

**Feasibility Analysis of Scanning 100% of Maritime
Cargo Containers for Fissile Material**

By

William E. Foley, III

Submitted to the Department of Nuclear Science and Engineering
in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Nuclear Science and Engineering

at the

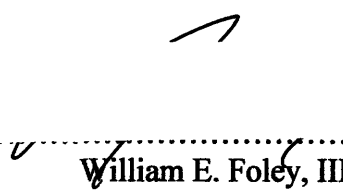
Massachusetts Institute of Technology

June 2008

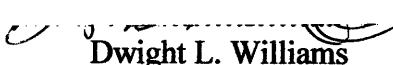
©2008 William E. Foley, III. All Rights Reserved

The author hereby grants to MIT permission to reproduce and to distribute publicly
paper and electronic copies of this thesis in whole or in part.

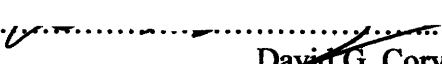
Signature of Author.....

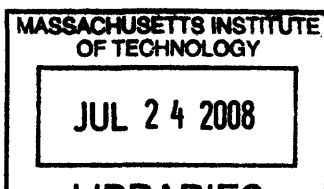

William E. Foley, III
Department of Nuclear Science and Engineering
May 9, 2008

Certified by.....


Dwight L. Williams
Martin Luther King Visiting Professor of Nuclear Science and Engineering
Thesis Supervisor

Accepted by.....


David G. Cory
Professor of Nuclear Science and Engineering
Chairman, NSE Committee for Undergraduate Students



ARCHIVES

FEASIBILITY ANALYSIS OF SCANNING 100% OF MARITIME
CARGO CONTAINERS FOR FISSILE MATERIAL

By

William E. Foley, III

Submitted to the Department of Nuclear Science and Engineering on May 16, 2008

In Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Nuclear Science and Engineering

ABSTRACT

On August 3, 2007, President George W. Bush signed into law H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007. The law mandates that 100% of air and maritime cargo must be scanned prior to entering the United States, and has been deemed unfeasible by many opponents. The analysis contained in this thesis shows that it is much more feasible for a major port to absorb the huge initial investments and operating costs than a smaller port. A port shipping 750,000 TEUs annually would charge a tax of \$49.48 for ten years to recover their initial investment, while a port shipping 150,000 TEUs annually would need to charge \$123.52 annually. This number rises exponentially as volume shipped drops.

Furthermore, a port that is willing to invest in the developing technologies will be able to handle scanning of 100% of maritime cargo with minimal delays. Using current technology would result in delays of over 80,000 hours annually. However, investing in four next generation scanning machines would result in delays of only 560 hours annually.

Finally, there exists a variety of political and logistical barriers that must be overcome. I recommend that in all circumstances, the United States retain control and oversight of all scanning operations in order to maintain quality control and throughput times. When weighed against the potential destruction of nuclear terrorism, this law is feasible for any port that is able to make the initial investment. A nuclear weapon would be destructive to both the U.S. and the country of origin, which should convince anyone that the benefits outweigh the costs.

Thesis Supervisor: Dwight Williams

Title: Martin Luther King Visiting Professor of Nuclear Science and Engineering

Acknowledgements

I would first like to thank my advisor, Dr. Dwight Williams. Over the past two years, I have had the privilege of working with Dr. Williams in the classroom and out. He brings a level of experience, expertise, and excitement that is unmatched by any professor that I have ever met. For this, I will be forever appreciative to Dr. Williams for allowing me to conduct my thesis under him.

I would like to thank my girlfriend Andrea for always being there for me in the past four years. Whenever I have gotten in over my head, she has been there for me without hesitation to give me encouragement and put things into perspective. She has taught me that there is much more to life than going to school, sleeping, and eating, and for this I am forever grateful. I am certain that I would not have been successful at MIT without her.

Finally, I would like to thank my family. My parents, Bill and Gerry, and my sister, Kristin, have supported me throughout my life unconditionally. Without their constant encouragement and support, I know that there is no way I would be where I am today. In my four years at MIT, they never once stopped believing in me, even if I stopped believing in myself.

Table of Contents

Abstract.....	2
Acknowledgements.....	3
List of Figures.....	7
List of Tables.....	8
1.0 Introduction.....	9
1.1 The Modern Day Terrorist.....	9
1.2 Procurement of Fissile Materials.....	10
1.3 Smuggling a Nuclear Weapon.....	12
1.4 Nuclear Attack Scenario.....	13
2.0 H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007.....	17
2.1 Obstacles of H.R. 1.....	18
3.0 Developing Technologies.....	20
3.1 Nuclear Resonance Fluorescence Imaging.....	20
3.2 Dual-Energy X-Ray Signal Detection.....	22
4.0 Economic Analysis.....	24
4.1 Initial Costs.....	24
4.2 Annual Costs.....	28
4.3 Tax Analysis.....	31
4.3.1 Varying Taxes Based on Port Size.....	32
4.3.2 Effects on Cost of Goods.....	34
4.3.3 Universal Tax.....	34

4.4 Economic Conclusion	38
5.0 Performance Analysis	40
5.1 Current Technology without Upgrades.....	40
5.1.1 False Positives.....	41
5.1.2 Increase in Scanning Time.....	42
5.1.3 Conclusion for Current Technologies	44
5.2 Developing Technologies	45
5.2.1 False Positives.....	45
5.2.2 Throughput times	46
5.2.3 Conclusion for Developing Technologies	48
5.3 Performance Analysis Conclusion.....	49
6.0 Logistical Analysis.....	50
6.1 Funding	50
6.2 Foreign Retaliation.....	51
6.3 Maintenance and Operations of Ports	52
7.0 Conclusion	55

List of Figures

Figure 1: Schematic of Nuclear Resonance Fluorescence Imaging.....	21
Figure 2: U-238 Measurement under NRFI.....	22
Figure 3: Illustration of a dual-energy map	23
Figure 4: Percentage breakdown of initial costs for each port.....	28
Figure 5: Percentage breakdown of annual costs for each port	31
Figure 6: Tax based on number of containers shipped per year	33
Figure 7: Timeline of debt repayment for major port.....	35
Figure 8: Timeline of debt repayment for a medium port.	36
Figure 9: Timeline of debt repayment for a small port.....	37
Figure 10: Years to recover initial investment based on tax.....	38
Figure 11: Graphical representation of delays for scanning with current equipment.....	44
Figure 12: Graphical representation of delays for scanning with developing equipment	48

List of Tables

Table 1: Initial investment for each port scenario	27
Table 2: Annual costs for each port scenario.....	30
Table 3: Schedule of Taxes on Each TEU	32
Table 4: Increased false positive time for current technology	42
Table 5: Increased scanning time for current technology	43
Table 6: False positive scanning time change for developing technology	46
Table 7: Increased scanning time for developing technology	47

1.0 Introduction

Since the introduction of Fat Man and Little Boy to the world in 1945, the threat of a nuclear attack on United States soil has loomed over the heads of Americans.

