associated with the deployment of only 1 set of scanning equipment is 20 seconds per truck. If 2 sets of scanning equipment are operational, the average scanning queue time drops to 1 second. The percentage US-bound volume of 60% used is much higher than the industry average. It is therefore safe to assume that any percentage lower than 60%, i.e. most of the other low volume ports in the world, will not face significant congestion as well.

Figure 24 shows that for a high volume export port with a 10% US-bound export volume resembling Antwerp, Belgium, the average queuing time associated with the gate-in process can range from up to 4 hours when there are only 5 sets of scanning equipment to as low as several seconds when there are more than 9 sets of scanning equipment. The average gate-in queue time increases exponentially with decreasing number of booths. Scanning queue times, on the other hand, remain very low – only a couple of minutes – regardless of the number of sets of scanning equipment deployed and the number of gate-in booths. Although this result shows that congestion due to scanning at a large port is minimal, a hasty generalization can be misleading. The percentage of total export volume bound for the US is only 10% and the optimistic result might arise because of this low percentage. With a higher percentage of US-bound containers, there is a chance that congestion might become more significant and more scanners might be needed.

6.1.7 Sensitivity Analysis for High Volume Export Ports

To test the sensitivity of the percentage of US-bound cargo on truck congestion at a large port, the model is run two more times based on different percentages – 20% and 30%. It is highly unlikely that a high volume port can have more than 30% of the total export containers bound for US. Even the 2.7 million TEUs shipped to the US in 2006 from the port of Yantian, China – the highest US-bound volume from a single port – represent only 15% of its total export volume. As such, the maximum percentage of US-bound cargo used for sensitivity analysis is capped at 30%. Results of the sensitivity analysis are shown in Table 33. Figure 25 and Figure 26 are the graphical representations of the results. Note that for some configurations, scanning queue times are so trivial that their graphs lie on the x-axis.

Table 33. Queue Times for a High Volume Port with different US-bound Volumes

Number of Booths	Gate-in Queue Time	Number of Scanners	10% US bound	20% US bound	30% US bound
			Scanning Queue Time	Scanning Queue Time	Scanning Queue Time
5	3:46:54	1	0:01:00	0:14:10	5:36:14
		2	0:00:04	0:00:18	0:00:55
		3	0:00:00	0:00:02	0:00:06
6	2:02:49	1	0:01:16	1:42:06	7:16:35
		2	0:00:05	0:00:29	0:02:03
		3	0:00:01	0:00:04	0:00:12
7	0:56:03	1	0:01:44	2:43:17	8:21:10
		2	0:00:07	0:00:48	0:18:41
		3	0:00:01	0:00:06	0:00:22
8	0:09:10	1	0:02:44	3:19:35	9:07:07
		2	0:00:08	0:01:12	1:03:32
		3	0:00:01	0:00:08	0:00:39
9	0:00:39	1	0:02:40	3:19:55	9:15:31
		2	0:00:09	0:01:23	1:11:01
		3	0:00:01	0:00:10	0:00:46
10	0:00:13	1	0:02:43	3:19:32	9:15:57
		2	0:00:09	0:01:25	1:10:44
		3	0:00:01	0:00:11	0:00:46

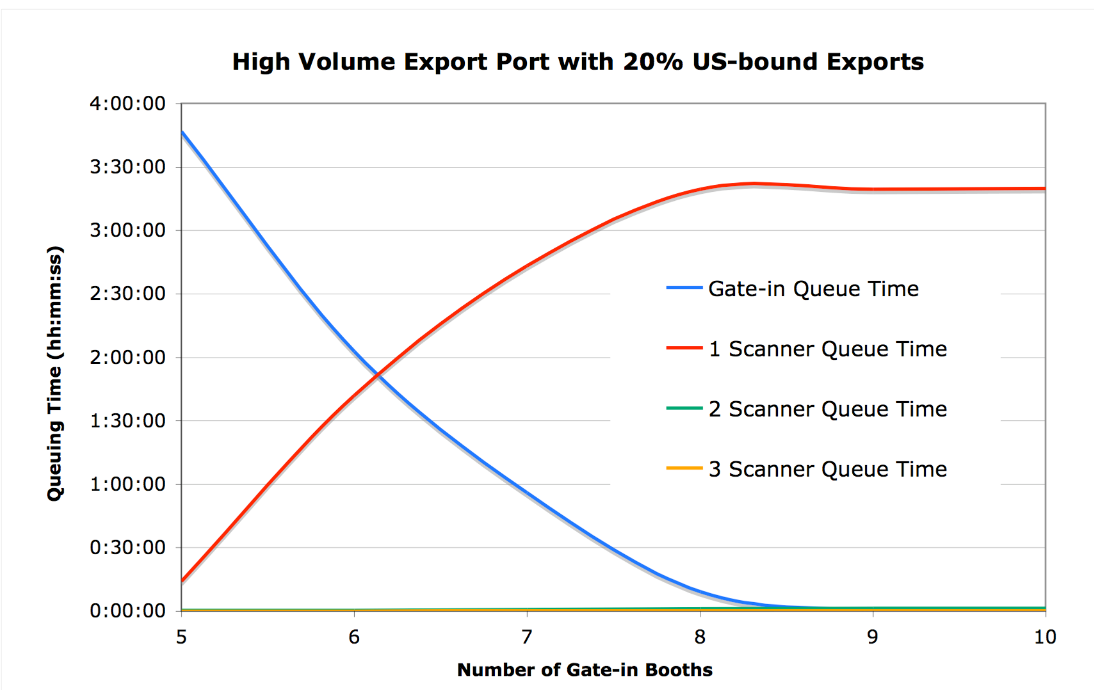


Figure 25. Queue Times for High Volume Export Port with 20% US-bound Exports

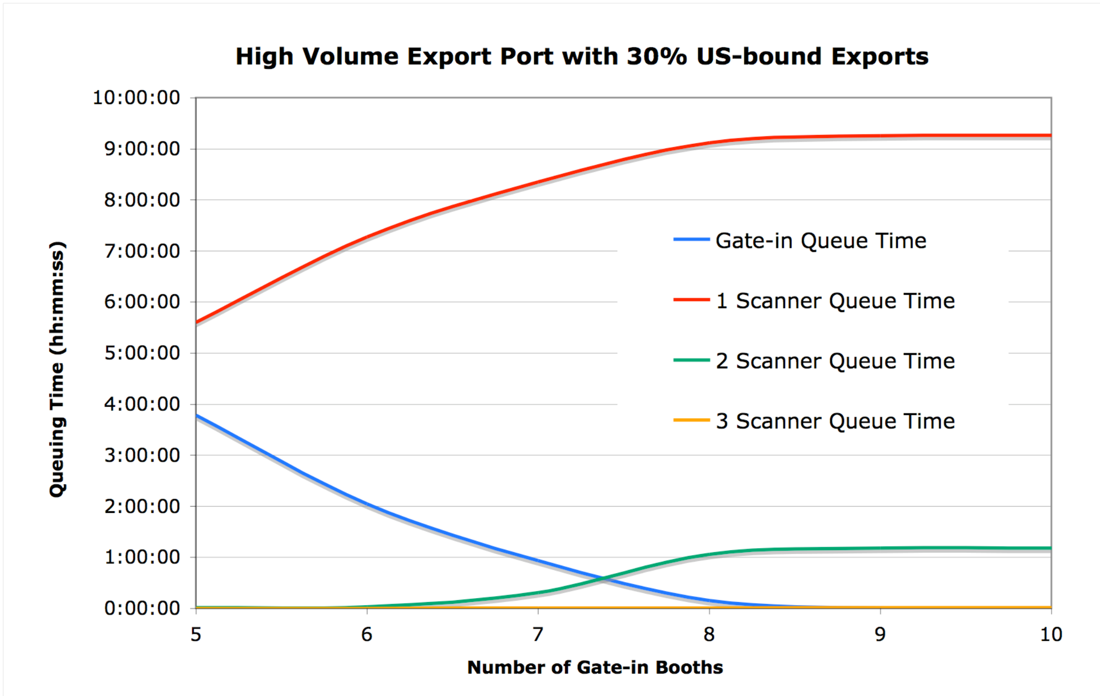


Figure 26. Queue Times for High Volume Export Port with 30% US-bound Exports

The results verify the hypothesis that a greater percentage of US-bound volume will require more scanners in order to keep congestion minimal. As observed in Figure 24, for a high volume port with only 10% US-bound volume, a minimum of 1 set of scanning equipment is adequate to ensure minimal delays regardless of the number of booths. For a 20% US-bound volume, the minimum number of sets of scanning equipment increases to 2 sets. For the case of a 30% US-bound volume, the minimum number is 3 sets.

It is also interesting to note that the consequence of having insufficient number of scanning equipment is a disproportionate escalation in congestion. For a 20% US-bound volume, if only 1 set of scanning equipment is deployed, scanning queue time can potentially increase to 3.5 hours. For a 30% US-bound volume, deploying only 2 sets potentially increases scanning queue time to 1 hour while deploying only 1 set results in more than 9 hours of scanning queue time.

6.1.8 "Ramp Metering" Effect of Entry Gate

Gate-in queue time decreases exponentially with increasing number of booths while scanning queue time increases at a decreasing rate. In Figure 25, the graph corresponding to "1 scanner queue time" shows that scanning queue times are relatively low when there are 5 gates but increases at a decreasing rate as the number of entry booths increases. It starts to level off at around 3.5 hours when the number of booths is 8 or more. The graph of "gate-in queue time" crosses the graph of "1 scanner queue time" when the number of booths increases from 6 to 7. This means that the bottleneck, i.e. the location where queuing time is longer, shifts from the entry gate to the scanning area as the number of booths increases. Results indicate that when gate-in queue time is long, the queue time associated with scanning is comparatively shorter. However, when the gate-in queue time is short, scanning queue time becomes more substantial.

This phenomenon is a result of the "ramp metering" effect of the entry gates. Ramp meters are devices typically installed on entry ramps to freeways to control the flow of vehicles onto the freeway. The entry gates function as a quasi-ramp meter that restricts the flow of trucks to the scanners by "storing" the incoming trucks in form of a queue at the entry gates. As such, queuing at the scanners is minimal. The entry gates also help to break up congregations of container trucks, staggering truck arrivals at the scanners. This effect occurs when utilization at the entry gates is high. As a result, considerable queuing will occur at the entry gates while queuing at the scanners will be minimal.

In contrast, as the number of booths increases, the "ramp metering" effect starts to weaken. More gate-in booths means that more trucks can be processed simultaneously at gate-in and the truck release rate will be higher. The entry booths will no longer be able to naturally control and stagger the flow of trucks to the scanners and thus, queuing at the scanners will increase.

This phenomenon of the "ramp metering" effect of entry gates is heartening to those who are concerned about how the 100% scanning legislation will further contribute to truck congestion. Some businesses have expressed concerns that most ports in the world are already facing serious truck congestion at the port entry gate and they fear that the additional burden of 100% scanning will exacerbate the problem. Fortunately, results indicate that if significant truck congestion is already occurring at a port entry, congestion will likely not worsen due to the "ramp metering" effect.

Even though the "ramp metering" effect will help to relieve congestion caused by scanning, it is prudent to not overstate its merits. The graph of "1 scanner queue time" in Figure 26 shows that despite the presence of the "ramp metering" effect of the gate-in booths, congestion at the scanners can still be severe. This shows that the "ramp metering" effect at the entry gate is insufficient to restrict the flow of trucks to the scanners such that congestion at the scanners is mitigated.