Although the apprehension that was present at the peak of the Cold War has certainly faded away, the threat is still very real. The nature of this threat, however, has evolved over the past several decades. With the end of the Cold War and the fall of the Soviet Union has come a rise in transnational terrorism that poses just as significant a threat to the U.S. in terms of nuclear terrorism. An attack from another state seems unlikely because of the threat of U.S. retaliation, but terrorist groups with no borders or citizens to protect have nothing to fear. This makes the threat of a nuclear attack as real as ever, and despite the changing dynamics of a possible threat, one thing has remained constant for over half a century: a successful nuclear attack on U.S. soil would be crippling economically, politically, and physically not only in America, but to the rest of the world as well.

1.1 The Modern Day Terrorist

Recent terrorist attacks on the U.S., England, Spain, and other developed countries around the world have clearly demonstrated that the most significant threat to these countries today is from terrorist organizations with little or no state affiliations. Present-day transnational terrorist organizations are not only different than state-based organizations that the U.S. has previously had to battle, but they are also very different from terrorist organizations that the U.S. has faced in the past. The new breed of terrorist is no longer out to achieve political objectives [1], but is out to punish infidels and kill

their enemies in the name of religious beings. They favor mass casualties to advance their religious and ideological beliefs as opposed to lesser strikes to deliver a political message. James Woolsey, former director of the CIA, summed up this new trend by saying, "Today's terrorists don't want a seat at the table, they want to destroy the table and everyone sitting at it." [2]

The doctrine of mutual assured destruction has effectively prevented large scale nuclear war between two parties at war in the past. This doctrine of military strategy simply states that full-scale use of nuclear weapons by two opposing sides would effectively result in the destruction of both the attacker and the defender. With a current nuclear stockpile estimated at over 5,500, the United States has the artillery to combat a nuclear strike on its soil [3]. Because of this, another state would be unlikely to carry out any kind of nuclear strike because they have borders, citizens, and infrastructure to protect. However, a well financed and technologically advanced terrorist group could theoretically carry out a nuclear strike because they lack the targets, infrastructure, or populace to launch a counter-attack on. This, coupled with their high mobility, make a terrorist attack from a transnational terrorist group far more probable in the present day than an attack from another state.

1.2 Procurement of Fissile Materials

The greatest challenge to any rogue group attempting a nuclear attack anywhere in the world is the securing of fissile material to use in the weapon. Even the most technologically advanced and well funded groups cannot simply purchase plutonium or highly enriched uranium (HEU) on the black market. Numerous physical and political

barriers have been constructed in order to prevent the proliferation of fissile material. Because of this, an independent terrorist group would find this the most daunting task in constructing a nuclear weapon. A report in June 2004 by the National Commission on Terrorist Attacks upon the United States found that even though an attempt by al Qaeda, one of the most well funded terrorist groups, in 1994 to purchase uranium failed, “al Qaeda continues to pursue its strategic objective of obtaining a nuclear weapon [4].”

However, despite these measures in place to prevent nuclear proliferation, the threat still exists. Dr. A. Q. Khan, a Pakistani scientist and purported founder of Pakistan’s nuclear program [5], supplied gas centrifuges and gas centrifuge parts to North Korea and, possibly, an amount of uranium hexafluoride gas[6]. The extent of Khan’s proliferation network is unknown; however the possibility exists for a terrorist group to receive fissile material through the network.

Another possible source of fissile material for a nuclear weapon is theft from Russia. It is estimated that Russia currently has more than 16,000 nuclear weapons in its arsenal [4]. Many of these materials are protected with very limited security. Due to poor working conditions, employees at the Russian nuclear sites are becoming more of a global security issue. According to the Center for International Trade and Security at the University of George, the United States General Accountability Office reported in 2001 that guards frequently left restricted areas unguarded or unlocked and failed to check for proper identification of individuals entering areas where fissile materials were stored. On top of this, the poor working conditions have led to a great deal of corruption and greed among the lower level employees, leaving the possibility for the sale of fissile material to a terrorist organization very real.

The last feasible method that a terrorist could gain possession of fissile material is by stealing or purchasing the HEU from one of the numerous research reactors in the world that currently use this kind of fuel. Naturally occurring uranium contains approximately .7% U-235 and 99.3% U-238, and is not fissile enough to be used in a nuclear weapon. Many research reactors, however, use HEU (which is typically classified as anything containing over 20% of the fissile U-235 or U-233) in order to maximize the output of the core with respect to their size constraints. This HEU from research reactors could theoretically be stolen by, or even sold to, a terrorist organization. Some reactors even use what is considered weapons-grade material, or greater than 93% fissile material [7].

Although these three scenarios of procuring fissile material are unlikely due to numerous barriers set up to prevent the proliferation of nuclear material, the possibility still exists. Once a terrorist organization is able to procure sufficient fissile materials for a nuclear weapon, the danger of a nuclear attack becomes far more likely. If a group were able to obtain the necessary materials, then they have already completed the most difficult step in carrying out a nuclear attack on the United States.

1.3 Smuggling a Nuclear Weapon

Once terrorists succeed in procuring fissile material, what is the next hurdle that must be overcome? Since there are many people that have the necessary knowledge to construct a nuclear weapon, that hurdle is then transporting the weapon inside the United States. In order to pinpoint the most significant security vulnerabilities, we must look at where there is the least oversight and most potential for undetected smuggling. The

United States has over 13,000 miles of coastline and 7,500 miles of borders with Canada and Mexico. The U.S. Customs and Border Protection is not equipped to adequately secure these thousands of miles of borders, making this one of the biggest security vulnerabilities the United States faces.

Of particular interest is the United States coast line. Every day, more than 22,000 cargo containers arrive in the United States, accounting for over 90% of international trade [8]. However, only 6% of these containers receive any kind of scanning or physical inspection upon arrival to the United States. The most evident problem here is the possibility of smuggling a nuclear weapon undetected into the country in one of these cargo containers, with only a slim chance of it being inspected. However, another serious issue with the current methods is that there is no inspection prior to the arrival at U.S. seaports, many of which are located in or near many major cities. Even if a weapon of mass destruction were detected once arriving at the port, it would not prevent the detonation of the weapon in a potentially highly populated area.

1.4 Nuclear Attack Scenario

Let us examine a brief scenario in which a terrorist group wishes to attack the U.S. with a nuclear weapon. We will assume that the adversary is rational and determined, meaning that he will always try to maximize civilian deaths. Despite fanatical religious and political views, terrorists have always proven themselves to be rational and have usually focused attacks on densely populated areas. For the purpose of this scenario, we will assume the terrorists: 1) have procured fissile material and will seek to weaponize it; 2) will weaponize the fissile materials prior to shipment to the United

States; 3) will seek areas with the highest probability of maximizing casualties; and 4) will provide some alternate plan to detonate the weapon should the weapon be discovered prior to planned detonation.

The assumption that a terrorist group will weaponize fissile material is justified based on the previous sections argument. There is strong evidence that many terrorist groups, including al Qaeda, have attempted many times to obtain fissile material to create some form of a nuclear weapon. A nuclear weapon is capable of far more damage than conventional weapons of mass destruction (chemical or biological) because it destroys in a much more indiscriminate manner. Chemical or biological weapons target parts of the human body and attack only those areas, but nuclear weapons have the ability to destroy people, buildings, and all economically vital infrastructure. For a rational terrorist seeking total destruction, assembling a nuclear weapon would be the most logical choice.

The assumption that the enemies would ship a functional weapon into the United States, as opposed to shipping the fissile material and assembling the weapon on U.S. soil, is plausible for two reasons. First, a terrorist organization would enjoy far more security abroad than in the U.S., with much less harassment from law officials and intelligence agencies. There would be a greater support network surrounding them, making the possibility of their plan being foiled less likely abroad. Secondly, a rational terrorist would choose to ship a functional weapon so that in the event that the weapon is discovered, detonation is still possible. Because of the current security protocols, detecting a nuclear weapon at a U.S. port is all but useless, because the weapon could be outfitted with a remote detonation device or booby-trapped to prevent tampering.

It is a plausible assumption to say that a rational terrorist would seek out a densely populated area in order to maximize civilian casualties and infrastructural damage. Regardless of the reasons behind the enemy's attack, their goal will be to maximize destruction, and this can only occur in the most densely populated metropolitan areas. Many of the most highly and densely populated areas are along the U.S. coast and have major shipping ports nearby. These include the metropolises of New York, Boston, Washington D.C., Miami, Los Angeles, and San Francisco. An attack on these major cities would not only have local affects, but would affect the economy and politics of the nation, and even the entire world.

Finally, as briefly mentioned already, the rational enemy would equip the device with some kind of fail safe mechanism to ensure detonation. This could be in the form of a booby-trap or some kind of remote detonation device. Either of these mechanisms would serve the purpose of preventing any kind of intervention by those being attacked. Both would be used to ensure that the weapon could not be tampered with or disarmed before carrying out its intended purpose.

The scenario described here is that of a rational and determined terrorist or terrorist organization. The purpose is simple: cause as many deaths and destroy as much infrastructure as possible to get the message through that they are trying to send. And with the current protocols at shipping ports within the U.S., this scenario is not out of the realm of possibility. Since only a small percentage of cargo is even scanned, a nuclear weapon could easily make its way into the country. And even if it were detected, chances are it would be armed with some kind of device to prevent tampering, which would cause detonation of the weapon regardless. These startling possibilities, along with the recent

changes in the United States attitude towards national security in light of the terrorist attacks of September 11, 2001, have led to drastic changes in the way cargo is screened before it reaches U.S. soil.

2.0 H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007

On August 3, 2007, President George W. Bush signed into law H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007. The law aims to send more deferral aid to areas of the country that are higher risk terrorist targets, improve emergency communications, fight nuclear proliferation overseas, and most importantly, scan 100 percent of all air-borne and ship- borne cargo before entering the United States. The bill call for all air-borne cargo entering the United States to be inspected within 3 years, and all ship-borne cargo to be scanned within 5 years, with discretionary 2 year periods added by the Department of Homeland Security thereafter [9].

While H.R. 1 is a monumental law that will increase homeland security throughout the United States, it is not without its shortfalls and its doubters. Primarily, those who oppose the law say that it is simply not feasible to scan 100% of cargo before it enters the country without seriously disrupting the economy. The scanning of maritime cargo containers entering the U.S. through its seaports poses a serious security threat to national security. Changes are imperative to the current methods, and H.R. 1 aims to do this.

The bill sets concrete metrics as to what needs to be accomplished for cargo scanning. For air cargo, the bill calls for 35% to be scanned by the end of fiscal year 2007, 65% by the end of fiscal 2008, and 100% by the end of fiscal 2009. For oceangoing containers, the specifications depend on the country of origin. Countries that shipped more than 75,000 TEUs (twenty-foot equivalent units) in 2005 will have 100%

of their cargo scanned by the end of fiscal 2009. By 2012, all origin ports will have to comply with the law.

A highlight of the law is the requirement for scanning to be at the point of origin. This eliminates the danger of scanning for radiation once cargo reaches U.S. soil. Instead, the containers must be scanned prior to being loaded on a U.S. bound ship, eliminating the possibility of detonating a weapon remotely if it were discovered once in the U.S. While this is a highlight, it is also one of the most contested points of the law. The fiscal burden is being left up to the individual cities and countries that are currently involved in trade with the United States. This affects more than 600 ports around the world, many without the financial means to meet such criteria.

2.1 Obstacles of H.R. 1

While the objectives of the bill are beneficial in many ways to national security, there are numerous hurdles that must be overcome in order for this bill to be feasible. The reason for this paper is to examine each of these hurdles and provide an overall analysis on the feasibility of implementing the bill. There are a variety of economical, performance, and political factors that currently oppose the bill.

Although screening at the point of origin of the cargo will prevent nuclear devices from making it to American soil, it also presents a major problem. Any country that has a shipping tie with America, or would like to establish one in the future, must be able to fund the necessary technology in the home port. This could cost the shipping country both in upfront capital and in maintenance, as H.R. 1 budgets nothing for construction of these facilities in seaports abroad. The main opponent of the new law, the International

Cargo Security Council (ICSC) argues that it is simply not possible to implement such a system in each of the approximately 600 shipping ports worldwide [10].

Another major concern is the technology that will be used to scan containers. The current technology used to scan cargo is either a non-invasive imaging system, such as an X-ray system, or a radiation portal monitor. The radiation portal monitor detects energies of particles released by an isotope if a fissile material is detected. The current systems, however, produce a high percentage of false positives. These false positives do not currently contribute too much of a delay because of the low volume being scanned, but an increase in volume will lead to huge delays. X-ray system scanning is also time consuming, as they require a trained professional to view these images and determine any suspicious items in the container. Because of these shortfalls, the Department of Homeland Security's Domestic Nuclear Detection Office plans to award up to \$1.2 billion over the next five years to develop and acquire a next generation radiation monitor for land and sea cargo known as the advanced spectroscopic portals [11].

3.0 Developing Technologies

Between 2006 and 2008, the Department of Homeland Security's Department of Nuclear Detection Office planned to fund more than \$90 million in research of a next generation 3D cargo scanning device [12]. These contracts have the potential to reach into the billions of dollars in the next 10-15 years [12]. This initiative, entitled the Cargo Advanced Automated Radiography System (CAARS), is designed to automatically detect shielded enriched uranium or weapons-grade plutonium hidden in trucks, shipping containers, air cargo, and other conveyances. Various technologies and prototypes are currently being tested. The development of an automated system could prove to be crucial in scanning 100% of cargo entering the country because it will decrease operating costs and human error, leading to a more efficient method of inspection.