6.1.9 Trade-off between Amortization of Scanning Costs and Delays

This section further builds on the cost analysis presented in Section 5 to illustrate the trade-off between the amortization of scanning costs and truck congestion. The cost analysis section of this paper showed that the amortization of all scanning-related costs over a port's entire export volume results in a much lower per-box cost than if the amortization were done only across US-bound containers. While this is a financially attractive option, the scanning of 100% of all exports can result in substantial truck congestion. Furthermore, choosing to scan all containers may also make the port less appealing to exporters.

To investigate the trade-off, all cost and delay estimates in this section are based on the number of scanners and booths assumed under the port authority level implementation of the 2 reference ports in Section 5. To replicate Antwerp, it is assumed that there are a total of 8 gate-in booths and 4 sets of scanning equipment (RPMs and NIIs). To replicate Puerto Cortes, it is assumed that there are 4 gate-in booths and 2 sets of scanning equipment.

Trade-off for Puerto Cortes

The queuing model is run for 2 cases – 100% scanning of only US-bound exports and 100% scanning of all exports – and the associated scanning queue times and amortized scanning costs for each case are compiled in Table 34.

Table 34. Trade-off between Costs and Delays for Puerto Cortes

Regime	***Number of Sets of RPM and NII***	***% of Exports Scanned***	***Per Box Scanning Cost***	***Scanning Queue Time***
Scanning of US-bound	2	60%	$63	0:00:02
Scanning of all exports	2	100%	$39	0:00:03

Results indicate that for a low volume export port like Puerto Cortes, it is possible to scan and amortize the scanning costs across 100% of all exports without compromising scanning queue time. Scanning of all exports results in an average scanning queue time of only 3 seconds but reduces the scanning cost per container from $63 to $39. It is thus both financially attractive and operationally viable for low volume ports to conduct 100% scanning on all exports.

This result corroborates the observations from actual site visit to Puerto Cortes, Honduras, where the deployment of 2 sets of scanning equipment to scan all its exports results in no perceivable delays.

Trade-off for Antwerp

Table 35 shows the associated amortized costs and scanning queue times for a high volume export port resembling Antwerp under different scanning regimes.

Table 35. Trade-off between Costs and Delays for Antwerp (A)

Regime	***Number of Sets of RPM and NII***	***% of Exports Scanned***	***Per Box Scanning Cost***	***Scanning Queue Time***
Scanning of US-bound	4	10%	$45	0:00:00
Scanning of all exports	4	100%	$4	6:02:23

Unlike Puerto Cortes where scanning of all exports results in no increase in scanning queue time, the port of Antwerp presents a different case. Although switching the scanning regime from US-bound only to all exports reduces scanning cost per container from $45 to only $4, the corresponding scanning queue time exploded to 6 hours. This shows that a switch in scanning regime without increasing the number of scanners may not be a practically viable option.

Table ***36*** shows the trade-off between costs and delays for Antwerp if they choose to install more scanning equipment to scan all exports. Based on our estimates, if Antwerp chooses to scan and amortize the costs across all its exports, the scanning cost per container increases by around $1 for every additional set of scanning equipment installed while scanning queue time decreases exponentially.

Table 36. Trade-off between Costs and Delays for Antwerp (B)

Regime	***Number of Sets of RPM and NII***	***% of Exports Scanned***	***Per Box Scanning Cost***	***Scanning Queue Time***
Scanning of US-bound	4	10%	$45	0:00:00
Scanning of all exports	4	100%	$4	6:02:23
Scanning of all exports	5	100%	$5	3:19:30
Scanning of all exports	6	100%	$6	1:43:02
Scanning of all exports	7	100%	$7	0:40:02
Scanning of all exports	8	100%	$8	0:02:24
Scanning of all exports	9	100%	$9	0:00:23
Scanning of all exports	10	100%	$10	0:00:07

Results from the trade-off analysis show that Antwerp is better off purchasing 9 or 10 sets of scanning equipment to scan all of its exports than to just install 4 sets to scan only US-bound cargo. Doing so results in a much lower amortized cost of $9 or 10 per container – compared to $45 – while keeping scanning queue time trivial.

6.1.10 Summary of Truck Congestion

This section presents an approach to analyze and model the queuing implications associated with the 100% scanning legislation. The gate-in and scanning rates should be changed to reflect the conditions of the specific port under consideration. The approach and queuing model is deliberately kept simple to allow businesses to quickly estimate the level of congestion without having to know details about specific port layout and operations.

Results from the queuing simulation indicate that congestion caused by 100% scanning may not be as severe as anticipated. For low volume export ports, a minimum of 1 set of scanning equipment is adequate whereas for high volume export ports, 2 to 3 sets would suffice to keep congestion minimal. This minimum number does not take into account the possibility of equipment failure and routine maintenance and thus it is recommended that extra scanning equipment be installed for redundancy purposes. Due to the "ramp metering" effect of the entry gate, congestion at the scanners can potentially be abated if there already exists congestion upstream at the gate-in booths.

Trade-off analyses also indicate that low volume ports might find it economically and operationally feasible to conduct scanning on all its exports to amortize the costs of implementation over a greater volume. High volume ports, on the other hand, will have to trade off between costs and scanning delays. In some cases, high volume ports might even find it more economical to install more scanning equipment to amortize over its entire export volume than to install a few sets just to scan US-bound cargo.

6.1.11 Assumptions of Truck Congestion

There are several underlying assumptions in this analysis that are important to note. Firstly, the model did not account for port layouts and space constraints. It is also assumed that trucks carrying US-bound containers can be efficiently diverted to the scanners and the different routing of US and non-US bound container trucks do not add any delays to the system. In reality, it is very difficult to efficiently recognize and divert trucks carrying US-bound containers.

Secondly, it is assumed that primary scanning takes an average of 60 seconds per truck. Although these service time estimates are derived from observations at the port of Puerto Cortes and represent the average port today, there may exist special circumstances or ports where these estimates do not apply. For example, safety regulations in some countries might mandate that truck drivers cannot drive through the NII equipment due to potential exposure to radiation. For ports in these countries, truck drivers will have to disembark from the truck and port security personnel will have to use mobile scanning units to conduct the scans, thereby increasing scanning time considerably.

Thirdly, it is assumed that primary scans are performed immediately after gate-in. This location is the most convenient since the gate-in procedure already presents a natural chokepoint and terminal operators interviewed have also reaffirmed this convenience. It is important to note that implementing the 9/11 Act requires a large area to observe the safety distance required by NII and thus, scanning equipment cannot be directly adjacent to the gate-in booths. Another possible location for conducting primary scans is at existing Customs inspection areas that are en route from the main gate to the terminals. However, ports may still vary their scanning location depending on space availability, regulations, etc. To model these ports, one may have to redesign the modeling approach.

6.2 Secondary Inspection and Missed Sailings

Interviews with maritime stakeholders revealed that the 100% scanning requirement could potentially lead to increased secondary inspections of containers, which in turn increases the risk of containers missing their vessel sailing. This is a serious concern for importers because a container that misses its vessel may potentially have to wait up to a week before being loaded on the next vessel bound for the US. In worse cases, there might not even be space available on the next vessel to accommodate the delayed container. A one-week delay of a container of perishable goods may result in the spoilage of the entire container. In the high-fashion industry, a one-week delay can result in obsolescence, lost sales and price markdowns. For manufacturing systems running on Just-in-Time strategies, the delay of a container of a critical part can result in production disruption and line shutdowns. This section aims to develop an approach to quantify the increased risk of containers missing their vessel sailings so that importers can better prepare themselves against the uncertainty.

6.2.1 Monte Carlo Simulation for Secondary Inspections

A Monte Carlo simulation model is developed to estimate the probability of a container missing its vessel due to secondary inspection after the implementation of 100% scanning requirements. For an average-sized containership with a capacity of 5,000 TEUs headed toward the United States, the model simulate the arrival and customs clearance of each container at the last port of loading. Note that since all results are based on percentages and probabilities, containership capacity does not affect the final results.

For the base case, it is assumed that the port requires all containers bound for the vessel to arrive 1 day before the vessel departs, i.e., the cut-off time is 1 day before departure. It is also assumed that the distribution of container arrivals throughout the days before cut-off resembles the probability distribution function of a Poisson process with a mean of 1.5 days before cut-off time. This means that 22% of the containers are expected to arrive on the cut-off day, 33% are expected to arrive 1 day before cut-off, 25% are expected to arrive 2 days before cut-off, 13% are expected to arrive 3 days before cut-off, 5% are expected to arrive 4 days before cut-off and 1% are expected to arrive 6 days before cut-off. These percentages can also be interpreted as the probability of a container arriving on a particular day before cut-off, for example, the probability of a particular container arriving 2 days before cut-off is 25%. Furthermore, the inter-arrival times of containers for one particular day are exponentially distributed. Table 37 shows the summary of the distribution and arrival rates of containers.

Table 37. Distribution of Container Arrival Rates for Mean Arrival Day = 1.5

Day(s) before cut-off	%	Expected Number of Container Arrivals	Arrival Rate (containers/hour)	Arrival Rate (seconds/container)
0	22%	1116	46	77
1	33%	1673	70	52
2	25%	1255	52	69
3	13%	628	26	138
4	5%	235	10	367
5	1%	71	3	1224

Arriving containers undergo primary scanning after which some of the scanned containers might be sent for secondary inspection according to a Bernoulli random process with a probability of 5%, representing the probability of triggering an RPM alarm on the primary scans. The choice of 5% is a high but conservative estimate for the current level of alarms triggered on primary scans obtained from interviews with terminal operators.

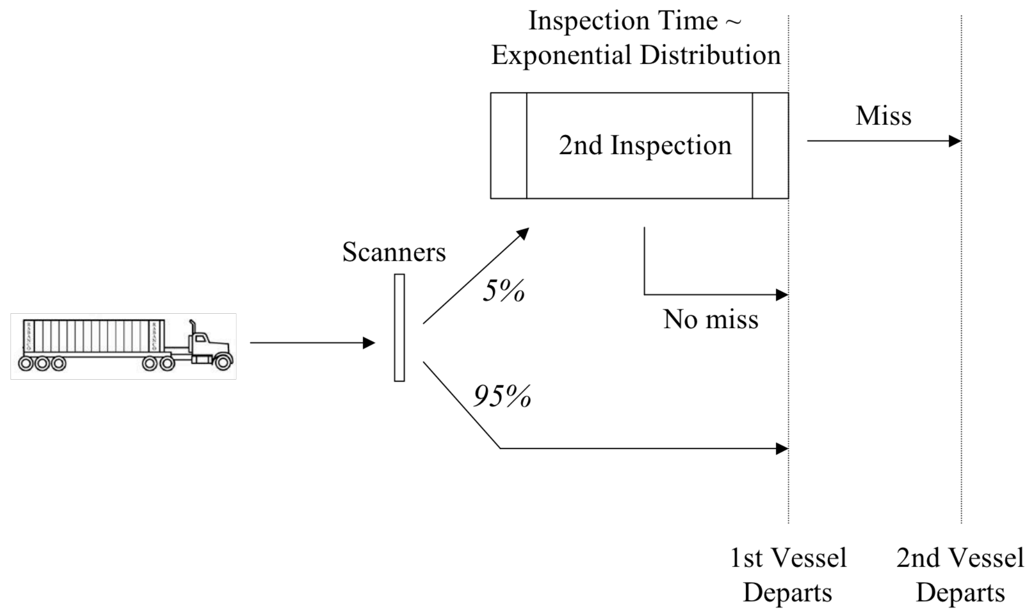


Figure 27. Secondary Inspection Process

If a container clears primary scanning, it will continue on its way to the terminal operator and will not miss its appointed sailing. However, if a container is directed to secondary inspection, the model will then generate a secondary inspection time according to an exponential distribution with a mean of 0.5 day/container for efficient ports, 1 day/container for average ports and 2 days/container for inefficient ports. These average secondary inspection times are based on estimates provided by terminal operators in interviews.