3.1 Nuclear Resonance Fluorescence Imaging

Passport Systems Inc., a company based in Billerica, Massachusetts, currently develops a system for scanning in conjunction with American Science and Engineering, Inc. that utilizes nuclear resonance fluorescence imaging (NRFI). NRFI is able to non-intrusively scan a region in space and measure the isotopic content of the matter contained in that space for any element with an atomic number greater than 2.

The process works by first accelerating photons to energies between 1.5 and 8 MeV. These photons are able to penetrate through the thick steel cargo containers and cannot be shielded by high-Z materials, such as lead [13]. The photons cause the isotopes it passes through to fluoresce, which release photons specific to the isotope. The fluorescent photons from the de-excitation of these states are detected using a back-angle,

segmented and collimated detector array thereby yielding the 3-D distribution of all isotopes in the cargo. The process is shown schematically below in Figure 1 [13].

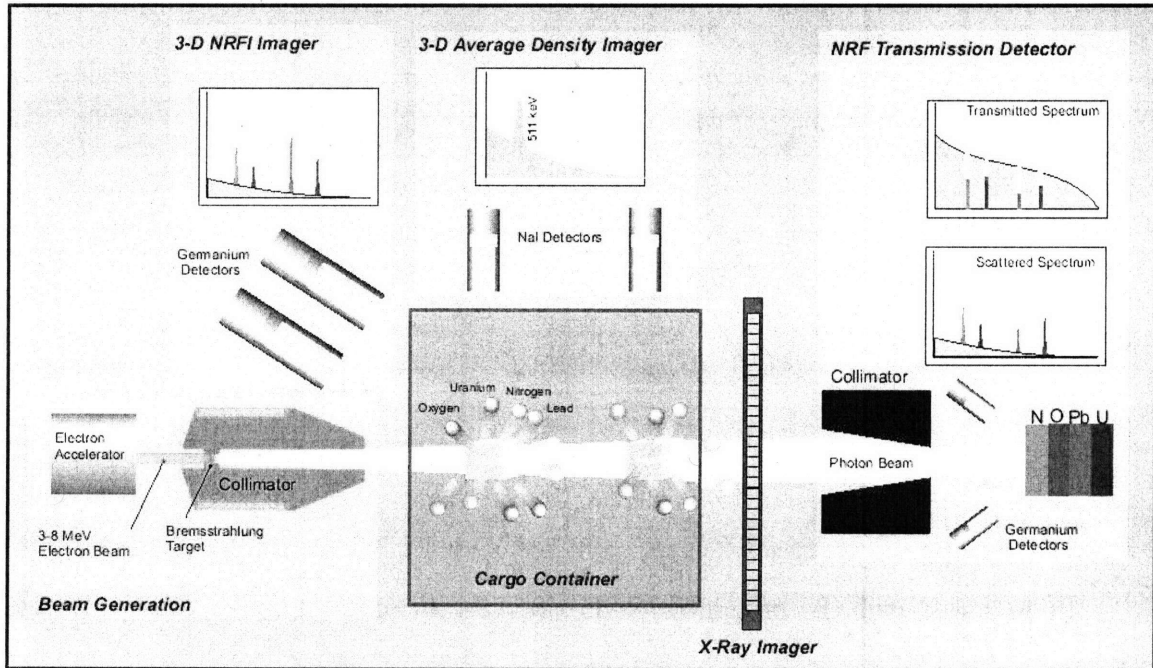


Figure 1: Schematic of Nuclear Resonance Fluorescence Imaging

NRFI is an attractive option because systems can be designed to involve minimal operator intervention, to minimize dose to the sample, and to provide high throughput at commercial seaports, airports and other entry points. Figure 2 is a sample of U-238 placed under an NRFI detector [13]. As you can see, it has 6 clear peaks that are well above background, allowing for the process to be automated more easily, leading to many of the benefits of the system.

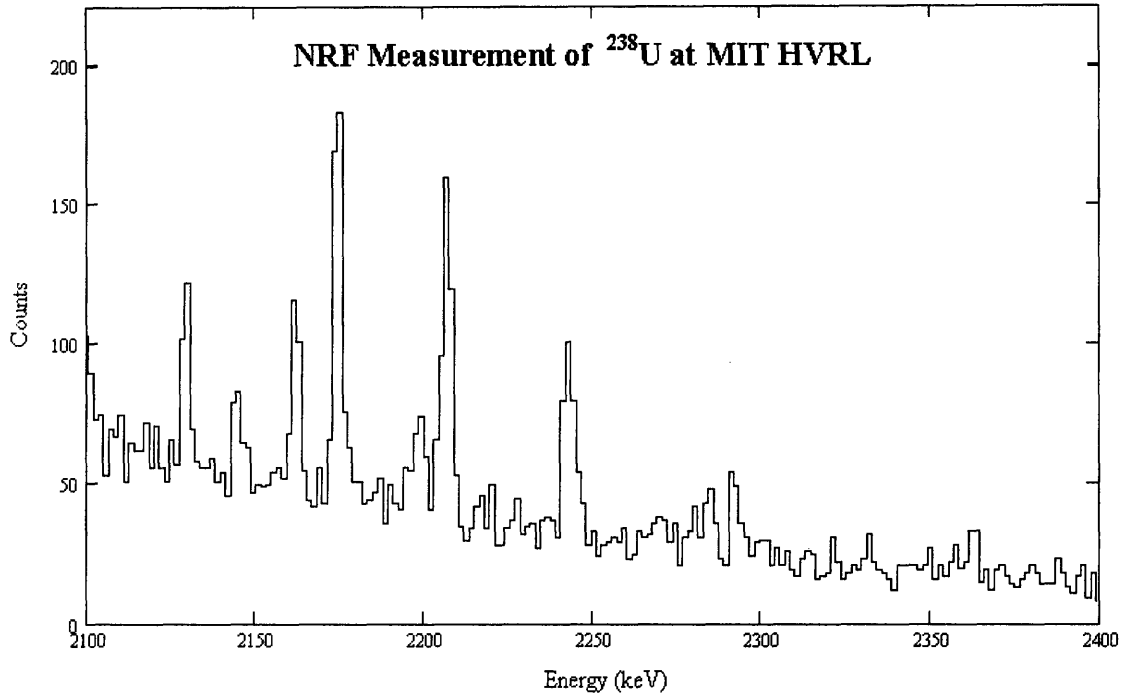


Figure 2: U-238 Measurement under NRFI

3.2 Dual-Energy X-Ray Signal Detection

L-3 Communications Security and Detection Systems division, based in Woburn, Massachusetts, is also a primary contractor for the next generation screening system. Their system uses dual-energy X-ray signal detection to scan large amounts of cargo. The basis of dual-energy scanning is that when the attenuation ratio is plotted against object thickness, different materials will show up on different curves. The total attenuation coefficients change with photon energy. Therefore, the detector signal will be attenuated differently by the same object at different source energies. By taking measurements using differing energies, it is possible to determine the material being scanned using these curves as references. Figure 3, shown below, shows an illustration of a dual-energy map. Each curve in the plot represents a different material [14].

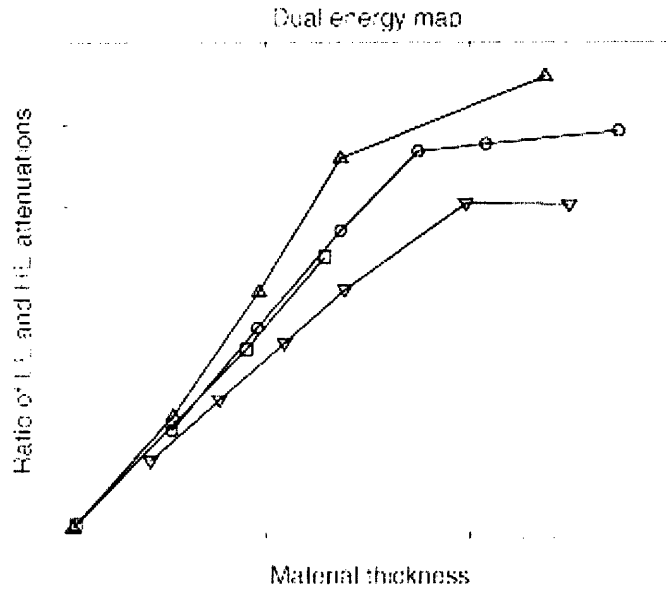


Figure 3: Illustration of a dual-energy map

Passport Systems, Inc., partnered with American Science and Engineering Corp, and L-3 Communications are both leading companies developing technologies that will certainly be needed for 100% scanning to be feasible. These are two of the more successful companies in developing new CAARS scanners, although there are many other technologies being developed for the same purpose.

4.0 Economic Analysis

One of the main concerns of scanning 100% cargo bound for the United States is that it will have a severe economic impact, and that it may be cost prohibitive for some ports. Without a doubt, the cost of scanning cargo will be handled by the shipping companies and passed onto the consumer. Whether this cost is significant will greatly impact the feasibility of scanning all cargo bound for the United States.

In this section, I will explore the economics involved with inspecting 100% of cargo. The combination of the initial investment in the system and the annual costs associated with maintaining the safety and security of the system will be taken into account. Because different sized ports' needs will vary in terms of equipment needed and costs, I will examine a hypothetical large, medium, and small port to show how each size port will be affected by the mandate.

In addition, the possible taxes imposed on each TEU will be examined, and how these taxes may affect the cost of goods in the United States. Taxes will vary with the size of the port, but for comparison reasons, an analysis will be done comparing a universal tax on each TEU, regardless of the size of the port.

Finally, an analysis will be done to determine if this mandate is cost prohibitive for smaller ports. Larger ports will be able to utilize economies of scale better than smaller ports, so it is clear that smaller ports will have a greater cost per scanned container. But the question remains whether this is cost prohibitive, and if it is, what can be done to ensure that these smaller ports can maintain trade with the United States.

4.1 Initial Costs

Every port involved with maritime trade with the United States is going to have to produce a significant initial investment into the technology necessary to scan 100% of U.S.-bound cargo exiting the port. For the purpose of this economic analysis, we will assume that newer technologies are used because it is projected that these will be necessary in order to maintain performance (although a performance analysis will also be done later).

The major initial costs will include the equipment, modifications and construction to accommodate the new equipment, establishing the necessary IT infrastructure to link operations with the United States, and various legal and miscellaneous fees associated with startup. These costs are all estimated to the best of my ability based on my research into prior publications on this matter. There are also three different scenarios presented: that for a major port, a medium sized port, and a smaller port. The parameters used are shown below:

- Major port: 750,000 TEUs exported annually to the United States
- Medium port: 400,000 TEUs exported annually to the United States
- Small port: 150,000 TEUs exported annually to the United States

Based on these numbers, I was able to estimate the number of scanners necessary for each scenario. A typical scanner is able to process approximately 40-60 containers per hour [15]. Going under the assumption that this operates 16 hours per day and 300 days per year at maximum efficiency, this is 192,000 containers scanned annually by a machine. This would mean that a major port would require 5 scanners in order to operate efficiently. In order to account for necessary maintenance to machines, I estimated that a major port would actually need 7 scanners to ensure operability at all times. By this same

logic, I estimated a medium port would necessitate 4 scanners and a small port would need 2 scanners. The price of each scanner is approximately \$500,000 [16].

Installation of these new machines will perhaps mean that the seaport premises will need to be reconfigured in some way to accommodate more machines. New rights of way will need to be established for trucks to haul containers through in order to be scanned for fissile material. Although this number is difficult to estimate because it varies so widely from port to port, I assigned construction and installation costs of \$15 million, \$10 million, and \$7 million to the major, medium, and small ports, respectively. These numbers should account for any construction that is necessary, and if anything, they tend to be on the liberal side of the estimation.

The new law requires that the U.S. Department of Homeland Security has real time access to a port's screening operations [9]. In the event of an alarm, officials in the U.S. will be notified and they will decide the steps to be taken from there. This network will require a network of computers set up over a secure connection from each port to the U.S. I have estimated these costs to be universal, regardless of port size, because each port will require a similar security system with only slight differences in the amount of physical computer equipment necessary. I have estimated these costs to be \$750,000 for each port.

Finally, the most ambiguous number in the estimation of initial investment is the various fees that will be necessary in the home country to establish these screening activities. These will include various legal fees, education and training programs for workers, possible settlements to local exporters to account for delays during construction, and any other miscellaneous expenses associated with installing the system. Again, this

estimation was universal to all ports because each port will have these fees upon installation of new scanning equipment. They were estimated to be \$2 million for each port.

The purpose of this study is to examine whether it is economically possible to implement 100% scanning at ports around the globe. Therefore, my estimates tend to be more liberal. In addition, I have included a 20% overhead section of the budget to account for any cost increases or unforeseen circumstances during construction. The initial costs are illustrated in Table 1 for all three scenarios described.

	Major Port	Medium Port	Small Port
Scanners	\$3,500,000.00	\$2,000,000.00	\$1,000,000.00
Modification/Construction of Port	\$15,000,000.00	\$10,000,000.00	\$7,000,000.00
Establishment of Information Network	\$750,000.00	\$750,000.00	\$750,000.00
Legal Fees/Misc.	\$2,000,000.00	\$2,000,000.00	\$2,000,000.00
Overhead (20%)	\$5,312,500.00	\$3,687,500.00	\$2,687,500.00
Total	\$26,562,500.00	\$18,437,500.00	\$13,437,500.00

Table 1: Initial investment for each port scenario

The percentage of the budget that each part consumes is fairly even for each scenario. However, as shown in Figure 4, it is clear that major ports will be able to take advantage of their size and absorb the universal costs easier than the smaller ports. By devoting a smaller percentage of their budget to these costs, they will be able to make up these initial costs quicker than smaller ports with taxes that they choose to impose on their exporters.