The day of clearance for the inspected container is the arrival day less the secondary inspection time. If the clearance day is after the vessel has departed, then the container has missed its vessel sailing and will have to wait for the next available vessel, which will arrive weekly after the first departs. The choice of a weekly vessel departure is based on industry rule of thumb. If the clearance day is before the vessel has departed, then the container is still in time for the vessel.

For example, if a container arrives 4 days before vessel departure (equivalent to 3 days before cut-off), fails primary scanning and undergoes a 3-day secondary inspection, it will be released 1 day before vessel departure. In this case, the container is still in time to make the vessel sailing. The container dwell time is equal to 4 days since it arrives 4 days before departure. However, if a container arrives 2 days before vessel departure (equivalent to 1 day before cut-off), fails primary scanning and undergoes a randomly generated 3-day secondary inspection, it will be released "-1" day before vessel departure. In this case, the container has missed its vessel and will have to wait for the next available vessel. The container dwell time is then 9 days (arrival 2 days before departure plus 7 days wait for the next vessel). In an even worse scenario, a container may arrive 2 days prior to vessel departure, fail primary scanning and undergo a 10-day secondary inspection. In this case, it will be released "-8" days before vessel departure, missing not only its scheduled vessel but the next one as well, and has to wait for the third vessel to arrive. The container dwell time is 16 days (arrival 2 days before departure plus 14 days wait for the third vessel).

After simulating the arrivals and inspection process of all the containers bound for the vessel, the model then calculates the average probability of a container missing the vessel. It also calculates the probability of missing the vessel broken down by days before vessel departure. This will give exporters and importers a better understanding of the risk involved in having their containers arrive at different days before vessel departure. The model also estimates the total container dwell time in container-days so that ports can understand the amount of capacity required at the port to serve all the containers bound for the vessel. The simulation is then run under various scenarios by changing the cut-off time, container arrival patterns, scanning percentage and secondary inspection time to better understand the effect of secondary inspection on delays.

6.2.2 Secondary Inspection Time on Probability of Missing Vessel

As mentioned in Section 6.2.1, the base scenario is chosen to be a port with cut-off time of 1 day before departure and where the average container arrival day is 1.5 days before cut-off. This configuration is chosen as the base scenario since it is reflective of most generic ports in the world today. From this base scenario, we vary the mean secondary inspection time to observe its effect on the probability of a container missing its vessel. Note that the probability shown is only the *average* probability for all containers arriving prior to vessel departure. The probability of missing the vessel associated with different arrival days will be discussed in detail in Section 6.2.3. Results of the simulation are shown in Figure 28.

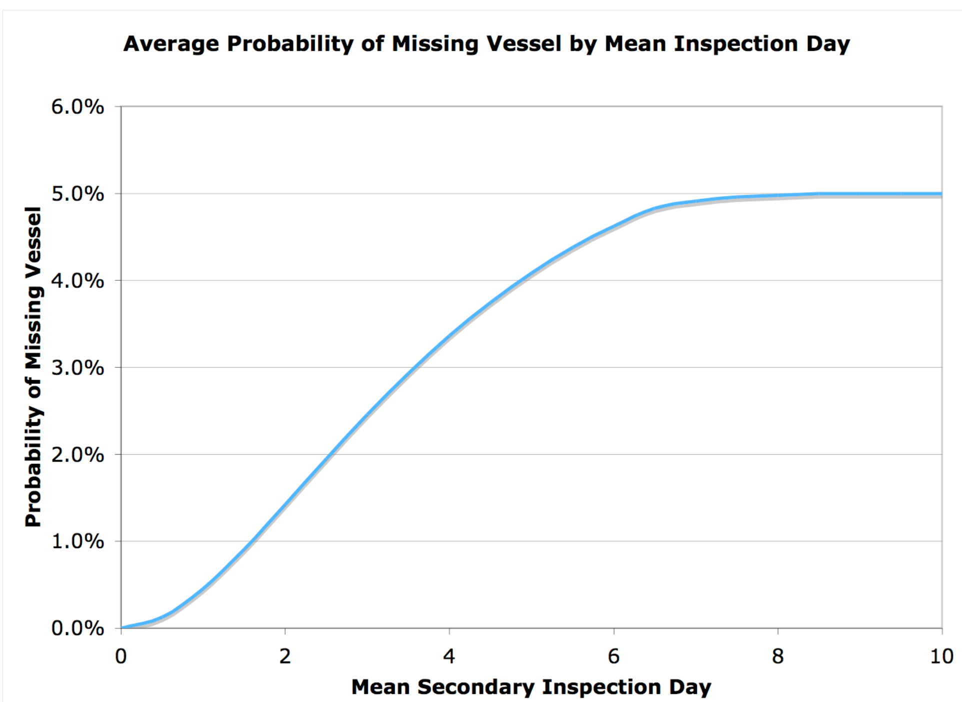


Figure 28. Probability of Missing Vessel by Mean Inspection Time

The probability of a container missing its vessel increases as the mean secondary inspection day increases until it reaches an equilibrium point of 5% when mean inspection time is 8 days. This is when every single container that fails primary scanning misses the vessel. Ports in the world today have average secondary inspection times of 2 days or less. As such, a more realistic estimate for the probability of a container missing its vessel is around 1.5% or less.

Although the probability seems small, it is a cause for concern. Currently, the probability of a container missing its sailing due to secondary inspections is almost non-existent. With the implementation of the 9/11 Act, the probability may potentially increase up to 1.5%. That is to say if a company imports 1 million containers a year, 15,000 containers would be expected to miss their vessels.

Containers that missed their vessels will have to wait for the next available vessel, which might take up to a week to arrive. This will significantly add to the cycle times of containers. Furthermore, companies will have to pay for the additional days that the container dwells in the port while waiting for the next vessel.

6.2.3 Probability of Missing Vessel by Container Arrival Day

Currently, businesses prefer to send their containers to ports as late as possible to avoid container-holding charges at ports or to have more time to stuff their containers. However, sending in containers at the last minute before vessel departure will reduce the amount of "buffer time" they have if their containers are selected for secondary physical inspections and this will increase the risk of the container missing its vessel sailing. With the increased risk, companies might respond by sending their containers earlier to increase their “buffer time.” Doing so will mean that containers have to be stuffed earlier or faster, and they might incur a greater holding charge at ports.

This section aims at providing some estimates for the probability of a container missing its vessel, given different arrival days and different secondary inspection times. This will allow companies to better assess the risk of a container missing its vessel associated with different arrival days. Companies can ascertain their risk tolerance and decide how much earlier they would like their containers to arrive at a port. Table 38 shows the probabilities of a container missing its vessel sailing on different arrival days under different assumptions of secondary inspection time obtained running our simulation. Figure 29 is a graphical representation of the results under different assumptions of the average secondary inspection time.

Table 38. Probability of Missing Vessel by Days before Departure

Days Before Departure	***Mean 2nd inspection time = 2 days***	***Mean 2nd inspection time = 1 day***	***Mean 2nd inspection time = 0.5 day***
0	3.62%	3.16%	1.76%
1	2.57%	1.26%	0.23%
2	1.59%	0.45%	0.03%
3	0.90%	0.16%	0.00%
4	0.49%	0.06%	0.00%
5	0.30%	0.00%	0.00%
6	0.10%	0.00%	0.00%
7	0.04%	0.00%	0.00%

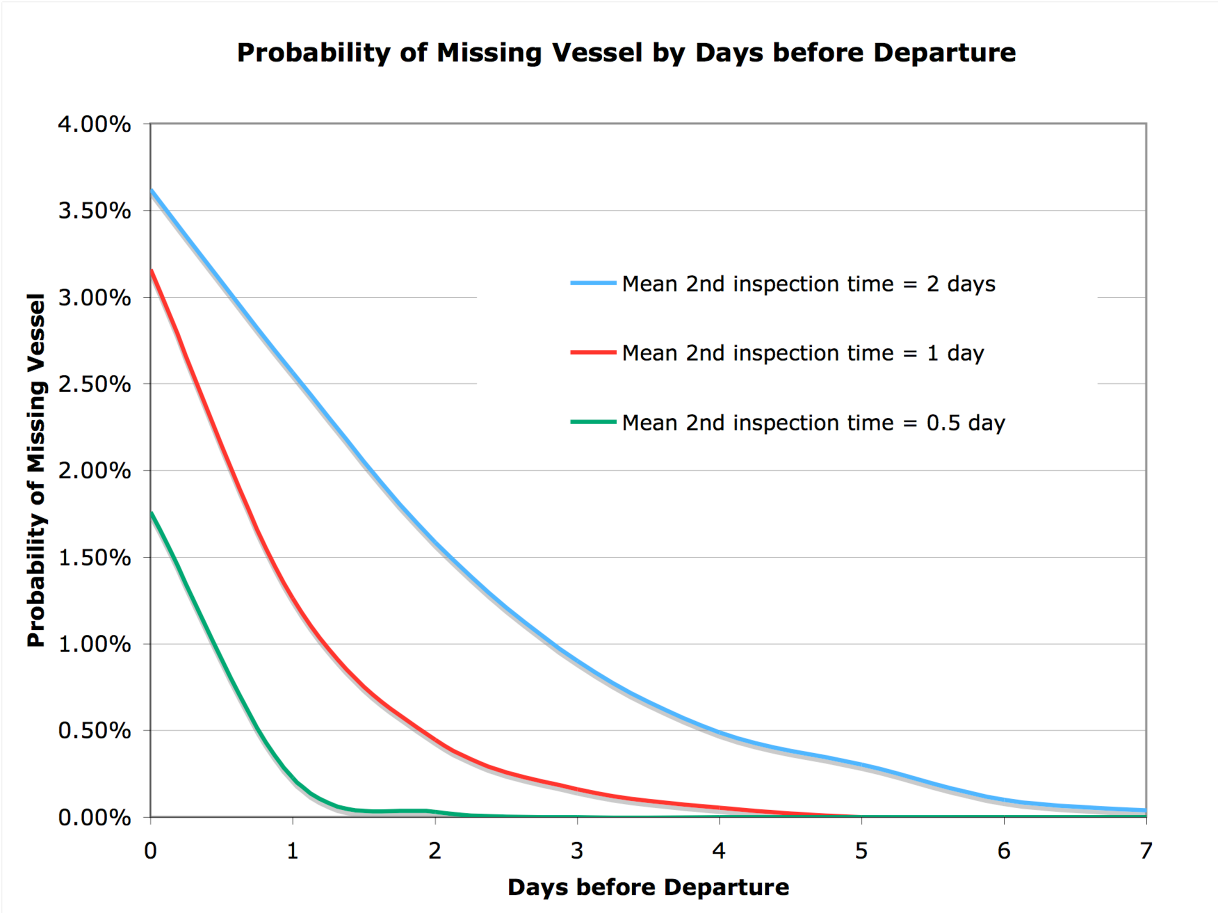


Figure 29. Probability of Container Missing Vessel vs Arrival Day Before Departure

In a low efficiency port where secondary inspection takes an average of 2 days, the risk of arriving on the actual day of departure is as high as 3.62%. Even in highly efficient ports with short inspection times of 0.5 days, the risk of last-minute arrival is almost 1.8%.