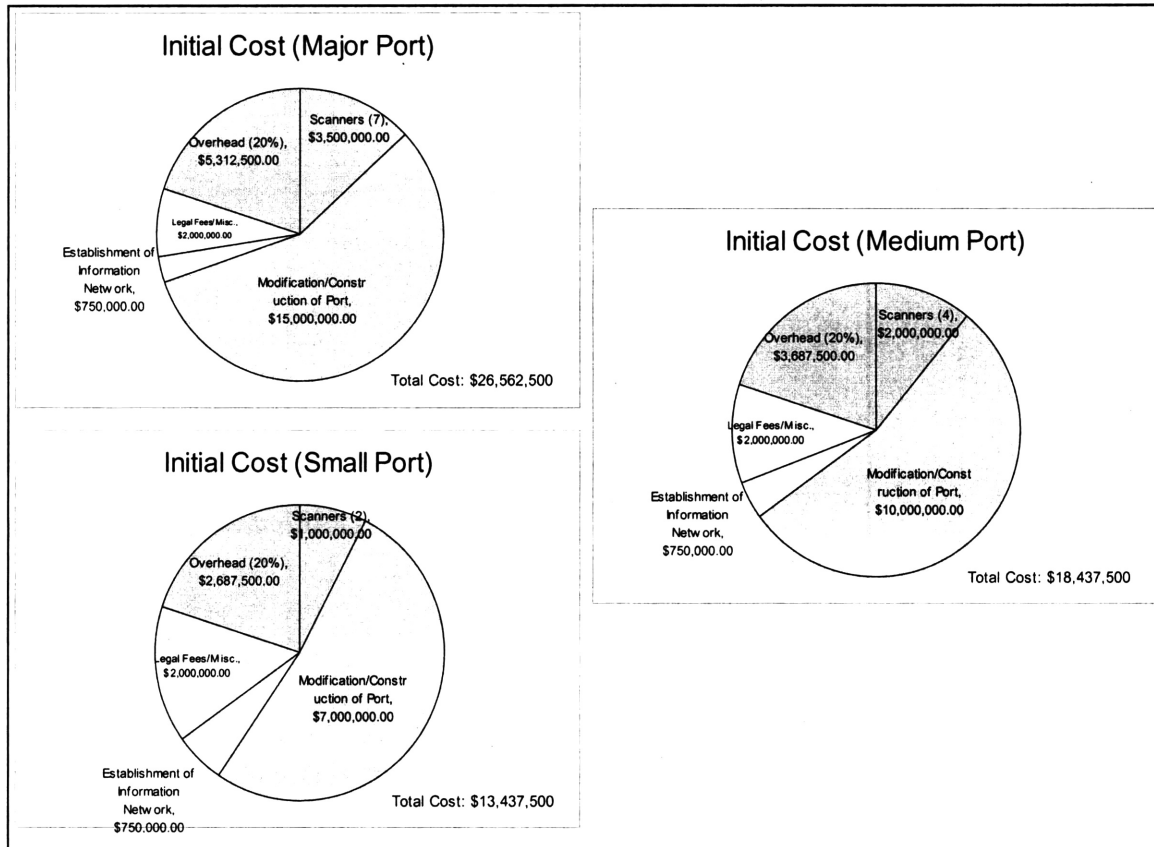


Figure 4: Percentage breakdown of initial costs for each port

4.2 Annual Costs

After the initial investment in the system, a port will incur yearly costs as well for things such as maintenance and wages. According to my research, these annual costs can match, or even exceed, the initial investment of the system. Estimates vary widely among sources, as some have estimated that \$100 million is needed annually to safely and securely screen all cargo [17]. I have itemized my estimates for each sized port, and again estimated liberally. The major annual costs consist of wages for workers, general maintenance to the facility and equipment, upgrades to equipment, data transmission and analysis, and legal fees. Again, I have incorporated a 20% overhead into my estimations to account for any unforeseen circumstances.

The greatest variance in costs for different sized ports was with the wages for workers. Workers are needed to operate the equipment, maintain the equipment, operate as security, and manage all other aspects of these new processes. Workers will be from the U.S. and the home country of the port; however it is implied in the law that the port will bear all of the costs associated with running the port. In order to determine the annual wages, I took into account the number of shifts per week that would be worked and the average salary and benefits of each worker. For a major port, this worked out to \$19,710,000 (225 shifts per week at \$30 per hour inclusive of salary and benefits). For a medium sized port, the annual wages will be \$11,826,000.00 (135 shifts per week), and for the small port, annual wages of \$6,570,000.00 (75 shifts per week).

General maintenance of the facility and upgrades to equipment are directly related to the amount of equipment at each port. Therefore, they are correlated accordingly. A major port is estimated to incur \$1 million in maintenance and \$1 million in upgrades yearly. A medium sized port is estimated to incur \$700,000 in maintenance and \$500,000 in upgrades yearly, and a small port is estimated to have \$500,000 in maintenance and \$250,000 in upgrades yearly. Upgrades include savings for future changes to better technologies, IT upgrades, and upgrades to infrastructure to increase throughput at the port. Maintenance covers typical maintenance to the equipment and the port area that the equipment is housed in.

Similar to the initial costs, legal expenses and data transmission and analysis are universal regardless of the size of the port. Legal expenses are expected to amount to \$2 million and data transmission and analysis to \$5 million annually. Data transmission and analysis are fairly expensive because there is the possibility that outside contractors will

need to be hired in order to perform data analysis both at the port and in the U.S. Legal expenses are expected to cover any disagreements with exporters who may be adversely affected by the law and any other miscellaneous expenses.

For comparison purposes, the annual costs associated with each port scenario are shown below in Table 2.

	Major Port	Medium Port	Small Port
General Maintenance	\$1,000,000.00	\$700,000.00	\$500,000.00
Wages	\$19,710,000.00	\$11,826,000.00	\$6,570,000.00
Upgrades	\$1,000,000.00	\$500,000.00	\$250,000.00
Data Transmission and Analysis	\$5,000,000.00	\$5,000,000.00	\$5,000,000.00
Legal/Misc. Fees	\$2,000,000.00	\$2,000,000.00	\$2,000,000.00
Overhead (20%)	\$5,742,000.00	\$4,005,200.00	\$2,864,000.00
Total	\$34,452,000.00	\$24,031,200.00	\$17,184,000.00

Table 2: Annual costs for each port scenario

Figure 5 shows the percentage breakdown for each of the three port scenarios. Much like the initial costs, the major ports are able to absorb the fixed costs (legal fees, networking, etc) easier than the smaller ports. They are then able to devote a larger portion of their budget to operational expenses, such as maintenance and wages.