The closer to departure date a container arrives, the higher the probability of it missing its vessel. This risk decreases exponentially with earlier arrivals up to a point where it becomes insignificant. In general, the longer the average secondary inspection time, the earlier containers have to arrive in order to keep the risk minimal. For example, if a port has secondary inspection time of 0.5 days, companies can send in their containers as late as 2 days before departure to maintain a risk lower than 0.05%. However, if inspection time takes an average of 2 days, containers have to arrive as early as 7 days before departure to maintain a risk lower than 0.05%.

6.2.4 Companies' Response to Increased Risk of Missing Vessel

Companies' responses to the increased risk may differ greatly depending on their respective risk tolerances. For a company importing highly perishable goods like bananas, a container missing its vessel and having to wait 7 days for the next one could mean the spoilage of the entire container of goods. As noted previously, for a US manufacturing plant running on Just-in-Time strategy, the delay of a container carrying critical parts could mean shutdown of the entire production line; for a company competing in high fashion or technology markets, a delay can potentially lead to increased obsolescence or lost sales.

On the other hand, if a company already has excess inventory at the destination and has high risk-tolerance, it might choose to maintain its current container arrival schedules to avoid port holding charges. A company adopting a postponement strategy might also prefer the flexibility of being able to stuff its containers as late as possible and bear the risk of missing vessels. There is also a saying in the industry: "A container at rest is container at risk." An earlier container arrival will mean a longer container dwell time at ports and this will increase the risk of container sabotage and pilferage.

In either case, companies have to make a trade-off between the cost of missing a vessel and the cost of earlier container arrivals. Table 39 below shows some of the factors to consider when making the trade-off.

Table 39. Trade-Off Between Missing Vessel and Earlier Port Arrival

Cost of Missing Vessel		***Cost of Earlier Arrival***
Lost sales		Expedited container packing
Stock-out		Expedited document preparation
Obsolescence/Perishability	VS	Impact on postponement strategy
Potential production shutdown		Increased risk of sabotage and pilferage
Additional port holding fees while waiting for next vessel		Additional port holding fees for longer dwell time

It is expected that with the 100% scanning legislation, companies will be prone to sending their containers to ports earlier. Ports may even begin to require earlier cut-off times. This will shift the average container arrival day from our current assumption of 1.5 days before cut-off to an even earlier average arrival day. Furthermore, due to varying risk tolerances, the range of days of container arrivals will potentially increase as well. Under different assumptions of the mean arrival day, the percentage of containers arriving on each day may vary. The distribution of container arrivals under different mean arrival day is shown below.

Table 40. Distribution of Container Arrivals by Day

Day before Cutoff	***Percentage of Containers Arriving on the Day***		
	1.5 Day before Cutoff	***2.5 Days before Cutoff***	***3.5 Days before Cutoff***
0	22%	8%	3%
1	33%	21%	11%
2	25%	26%	18%
3	13%	21%	22%
4	5%	13%	19%
5	1%	7%	13%
6	0%	3%	8%
7	0%	1%	4%
8	0%	0%	2%
9	0%	0%	1%
10	0%	0%	0%

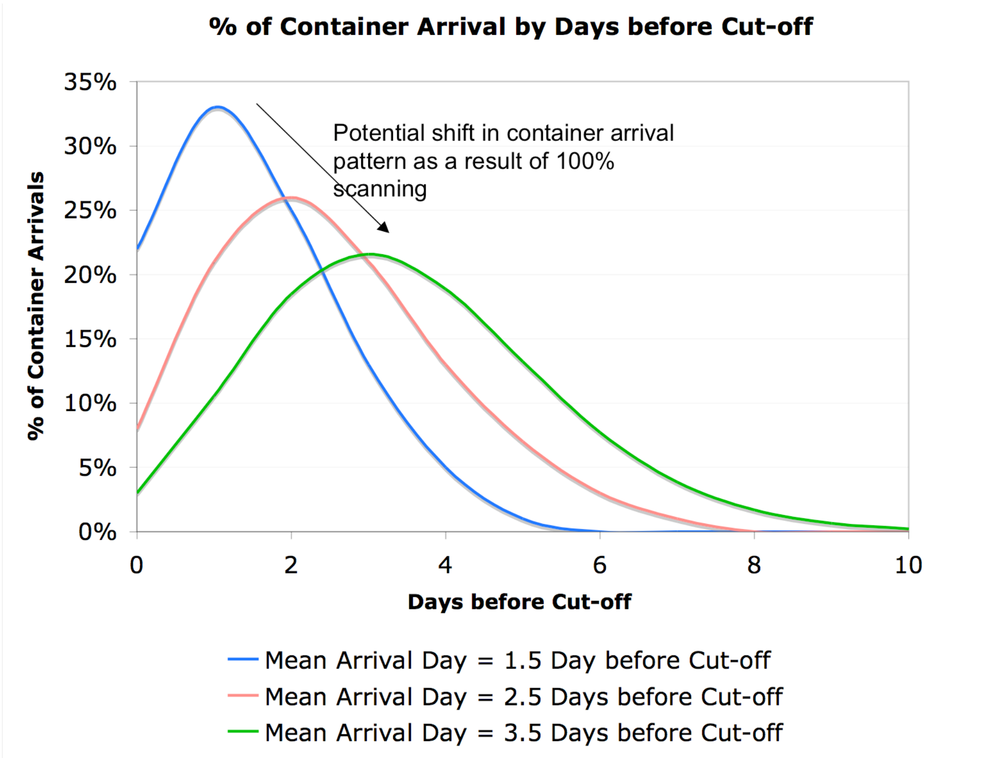


Figure 30. Potential Shift in Container Arrival Due to 100% Scanning

The Monte Carlo simulation is used to estimate how the probability of a container missing its vessel will change with earlier average arrival days and how port capacity has to change to accommodate the shift in trend to earlier arrivals. The analysis is based on ports with different average secondary inspection times but with the same cut-off time at 1 day before vessel departure. The results of the simulation are shown in Figure 31 and Figure 32. The percentages shown in Figure 32 are derived from normalizing the total capacity, in container-days, required at different average arrival days by the capacity required under the current assumption of the average arrival day being 1.5 days before cut-off. Note that these results will no longer be applicable for a different cut-off time but the general trend will remain the same.

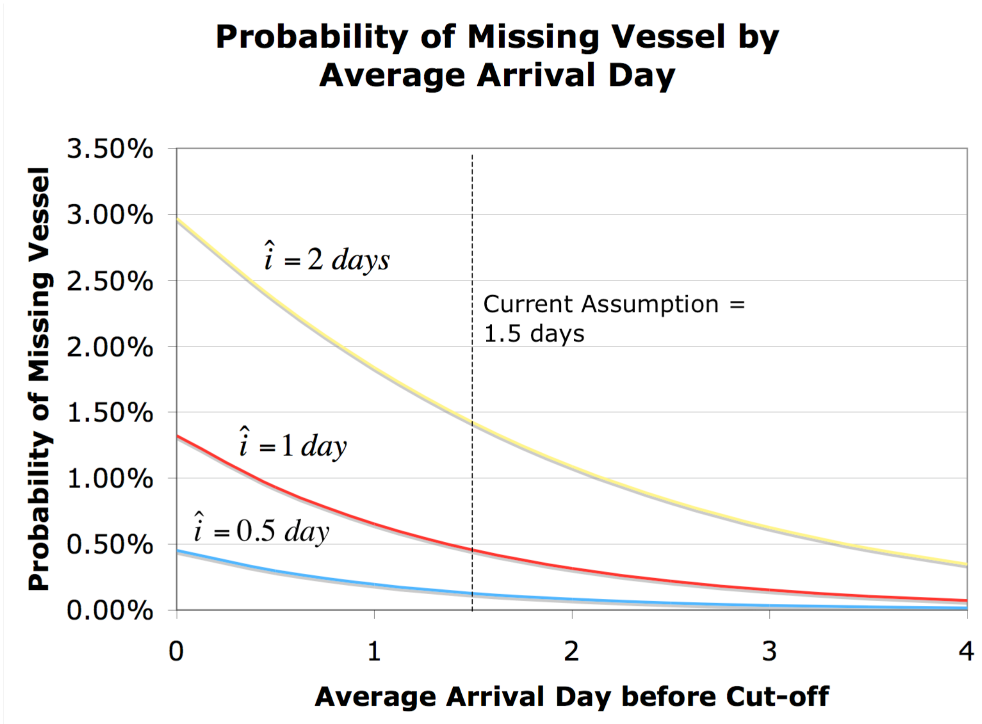


Figure 31. Probability of Missing Vessel by Average Arrival Day at Different Average Secondary Inspection Time, *i*

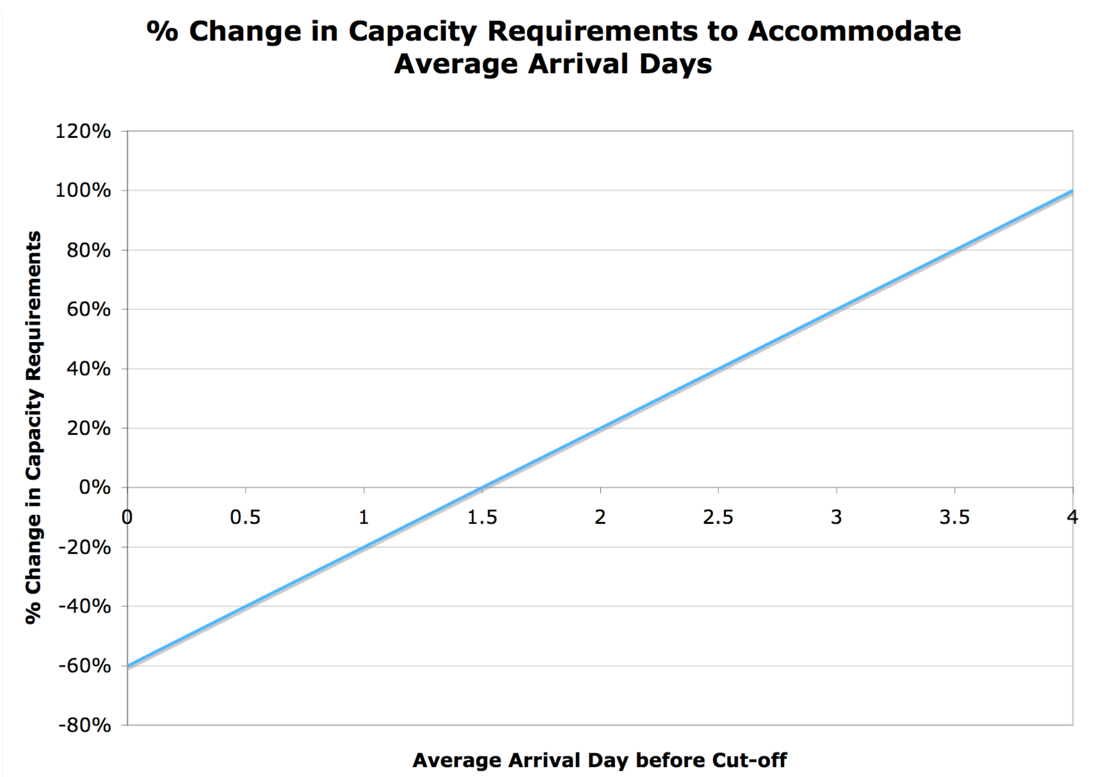


Figure 32. % Change in Capacity Required to Accommodate Different Arrival Days

An earlier average arrival day will result in a decrease in the probability of a container missing its vessel sailing. The decrease is exponential with respect to earlier average arrival days.

In contrast, an earlier average arrival day will linearly increase the capacity required at ports to accommodate the longer container dwell time associated with earlier arrivals. In general, for every day that the average arrival day becomes earlier by, capacity required will increase by 40%. Vice-versa, for every day that the average arrival day becomes later by, capacity can be reduced by 40%.

6.2.5 Sensitivity Analysis of Secondary Inspection Time on Inventory

Implementation of the 9/11 Act can potentially increase maritime lead times and lead time variability, making it more difficult for companies to predict the reliability of container shipping. To protect against these greater uncertainties, US importers potentially have to increase safety stock and inventories. This section presents a simple mathematical formulation to estimate the increase in safety stock required under the new 100% scanning legislation.

Imagine a company requires $E(D)$ containers worth of inventory daily with a coefficient of variation CV. The standard deviation is thus $CV \cdot E(D)$ containers per day. The company imports the containers from a foreign port with standard ocean transit time T_s. The ship leaves the foreign port every t days. The cut-off day for the foreign port is c day(s) before vessel departure. The number of days before cut-off, X, that a container arrives at the port is assumed to follow a Poisson distribution with a mean of $\hat{x}$ days before cut-off. For example, the probability of a container arriving 2 days before cut-off or (2 + c) days before departure is thus $\Pr(X = 2 \mid X \sim Poisson(\hat{x}))$.

The probability of a container failing primary scanning and having to undergo secondary inspection is 5%, as mentioned in Section 4.1. Secondary inspection time is denoted by the variable I with a mean inspection time of $\hat{i}$.

Definition of Variables

D = Daily demand for containers

$E(D)$ = Expected daily demand for containers

CV = Coefficient of variation of the daily demand for containers

T = Transit time of vessel

T_s = Standard transit time of vessel, i.e. transit time specified by ocean carriers

t = Time between vessel departures

c = Cut-off day measured in days before departure

X = Container arrival day measured in days before cut-off

$X + c$ = Container arrival day measured in days before departure

I = secondary inspection time

$\hat{i}$ = mean secondary inspection time

For a container arriving on any given day $(x + c)$ before departure, its probability of missing n vessels but making the n^{th} vessel is given by the probability of failing primary scanning multiplied by the probability of the secondary inspection taking longer than $(x + c + (n-1)t)$ days but shorter than $(x + c + nt)$ days.

$$\Pr(miss\ n\ vessels \mid X = x) = 0.05 \cdot \Pr(x + c + (n-1)t < I < x + c + nt)$$

Since container arrival day $(x+c)$ follows a Poisson distribution, the probability of a container arriving on day $(x+c)$ and missing n vessels is:

$$\Pr(X = x \ \cap \ miss\ n\ vessels) = 0.05 \cdot \Pr(X = x) \cdot \Pr(x + c + (n-1)t < I < x + c + nt)$$

The total probability of containers missing n vessel(s) but making the *(n+1)*th vessel for all the days before vessel departure is:

$$\Pr(miss\ n\ vessels) = 0.05\sum_{x=0}^{\infty}\Pr(X = x) \cdot \Pr(x + c + (n-1)t < I < x + c + nt)$$

Note that $\sum_{n=1}^{\infty}\Pr(miss\ n\ vessels)$ is the probability of missing at least the first vessel. Therefore, $1-\sum_{n=1}^{\infty}\Pr(miss\ n\ vessels)$ is the probability of not missing any vessel. The expected transit time *E(T)* is thus:

$$E(T) = \left[1-\sum_{n=1}^{\infty}\Pr(miss\ n\ vessels)\right]\cdot T_s + \sum_{n=1}^{\infty}\left[\Pr(miss\ n\ vessels)\cdot(T_s + nt)\right]$$

with a variance of:

$$\begin{aligned}\mathrm{var}(T) &= E(T^2) - \left[E(T)\right]^2 \\ &= \left[1-\sum_{n=1}^{\infty}\Pr(miss\ n\ vessels)\right]\cdot T_s^2 + \sum_{n=1}^{\infty}\left[\Pr(miss\ n\ vessels)\cdot(T_s + nt)^2\right] - \left[E(T)\right]^2\end{aligned}$$

The standard deviation in lead-time demand is given by:

$$\sigma_L = \sqrt{E(T)\cdot\left[CV\cdot E(D)\right]^2 + \left[E(D)\right]^2\,\mathrm{var}(T)}$$

The required safety stock is:

$$Safety\ Stock = k\sigma_L$$

In order to estimate how much inventory has to be increased with increasing secondary inspection time, the calculated safety stock is normalized by the current level of safety stock where the probability of a container missing its sailing is 0%.

$$\frac{New\ Safety\ Stock_{I=i}}{Current\ Safety\ Stock} = \frac{\sqrt{E(T)_{I=i} \cdot \left[CV \cdot E(D)\right]^2 + \left[E(D)\right]^2 \mathrm{var}(T)_{I=i}}}{\sqrt{T_s \cdot \left[CV \cdot E(D)\right]^2}}$$

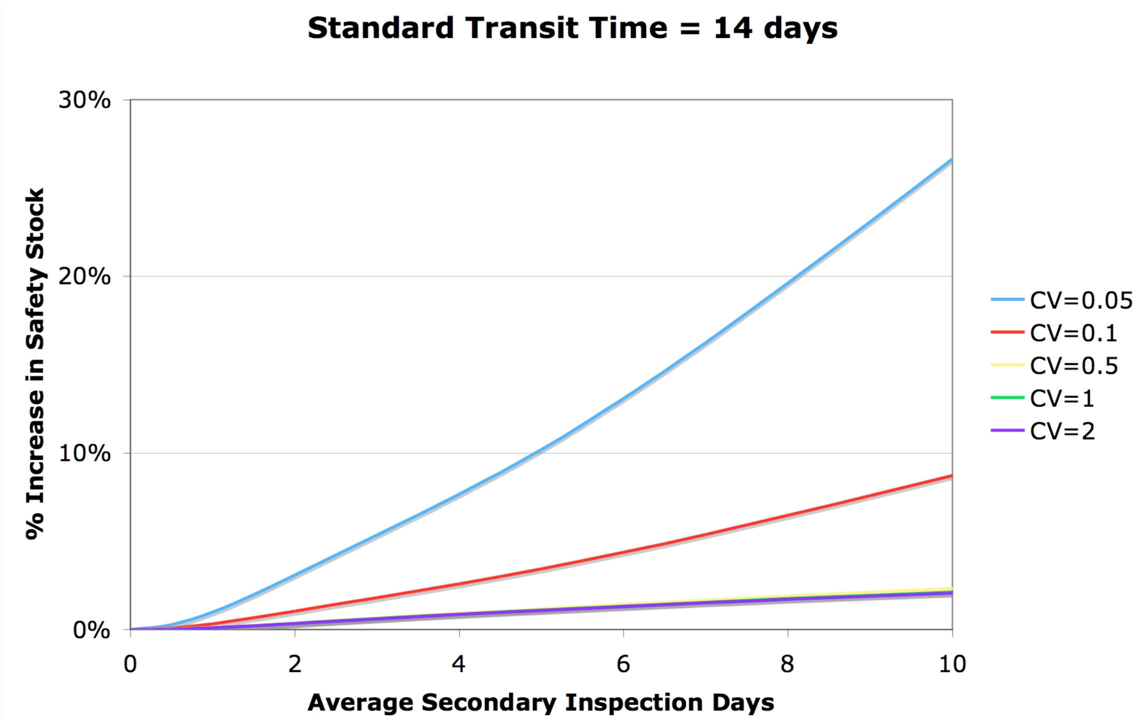
Factorizing:

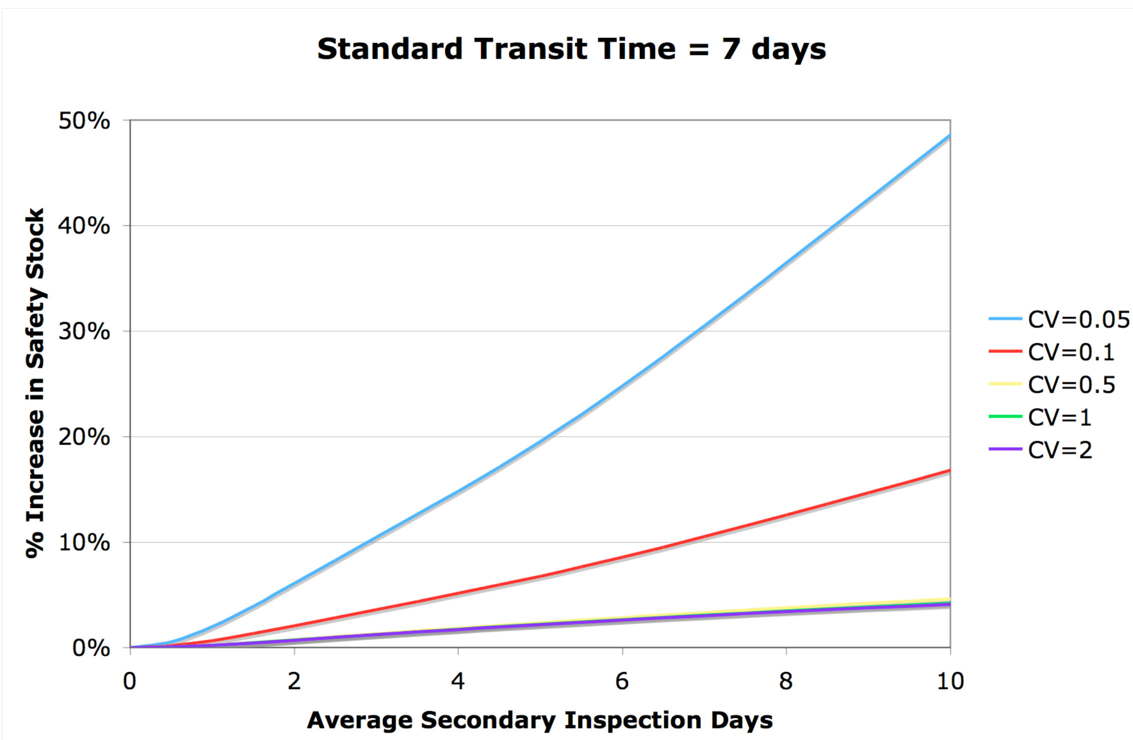
$$\frac{New\ Safety\ Stock_{I=i}}{Current\ Safety\ Stock} = \sqrt{\frac{E(T)_{I=i}}{T_s} + \frac{\mathrm{var}(T)_{I=i}}{T_s \cdot CV^2}}$$

6.2.6 Results of Sensitivity Analysis of Secondary Inspection Time

The approach shown above provides a mathematical formulation to estimate the percentage increase in safety stock when 100% scanning is implemented. There are several input variables required in order to provide a proper estimation. These inputs vary greatly for different ports and companies. For the purpose of this analysis, some variables are held constant while others are varied to investigate their effects on safety stock levels.

Since most ports currently have a cut-off time of 24 hours before vessel loading and most US-bound vessels operate on a weekly basis, cut-off day c is set to 1 day before departure and time between vessels t is set to 7 days. CV, T_s and $\hat{i}$ are then varied to test the effects of demand variability, transit time and secondary inspection times on inventory levels. The results are shown in Figure 33 below.