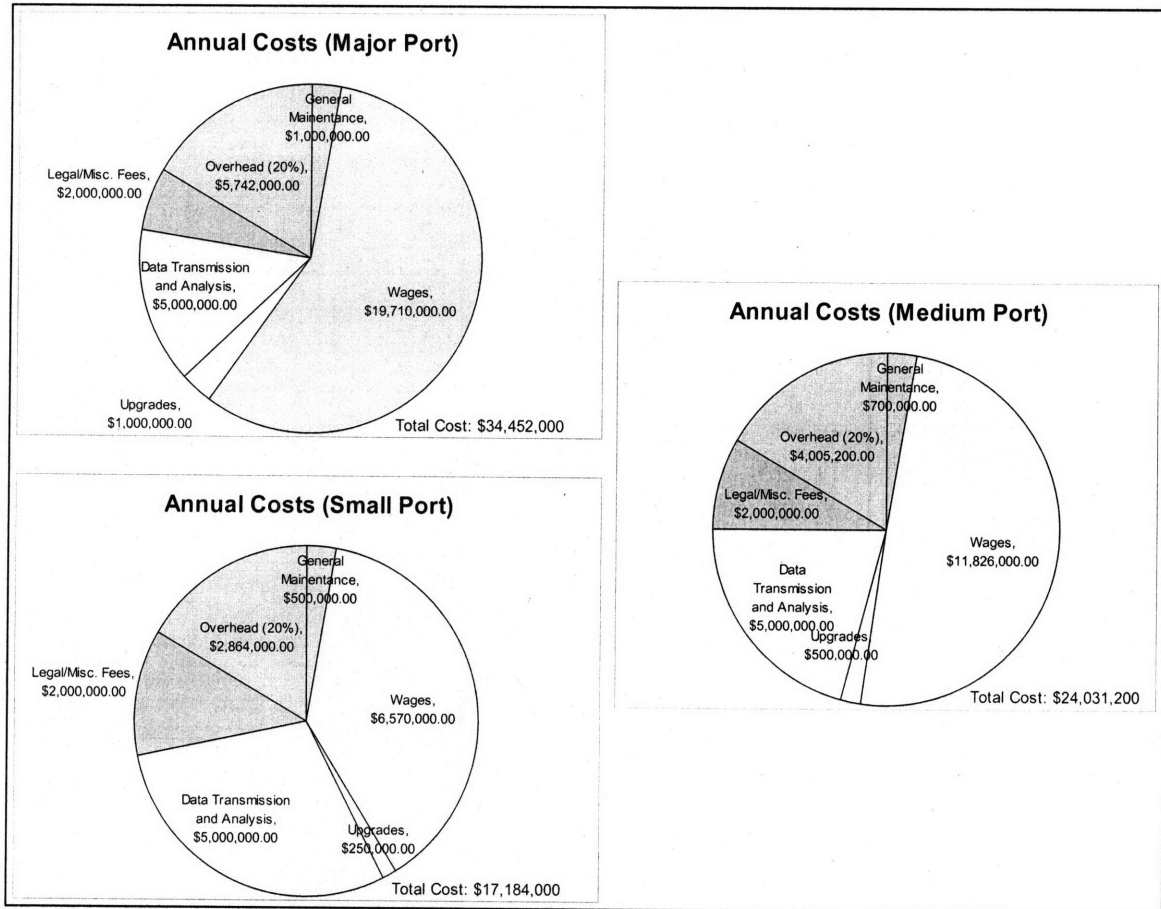


Figure 5: Percentage breakdown of annual costs for each port

4.3 Tax Analysis

Now that we have established the expected economic contribution from each port, the question still remains as to how this will be paid for. Larger ports may have the necessary capital to fund an initiative, but smaller ports would most likely be lacking the liquid capital to invest in and maintain this infrastructure. The most likely scenario for funding would be a tax imposed on each TEU that passes through a port bound for the U.S.

Many questions can be posed in this situation. For instance, would it be a universal tax imposed globally, or a tax imposed by the host port? By giving the host port the flexibility to collect the tax that they want, it would give them the ability to recoup their initial investment into the system in whatever number of years they wish to. However, if the tax were globally set, some ports would not be able to collect enough money to support their operations. The following analysis explores these questions and shows what level taxes could potentially be set at to ensure that every sized port examined would be able to maintain trade with the United States.

4.3.1 Varying Taxes Based on Port Size

In order to compare the three ports that we have examined, I am first going to calculate the tax that would be required for each port in order to recoup their initial investment within 10 years. Once the tax has been imposed for 10 years, and the initial investment recovered, the tax will go down on each TEU following the 10th year because it only needs to cover operating costs at this point. Table 3 illustrates the taxes for each sized ports that were calculated using the data in Tables 1 and 2:

	Major Port	Medium Port	Small Port
Initial 10 yr. Tax	\$49.48	\$64.69	\$123.52
Tax After 10 yrs.	\$45.94	\$60.08	\$114.56

Table 3: Schedule of Taxes on Each TEU

These taxes are certainly modest when compared to the average retail value of \$66,000 contained in every container [18]. However, it is clear that smaller ports are at a disadvantage because their tax would need to be almost 250% that of a major port. This again illustrates the point that smaller ports will have a more difficult time making this

law economically possible. This could even drive shippers away from smaller ports because of the higher taxes, crushing the economic infrastructure of areas around the world dependent on their maritime trade with the United States.

The data analyzed for the three port scenarios can be extrapolated to determine what kinds of taxes will be necessary for a port of a certain size. As stated earlier, I have defined a major port as shipping 750,000 TEUs annually, a medium port as shipping 400,000 TEUs annually, and a small port shipping 150,000 TEUs annually. But there are certainly ports out there that ship far less than 150,000 TEUs annually and far more than 750,000 TEUs annually. How are these ports affected by a possible tax? Figure 6 illustrates this below.

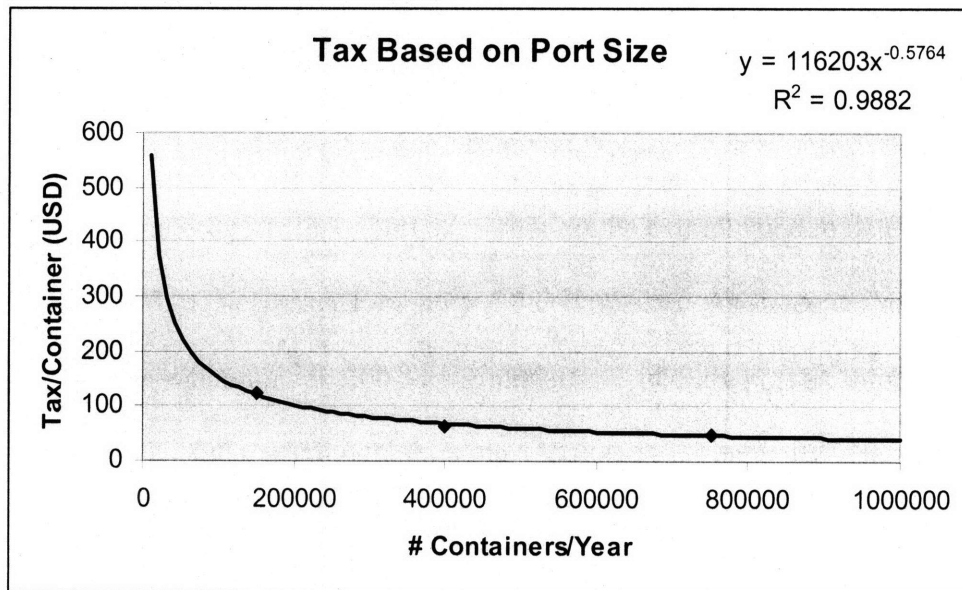


Figure 6: Tax based on number of containers shipped per year

Once the number of containers shipped annually extends past 750,000, the increase in tax per TEU shipped is very small. However, the interesting fact is that the tax grows exponentially as the number of containers per year decrease below 150,000. The power regression calculated here has an R^2 value of .9882, an extremely accurate fit.