Standard Transit Time = 14 days
% Increase in Safety Stock
30%
20%
10%
0%
0
2
4
6
8
10
Average Secondary Inspection Days
CV=0.05
CV=0.1
CV=0.5
CV=1
CV=2


Standard Transit Time = 7 days
% Increase in Safety Stock
50%
40%
30%
20%
10%
0%
0
2
4
6
8
10
Average Secondary Inspection Days
CV=0.05
CV=0.1
CV=0.5
CV=1
CV=2

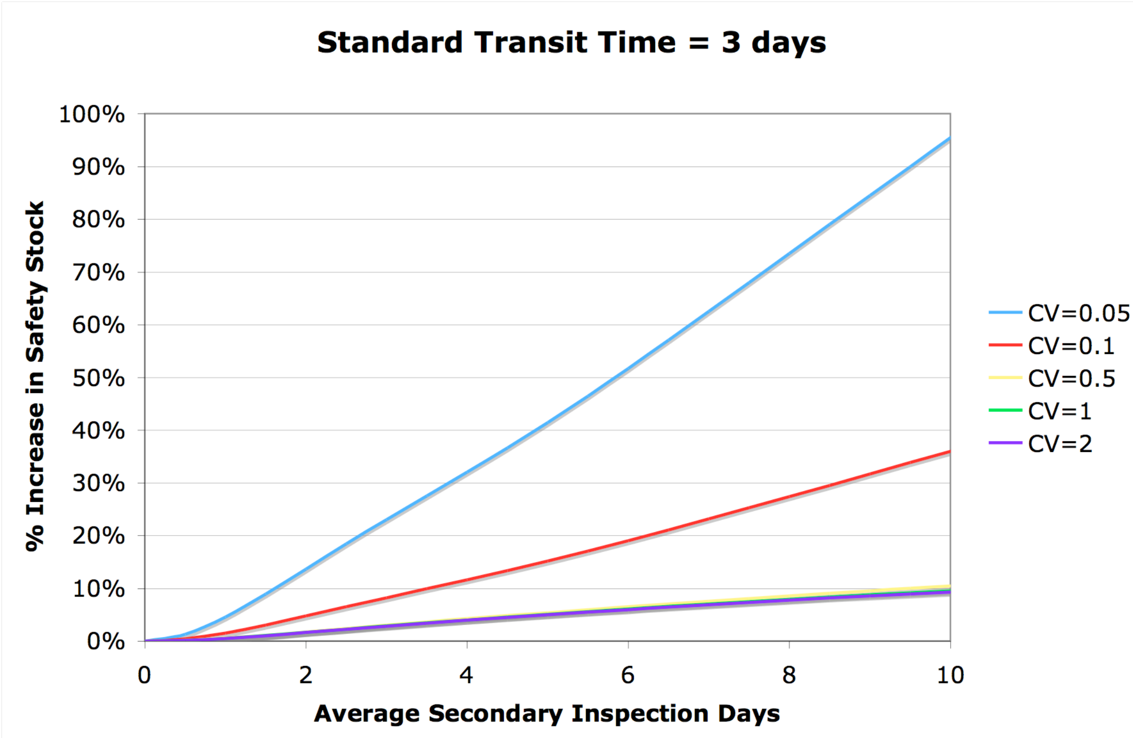


Figure 33. % Increase in Safety Stock vs Average Secondary Inspection Days

Figure 33 shows that as the average secondary inspection time increases from 0 to 10 days per container, safety stock will have to be increased to protect against the additional lead time and lead time variability. The percentage increase in safety stock is not a linear function of $\hat{i}$, but rather, increases at a very slightly increasing rate. This exponential effect is not strong as evident from the graphs and can be approximated to a linear relationship for quick estimations.

Results also reveal that the safety stock of a product with low *CV* requires a greater percentage increase than a product with high variability. This is because a product that has high demand variability would already have a significant level of safety stock to protect against fluctuations in demand. Although increasing the average secondary inspection time leads to an increase in lead-time variability, the high demand variability still overwhelms the increased lead-time variability. As such, percentage increase in safety stock required is minimal. On the other hand, if a product has low *CV*, the variability of demand will be dominated by the increased variability in lead-time and thus, percentage increase in safety stock is higher.

Different standard transit times T_s also have an effect on safety stock. A short transit time causes safety stock ratio to be more sensitive to changes in $\hat{i}$ than a long transit time. For a given product with low variability in demand (*CV*=0.05) going through a port where $\hat{i}$=5 days, a company has to hold 10% additional safety stock if transit time is 14 days. If transit time is 7 days, safety stock will have to increase by 20% and for a 3-day transit time, the company has to hold 40% additional safety stock. This is because for a container with short standard transit time, the relative variability caused by missing a vessel and having to wait an additional 7 days is higher than if a container has a long transit time. This greater variability in expected transit time results in a need to increase safety stock to a greater percentage.

Note that this result does not mean that companies have to hold a greater inventory for short transit time items. It only means that the percentage increase in inventory for a short transit time item is greater than for a long transit time item. For example, a company might be currently holding 10 containers worth of item A that has a 3-day transit and 50 containers of item B that has a 14-day transit. Given identical *CV* of 0.05 and $\hat{i}$ of 5 days, the safety stock of item A has to be increased by 40% to 14 containers while the safety stock of item B has to be increased by 10% to 55 containers.

6.2.7 Summary of Secondary Inspection and Missed Sailing

This section presents an approach of setting up a simple Monte-Carlo simulation to estimate the probability of a container missing its vessel due to secondary inspections. The approach is generic and flexible enough to allow one to input different values for secondary inspection times, cut-off days and average container arrival days to estimate the risk associated with different port configurations. It is important to note that the approach only helps to estimate the risk of missing a vessel as a result of secondary inspections. There can be other reasons for a container missing its vessel that may not due to secondary inspections.

Results show that the risk of a container missing its vessel increases exponentially as it arrives closer to the departure day. An exporter should ascertain its own risk tolerance and use the approach to estimate how much earlier to send containers to ports. In doing so, exporters would have to make a trade-off between the cost of earlier container arrivals and the cost of missing a vessel. Earlier container arrivals, however, will put greater pressure on ports to increase capacity. Some ports with limited capacity might limit the earliest arrival time or charge higher holding fees to deter early arrivals.

A mathematical formulation is also developed to estimate the impact of secondary inspection times on inventory levels. Results of the analysis show that the safety stock of long transit time products is less sensitive to secondary inspection times than that of short transit time products. Another interesting result is that products with low demand variability are much more sensitive to secondary inspection times than products with moderate to high variability. Since many products have a CV of 0.1 or higher, this finding presents a cause for relief. Given that current average secondary inspection times typically do not exceed 2 days per container and assuming this rate remains the same after the implementation of 100% scanning, the percentage increase in safety stock required at the importer ranges from 1 to 5%. Although many importers have originally anticipated a substantial increase in inventory, this finding shows that the inventory impact might not be that great after all.

However, this finding also suggests that 100% scanning can potentially reduce the effectiveness of strategies designed to smooth out demand and reduce inventory, such as JIT replenishment, etc. Results show that for products with CV less than 0.1, the percentage increase in inventory required is 5% to 15%, assuming an average inspection time of 2 days. As such, inventory reduction derived from decreasing demand volatility may be offset by the need to hold greater inventory to protect against the increase in lead-time variability.

6.2.8 Assumptions of Secondary Inspection

There are several assumptions made in the approach that can be altered to better reflect different port specific attributes. For example, the percentage of container arrivals each day is assumed to follow a Poisson distribution. Although this is a realistic assumption, it might not be appropriate for all ports. This assumption could be changed to reflect other distributions if they fit arrival patterns better. A second assumption made is that there is no queue for secondary inspections. This is a practical assumption since secondary inspection typically does not follow a first-in, first-out system and a single inspection team can work on multiple containers at a time. As such, it is unnecessarily complex to model queuing for secondary inspection. The exponentially distributed inspection time is meant to embed any queuing phenomenon.

7 CONCLUSION

7.1 9/11 Act

Currently, the 9/11 Act does not address a number of key factors necessary to appropriately plan and implement this legislation. Some of the areas that should be addressed include:

(1) Equipment Standards

As tasked by the 9/11 Act, the Secretary of DHS, in conjunction with other agencies, should prepare equipment specification requirements or guidelines to ensure that the inspection equipment purchased is capable of detecting targeted quantities of special nuclear material. Health and safety issues associated with NII should be addressed through equipment specifications, while respecting sovereign standards.

(2) Equipment Operations

As tasked by the 9/11 Act, the Secretary of DHS should prepare operational standards associated with the scanning systems. Operationally, the Secretary should determine what scanning at a foreign port prior to loading actually means. This should define specifically where in the supply chain a container scan is considered valid. This could include clarifications on whether the scanning is valid upstream at the port of origin, intermediary transshipment ports, or the last port of loading. The Secretary should be cognizant that individual ports have unique dynamics when determining whether or not to require that inspection decisions be made immediately or whether primary scanning and secondary inspection can be decoupled activities.

(3) Alarm Review and Adjudication

A determination must be made on the level of data review that is required. Currently, the 9/11 Act does not address whether the data generated by the RPM and NII equipment must be reviewed. A generic concept of operations should clearly address the expectations for alarm and image review. Additionally, it is unclear what type of scientific assistance the US government will provide, or what the expectations are for a nation to inherently have to assist in reviewing difficult radiation profiles and handling tertiary inspections and nuclear material containment. The US should consider whether alarms can be adjudicated with or without commodity manifest details.

(4) Entities Permitted to Perform Scanning

DHS should outline who is allowed to perform the scanning and analysis. Additionally, what groups have the responsibility or option of purchasing equipment? It is important to define whether this is a government, port authority, terminal operator or third-party task. Also, if any of these groups are precluded from these tasks, DHS should make this information known. DHS should differentiate, as necessary, between those entities that can operate equipment versus those that shall make inspection decisions.

(5) Training

The 9/11 Act identifies that further inspection should be carried out by appropriately trained personnel; however, no guidance is provided for determining training standards. These standards should include training for primary scanning and secondary inspection.

(6) Alarm Storage and Transmission

The 9/11 Act does not address whether any of the data needs to be stored locally or to be transmitted back to US. If it is determined that this data must be stored locally, DHS must determine metrics for the data required to be stored and the duration of storage as well as security measures and authorization. If US-bound container scanning data must be transmitted in a delayed or real-time manner, it will greatly affect the cost of the compliance; particularly if data is desired for both alarming and non-alarming containers.

(7) Extensions

Several of the extension parameters require metrics to substantiate a threshold or even measure across ports for efficiency, physical characteristics, integration, significant impact to trade or flow of cargo. As an example, one of the valid reasons for an extension request is if the "systems to scan containers . . . do not adequately provide an automated notification of questionable or high-risk cargo as a trigger for further inspection by appropriately trained personnel." Currently, commercially available NII software does not include this capability. The Secretary should clarify whether this provides a valid extension for both the RPM and NII or only the NII, as "system" is not clearly defined as 2 separate technologies that can be decoupled. The presence of extensions is valid; however, the lack of metrics makes each extension an arbitrary decision.

7.2 Summary of Results

Cost analysis showed that port authority level implementation of the 9/11 Act results in a lower per box cost than terminal operator level implementation due to greater economies of scale. This highlights the importance of governments and port authorities in taking jurisdictional control of implementation, or at minimum encouraging terminal operators to share scanning resources. For ports shipping less than a 100 TEUs to the US a year, the per box cost of scanning only US-bound containers can amount to tens of thousands of dollars, making it financially unjustifiable to pass all costs to US importers. These ports will need to consider government subsidies, scanning and charging fees across a larger percentage of container volume, or no longer being the last port of loading for US-bound containers. This could add additional costs and transit time to US imports arriving from approximately 300 ports that fall into this category.

Analysis of truck congestion showed that queuing delays due to scanning at small volume ports are likely to be trivial. This allows US-bound export scanning to be accomplished with 2 sets of scanning equipment regardless of the US-bound volume, within the assumptions of this thesis. This result corroborates observations made in the field study visit to Puerto Cortes, Honduras.

For a high-volume port, the percentage of US-bound cargo becomes a more significant element for determining the number of scanning systems required. The heartening finding is that even for a large port exporting 2.4 million containers annually with as high as 30% US-bound cargo, only a minimum of 3 sets of scanning equipment may be needed to ensure minimal congestion. This result allays industry concerns that high volume ports will require a proportionally large number of scanners to maintain efficiency. It is prudent to note, however, that the congestion analysis performed did not consider space constraints, infrastructural layout issues and the ports' ability to separate US-bound from non-US-bound cargo, which might also contribute to congestion.

An interesting finding is the “ramp-metering” effect of the entry gate that helps to stagger truck traffic to the scanning area and abates congestion. There are misconceptions that scanning will increase the gate processing time for trucks. If one were to model both gate processing and scanning as one process, the benefit of the “ramp-metering” effect may be overlooked and delays may be overstated.

The combination of both cost and congestion analyses reveals the trade-off between cost per container and scanning delays. Ports may determine to scan all export traffic for cost savings, security benefits, or to avoid the need to separate US-bound from non-US bound containers. Amortizing scanning costs over the total export volume results in a significantly lower per box cost but may incur greater scanning queues and truck congestion. In low-volume export ports, scanning of all exports is likely to be achieved without additional equipment investment and delays; however, at high-volume ports, this effort may require a higher number of scanning systems. Results from a high-volume port case study show that it may be more economical to install more equipment to scan all exports and amortize the costs over all exports than to deploy fewer sets of equipment to scan and amortize over only US-bound containers. This result, however, may be unique only to the particular port studied in this thesis. Thus, high-volume ports need to examine the benefits and equipment requirements when determining which subset of container traffic should be scanned.

Analysis on secondary inspection delays revealed that the probability of a container missing its vessel could potentially increase up to 5% if the average secondary inspection time takes 7 days or longer. Since most ports today have average inspection time of 2 days or less, a more realistic assumption of the risk is around 1%. Although containers missing their vessel sailings add undesirable variability to lead time, the increase in importers' inventory may not be as drastic as some expect. If a product currently has moderate to high demand variability, the percentage of additional inventory required is small since the variability of demand already dominates the increased variability in lead-time. Only products with relatively constant demand require a significant adjustment in inventory.

7.3 Road Map

Our interviews and literature review highlighted the lack of preparation and quantitative analysis performed for the 9/11 Act. April 2008 statements by DHS Deputy Commissioner Jayson Ahern that "DHS does not believe that, at the present time, the necessary technology exists to adequately improve container security without significantly disrupting the flow of commerce" substantiates industry's hesitance to take a proactive compliance posture (Secure Freight Initiative, 2008). One might conclude that this statement coupled with current NII technology's inability to produce alarms provide ample evidence for all foreign ports to qualify for implementation extensions. This provides some credence to the value of not being the first mover to proactively comply with the 9/11 Act.

First, the US government should provide clear analysis of the SAFE Port and SFI pilot activities and officially assess whether current technology provides the capabilities to achieve the goals of the 9/11 Act. DHS in conjunction with DOE is beginning to develop crane-mounted radiation detection technology, which already involved solicitations from vendors, with tentative testing to begin in summer 2008 (Secure Freight Initiative, 2008). If this technology is proven to identify target quantities of radioactive materials in the rugged maritime environment, this would be an important step forward, particularly for RPM scanning of transshipment containers.

Based on site visits, interviews and calculations, NII is the greatest inhibitor to efficiently scanning export containers. Its cost, physical footprint, manpower, radiation health safety concerns and the speed of manual assessment are major drawbacks with no immediate solution. Domestically, import scanning utilizing RPMs is a functional reality across the majority of US ports of entry, while NII is only utilized for high-risk cargo.

DHS has long supported a layered, risk-based approach to container security. The majority of industry stakeholders support the data screening of 100% of US-bound cargo through ATS, including the newly proposed "10 + 2" Initiative to bolster the capabilities and effectiveness of this program. Requiring the scanning of 100% of US-bound containers abroad is not a reasonable interpretation of a layer. DHS should consider several paths:

1. Revising the 9/11 Act to require only 100% RPM scanning, with NII being utilized only for containers that cause RPM alarms, are identified as high-risk through ATS or are randomly selected
2. Waiting until technology has caught up with the demands of the port environment to enforce the 9/11 Act
3. Requiring the 9/11 Act for only high-risk countries with US government funding and data analysis assistance (similar to the SAFE Port and SFI pilot project in Port Qasim, Pakistan)

The "wait and see" mentality exhibited by industry stakeholders may currently be the most effective strategy for the 9/11 Act.

8 FUTURE RESEARCH

This section identifies further academic research that will contribute to quantifying the costs and delays associated with the implementation of 9/11 Act. Analyses of costs and delays performed in this study thus far have omitted considerations for specific port layouts and operations, which may play a far bigger role in determining costs and delays than assumed. This study also focuses on export ports and omits the study of transshipment ports and the operational challenges associated with the scanning of transshipment containers. Since transshipment plays a critical role in maritime transportation, it is imperative that analyses be conducted on transshipment scanning.

The cost analysis performed in this paper is an attempt to quantify the total costs of implementation of the 9/11 Act at ports of different volumes. Some of the values used are derived from DHS and DOE budgets and may not reflect actual costs. The analysis also assumes that labor and other operating costs are the same across countries, which is unrealistic. Future attempts at quantifying costs should take into account differences in currency exchanges and price indices between countries to generate a more accurate estimate.

The two models analyzing truck congestion and secondary inspections also make use of several assumptions that may have to be relaxed in order to generate more accurate delay estimates for a specific port under consideration. The assumptions used are discussed under their respective sections. Further research should also attempt to simulate truck congestion and secondary inspection delays simultaneously and take into consideration vessel arrivals and departures for a more robust model.

DHS has also yet to release its official cost and operational assessment of the 7 SFI pilot ports. Future research might draw findings from the report to explore cost and delay issues in greater depth.

Due to constant improvements in technology for both radiation scanning and NII imaging, the scanning rates used in this study may become obsolete. Furthermore, there are new technological developments in crane-mounted radiation detection that allows for scanning to be conducted while containers are being loaded on or off-loaded from ships. The advantage of such a system is that port configuration and space constraints will become a non-issue but thus far, there are concerns about its ability to detect nuclear materials and its reliability in the rugged environment of a crane with constant impacts and vibrations. It may be interesting to test the feasibility of such crane-mounted scanning systems and evaluate the benefits from a cost and efficiency perspective.

9 REFERENCES

Belgian Federal Public Service Finance. (2006). Brussels, Belgium: Presented at a Press Conference October 19. 2006. Retrieved May 5, 2008 from http://fiscus.fgov.be/interfdanl/nieuws/bestanden/press%20conference %2019_10_06_EN_long%20version.ppt

Bonewit, J. (2007). *Customs and security*. Retrieved April 30, 2008, from http://www.berr.gov.uk/files/file41333.ppt

Bridis, T. and Solomon, John. (2006). *US hiring Hong Kong firm for security at Bahamas port. The Boston Globe.* Retrieved April 30, 2008, from http://www.boston.com/news/nation/articles/2006/03/24/us_hiring_hong_kong_firm_for_security_at_bahamas_port/

Canada Border Service Agency. (2006). Ottawa, Canada: Retrieved May 5, 2008 from http://centreforforeignpolicystudies.dal.ca/pdf/businessofdefence06/Cooperation_and_Coordination.pdf

Collier International. (2005). 2005 Industry Leaders. Retrieved May 5, 2008 from www.colliers.com/Content/Repositories/Base/Markets/MultiModal/English/Market_Report/PDFs/IndustryLeaders2005.pdf

Connaughton, S. T. and Peters, M. E. (2007). *US water transportation statistical snapshot*. Retrieved May 5, 2008, from http://www.marad.dot.gov/MARAD_statistics/2007%20STATISTICS/USWTSR%20bOOKLET.pdf

Department of Homeland Security. (2006). *DHS and DOE launch secure freight initiative.* Washington, DC: Retrieved May 5, 2008, from http://www.dhs.gov/xnews/releases/pr_1165520867989.shtm

Department of Homeland Security. (2007). *DHS health and safety report on non-intrusive imaging (NII) container scanning technology*. Washington, DC:Retrieved May 5, 2008, from http://aapa.files.cmsplus.com/PDFs/NII%20Health%20and%20Safety%20Report%20to%20Congress%207%206%202007%20-%20Final.pdf

Department of Homeland Security (2008). *Budget-in-brief: Fiscal year 2009.* Washington, DC: Retrieved May 5, 2008, from http://www.dhs.gov /xlibrary/assets/budget_bib-fy2009.pdf

Department of Homeland Security (2006). *Technotes: radiation pagers.* Washington, DC: Retrieved May 5, 2008 from https://www.dhs-saver.info/actions/document.act.aspx?type=file&source=view&actionCode=submit&id=3581&file=SA-NTS-2006-03-TNRPT.pdf

Department of Homeland Security (2007). *Budget-in-brief: Fiscal year 2008.* Washington, DC: Retrieved May 5, 2008, from http://www.dhs.gov/xlibrary/assets/budget_bib-fy2008.pdf

Department of Homeland Security (2007). *DHS exhibit 300 public release BY08 / CBP-noni ntrusive inspection (NII) system program (large scale).* Washington, DC: Retrieved May 5, 2008, from http://www.dhs.gov/xlibrary/assets/mgmt/e300-cbp-nii-large2008.pdf

Detecting nuclear weapons and radiological materials: how effective is available technology?: Hearing Before the Subcommittee on Prevention of Nuclear and Biological Attacks and Subcommittee on Emergency Preparedness, Science and Technology for the House Committee on Homeland Security. 109th Cong., (2005)

Domestic Nuclear Detection Organization. (2006). *Cost Benefit Analysis for Next Generation Passive Radiation Detection of Cargo an the Nation's Border Crossings, May 30, 2006,* Washington: DC.

Erera, A, Lewis, B., and White, C. (2003). Optimization approaches for efficient container security operations at transshipment seaports. *Transportation Research Record, No. 1822*, pp. 1-8.

Erera, A., Kwek, K.H., Nandini, G., Zhang, H., and White, C. (2003) Cost of security for sea cargo transport, *TLI-AP White Paper*. Retrieved February 10, 2008, from http://www2.isye.gatech.edu/setra/reports/Security_Cost_Report_May2003.pdf

Flynn, S. E. (2006). Port security is still a house of cards. *Far Eastern Economic Review*. Retrieved April 28, 2008, from http://www.cfr.org/publication/9629/

General Services Administration. (2006). *Authorized federal supply schedule catalogue/price list*, *contract period august 1, 2006 through july 31, 2011.* Provided by Smith Detection, Inc.

Implementing recommendations of the 9/11 commission act of 2007, H. R. 1, 110th Cong. 6 U.S.C. § 1701 (2007).

Kimery. A. L. (2007, March 25). 100 percent air, ship cargo screening unlikely to get past Congress. *HSToday*. Retrieved January 23, 2008, from http://hstoday.us/index.php?option=com_content&task=view&id=39&Itemid=150

Lee, D. H., Raguraman, K. and Song, L. (2004) An optimization approach to security operations toward sustainable seaport. *International Journal of Sustainable Transportation, volume 2, issue 2*, pp. 115-133.

Maritime Administration. (2007). *Container trading partners, 1997-2006.* Washington, DC: Retrieved from http://www.marad.dot.gov/Marad_Statistics/2005%20STATISTICS/Container%20Trading%20Partners,%201997-2006.xls

Martonosi, S. E., Ortiz, D. S. and Willis, H. H. (2005). Evaluating the viability of 100 percent container inspection at America's ports. *The Economic Impacts Of Terrorist Attacks, Chapter 12.*

Miller. J. (2007, October 25). New shipping law makes big waves in foreign ports. *Wall Street Journal*. Retrieved April 12, 2008, from http://wakeupwalmart.com/news/article.html?article=1163

Mollema, P. (2007). Overview of supply chain security and SCS in the port of Rotterdam. Retrieved April 30, 2008, from http://www.iaph2007.com/Presentations/IAPH2007-Mollema.pdf

National Nuclear Security Administration. (2006). *Office of the second line of defense megaports initiative*. Retrieved April 30, 2008, from http://www.exportcontrol.org/library/conferences/1379/008_--_Megaports_--_Elly_Melamed_--_1125-1225.pdf

National Nuclear Security Administration. (2007). *Office of the second line of defense megaports initiative regional update october 2007*. Washington, DC: Retrieved from http://www.basc.org.do/PDF_files/PresentacionMegaports.pdf

National Nuclear Security Administration. (2008). *Megaports initiative Protecting the world's shipping network from dangerous cargo and nuclear materials.* Retrieved May 5, 2008, from http://nnsa.energy.gov/nuclear_nonproliferation/1641.htm

Rutherford, M. (2008). *Defense dept. doubles spending on systems that don't deliver.* Retrieved May 5, 2008, from http://www.cnet.com/military-tech/?keyword=GAO ed

SAFE port act: status of implementation one year later statements mr. vayle s oxford, DNDO: Hearing Before the House Committee on Homeland Security Subcommittee on Border, Maritime and Global Counterterrorism for the. 110th Cong., (2007)

SAIC. (2007). *Imaging systems - A revolution in cargo inspection.* Retrieved May 5, 2008, from http://www.saic.com/products/security/pdf/VACIS-P-7500.pdf

Secure freight initiative: statement of jayson p. ahern deputy commissioner U.S. customs and border protection department of homeland security: Hearing before the Committee on Appropriations Subcommittee on Homeland Security, 110th Cong., (2008)

Security and Prosperity Partnership. (2006). *Fact sheet: Security and prosperity partnership of north america.* Washington, DC: Retrieved May 5, 2008, from http://www.spp.gov/factsheet.asp?dName=fact_sheets

Supply Chain Digest. (2005, August 4). The future of cargo security – port of Hong Kong implements new screening technology. *Supply Chain Digest.* Retrieved January 3, 2008, from http://www.scdigest.com/assets/NewsViews/05-08-041.cfm?cid=237&ctype=content

Supply Chain Digest. (2007, October 29). Global logistics: 100 percent container scanning, if it comes will touch shippers in many ways. *Supply Chain Digest.* Retrieved January 3, 2008, from http://www.scdigest.com/assets/on_target/07-10-29-1.php?cid=1320

The International Maritime Organization. (2003). *Conference of contracting governments to the international convention for the safety of life at sea, 1974: 9 - 13 december 2002.* Retrieved May 5, 2008, from http://www.imo.org/Newsroom/mainframe.asp?topic_id=583&doc_id=2689

TSA Systems. (2008). *Portal monitors.* Retrieved May 5, 200, from http://www.tsasystems.com/products/portal_VM-250A.html

United Nations, United Nations Conference on Trade and Development (2007). *Review of maritime transport 2007.* Retrieved May 5, 2008, from http://www.unctad.org/en/docs/rmt2007ch4_en.pdf

United States Customs and Border Protection. (2003). *Enforcement of 24-hour rule begins february 2.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/xp/cgov/newsroom/news_releases/archives/cbp_press_releases/012003/01302003.xml

United States Customs and Border Protection. (2003). *Advance electronic cargo information section 343 of the trade act of 2002.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/linkhandler/cgov/trade/trade_outreach/advance_info/executive_summary.ctt/executive_summary.doc

United States Customs and Border Protection. (2007). *C-TPAT Overview.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/xp/cgov/trade/cargo_security/ctpat/what_ctpat/ctpat_overview.xml

United States Customs and Border Protection. (2007). *Secure freight scanning at a glance.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/linkhandler/cgov/newsroom/fact_sheets/trade_security/sfi/sfi_scanning.ctt/sfi_scanning.pdf

United States Customs and Border Protection. (2008). *Container security initiative.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/linkhandler/cgov/newsroom/fact_sheets/printer_fact_sheets/csi_factsheet.ctt/csi_factsheet.pdf

United States Customs and Border Protection CBP. (2008). *CBP issues proposed rule requiring additional cargo information.* Washington, DC: Retrieved May 5, 2008, from http://www.cbp.gov/xp/cgov/newsroom/news_releases/archives/2008_news_releases/jan_2008/01022008.xml

United States Government Accountability Office. (2005). *Preventing nuclear smuggling DOE has made limited progress in installing radiation detection equipment at highest priority foreign seaports.* (GAO No. GAO-05-375). Retrieved May 5, 2008, from GAO Reports: Main Pate via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2006). *Combating nuclear smuggling DHS has made progress deploying radiation detection equipment at U.S. ports-of-entry, but concerns remain.* (GAO No. GAO-06-389). Retrieved May 5, 2008, from GAO Reports: Main Pate via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2007). *Maritime security the SAFE port act and efforts to secure our nation's seaports.* (GAO No. GAO-08-86T). Retrieved May 5, 2008, from GAO Reports: Main Pate via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2007). *Maritime Security One Year Later: A Progress Report on the SAFE Port.* (GAO No. GAO-08-171T). Retrieved May 5, 2008, from GAO Reports: Main Pate via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2006). *Combating nuclear smuggling: challenges facing US efforts to deploy radiation detection equipment in other countries and in the united states.* (GAO No. GAO-06-558T). Retrieved May 5, 2008, from GAO Reports: Main Page via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2007). *DHS's cost-benefit analysis to support the purchase of new radiation detection portal monitors was not based on available performance data and did not fully evaluate all the monitors' costs and benefits.* (GAO No. GAO-07-133R). Retrieved May 5, 2008, from GAO Reports: Main Page via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

United States Government Accountability Office. (2007). *Combating nuclear smuggling: DHS's decision to procure and deploy the next generation of radiation detection equipment is not supported by its cost-benefit analysis*. (GAO No. GAO-07-581T). Retrieved May 5, 2008, from GAO Reports: Main Page via GPO Access: http://www.gpoaccess.gov/gaoreports/index.html

World Shipping Council. (2007). *Statement Regarding Legislation to Require 100% Container Scanning*. Retrieved December 12, 2007, from http://www.worldshipping.org/wsc_legislation_statement.pdf

Zin, C. T. (2007). US container screening bill slammed. *PortWorld.* Retrieved May 1, 2008, from http://www.portworld.com/news/2007/08/68737

Zin, C. T. (2008). US Customs repeats commitment to 100% scanning. *PortWorld.* Retrieved May 1, 2008, from http://www.portworld.com/news/2008/03/70927?gsid=9da6de6e2d912b5c7954294ae5ba2d6e&asi=1

10 APPENDIX

Appendix A. ‘‘Implementing Recommendations of the 9/11 Commission Act of 2007’’

TITLE XVII—MARITIME CARGO

SEC. 1701. CONTAINER SCANNING AND SEALS.

(a) CONTAINER SCANNING.—Section 232(b) of the SAFE Ports Act (6 U.S.C. 982(b)) is amended to read as follows:

‘‘(b) FULL-SCALE IMPLEMENTATION.—

‘‘(1) IN GENERAL.—A container that was loaded on a vessel in a foreign port shall not enter the United States (either directly or via a foreign port) unless the container was scanned by nonintrusive imaging equipment and radiation detection equipment at a foreign port before it was loaded on a vessel.

‘‘(2) APPLICATION.—Paragraph (1) shall apply with respect to containers loaded on a vessel in a foreign country on or after the earlier of—

‘‘(A) July 1, 2012; or

‘‘(B) such other date as may be established by the Secretary under paragraph (3).

‘‘(3) ESTABLISHMENT OF EARLIER DEADLINE.—The Secretary shall establish a date under (2)(B) pursuant to the lessons learned through the pilot integrated scanning systems established under section 231.

‘‘(4) EXTENSIONS.—The Secretary may extend the date specified in paragraph (2)(A) or (2)(B) for 2 years, and may renew the extension in additional 2-year increments, for containers loaded in a port or ports, if the Secretary certifies to Congress that at least two of the following conditions exist:

‘‘(A) Systems to scan containers in accordance with paragraph (1) are not available for purchase and installation.

H. R. 1—225

‘‘(B) Systems to scan containers in accordance with paragraph (1) do not have a sufficiently low false alarm rate for use in the supply chain.

‘‘(C) Systems to scan containers in accordance with paragraph (1) cannot be purchased, deployed, or operated at ports overseas, including, if applicable, because a port does not have the physical characteristics to install such a system.

‘‘(D) Systems to scan containers in accordance with paragraph (1) cannot be integrated, as necessary, with existing systems.

‘‘(E) Use of systems that are available to scan containers in accordance with paragraph (1) will significantly impact trade capacity and the flow of cargo.

''(F) Systems to scan containers in accordance with paragraph (1) do not adequately provide an automated notification of questionable or high-risk cargo as a trigger for further inspection by appropriately trained personnel.

''(5) EXEMPTION FOR MILITARY CARGO.—Notwithstanding any other provision in the section, supplies bought by the Secretary of Defense and transported in compliance section 2631 of title 10, United States Code, and military cargo of foreign countries are exempt from the requirements of this section.

''(6) REPORT ON EXTENSIONS.—An extension under paragraph (4) for a port or ports shall take effect upon the expiration of the 60-day period beginning on the date the Secretary provides a report to Congress that—

''(A) states what container traffic will be affected by the extension;

''(B) provides supporting evidence to support the Secretary's certification of the basis for the extension; and

''(C) explains what measures the Secretary is taking to ensure that scanning can be implemented as early as possible at the port or ports that are the subject of the report.

''(7) REPORT ON RENEWAL OF EXTENSION.—If an extension under paragraph (4) takes effect, the Secretary shall, after one year, submit a report to Congress on whether the Secretary expects to seek to renew the extension.

''(8) SCANNING TECHNOLOGY STANDARDS.—In implementing paragraph (1), the Secretary shall—

''(A) establish technological and operational standards for systems to scan containers;

''(B) ensure that the standards are consistent with the global nuclear detection architecture developed under the Homeland Security Act of 2002; and

''(C) coordinate with other Federal agencies that administer scanning or detection programs at foreign ports.

''(9) INTERNATIONAL TRADE AND OTHER OBLIGATIONS.—In carrying out this subsection, the Secretary shall consult with appropriate Federal departments and agencies and private sector stakeholders, and ensure that actions under this section do not violate international trade obligations, and are consistent with the World Customs Organization framework, or other international obligations of the United States.''.

(b) DEADLINE FOR CONTAINER SECURITY STANDARDS AND PROCEDURES.—

Section 204(a)(4) of the SAFE Port Act (6 U.S.C. 944(a)(4)) is amended by—

(1) striking ‘‘(1) DEADLINE FOR ENFORCEMENT.—’’ and inserting the following:

‘‘(1) DEADLINE FOR ENFORCEMENT.—

‘‘(A) ENFORCEMENT OF RULE.—’’; and

(2) adding at the end the following:

‘‘(B) INTERIM REQUIREMENT.—If the interim final rule described in paragraph (2) is not issued by April 1, 2008, then—

‘‘(i) effective not later than October 15, 2008, all containers in transit to the United States shall be required to meet the requirements of International Organization for Standardization Publicly Available Specification 17712 standard for sealing containers; and

‘‘(ii) the requirements of this subparagraph shall cease to be effective upon the effective date of the interim final rule and issued pursuant to this subsection.”