The analysis shows that a very small port would have major difficulties maintaining shipping relations with the United States because they would have to impose taxes up to 10 times that of a major shipping port. Not only would this significantly affect the cost of goods exiting the port, but it could potentially drive shippers to larger ports because the cost of transporting a TEU via ground or rail may be less than that of the tax.

4.3.2 Effects on Cost of Goods

A main argument from opponents is that this law will cause the cost of goods to increase. Adding anywhere between \$50 and \$120 to the price of a container does not seem like it will cause a huge increase, however if we examine it from a retail versus wholesale point of view, an argument can be made. Assuming that there is a markup of 200% on goods [19], the average wholesale value in each container drops to \$22,000. Adding a tax of \$123.52 will mean an increase in wholesale price of 0.56%, and a possible increase to consumers of 1.68% (assuming the company includes the tax price when marking up the product for retail). However, there is room for argument here, as this is the extreme case for a smaller port. A larger port would only end up increasing cost of goods up to a maximum of 0.67%. There is also room for government regulation here on how much of this tax can be passed on to the end consumer. Regardless, an increase in cost of goods anywhere in this range will be noticed by consumers.

4.3.3 Universal Tax

Another possibility is to globally impose a tax on every TEU shipped out of a port worldwide. It is immediately clear that a system like this would favor the larger ports,

however the graphic representations below show just how much of an advantage a larger port has over smaller ports. Figure 7 shows the annual costs and revenue for a major port. At year 0, an initial investment of \$26,562,500 is shown, and every year after that, an annual debt of \$34,522,000 is added along with the tax revenues for each year. For this part, I used a tax of \$75 per TEU, which is in the middle of the range of \$50 to \$100 that has been quoted by proponents of the bill, including Rep. Ed Markey (D-MA), the sponsor of the bill [20].

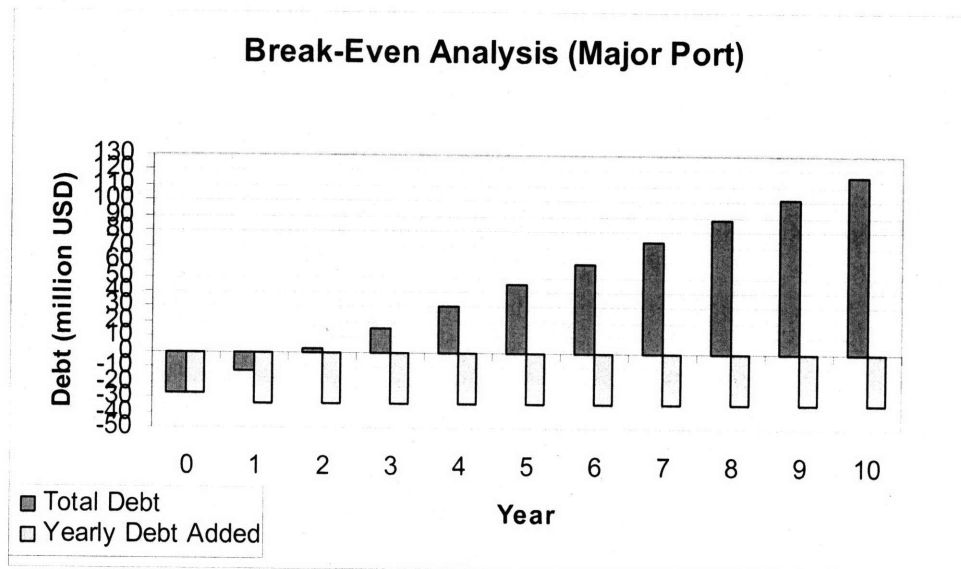


Figure 7: Timeline of debt repayment for major port

As you can see, the initial investment would be recouped between years 1 and 2, at which point the tax could be readjusted to \$45.94 (see Table 3) to only cover operating expenses. This gives major ports a serious advantage, as they would be able to offer shippers lower taxes sooner than medium and small ports, potentially drawing business away from these areas. The same analysis for a \$75 tax on a medium sized port is shown below.

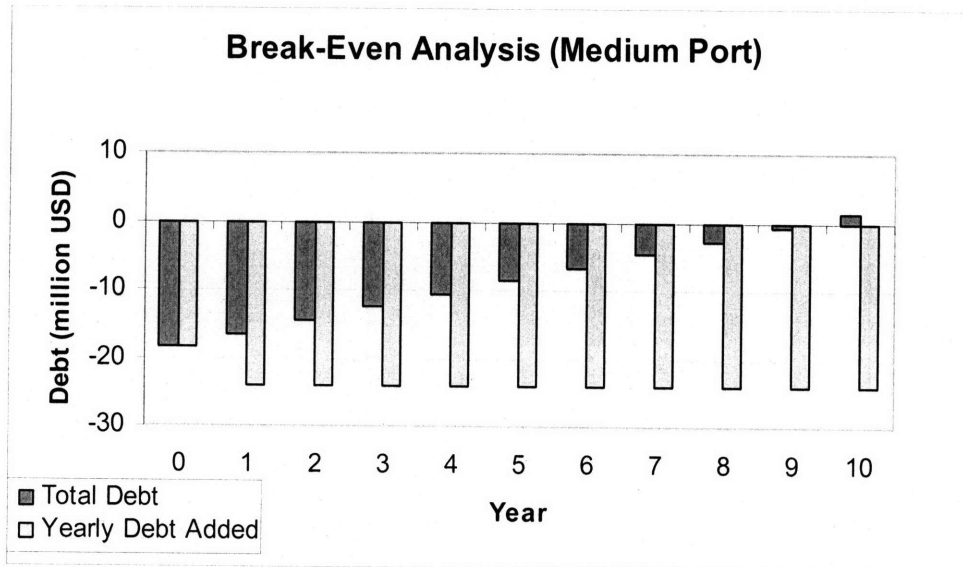


Figure 8: Timeline of debt repayment for a medium port.

A universal tax of \$75 would enable a port of this size to repay their initial investment in just over 9 years, at which point the tax could be reverted to \$60.08 to cover initial the operating expenses. Unfortunately, the same is not true for a smaller port. A \$75 tax on the medium and major ports is able to cover the operating expenses and some of the initial investment because of their large volume, but a smaller port would not even be able to cover operating expenses. The analysis is shown below in Figure 9.

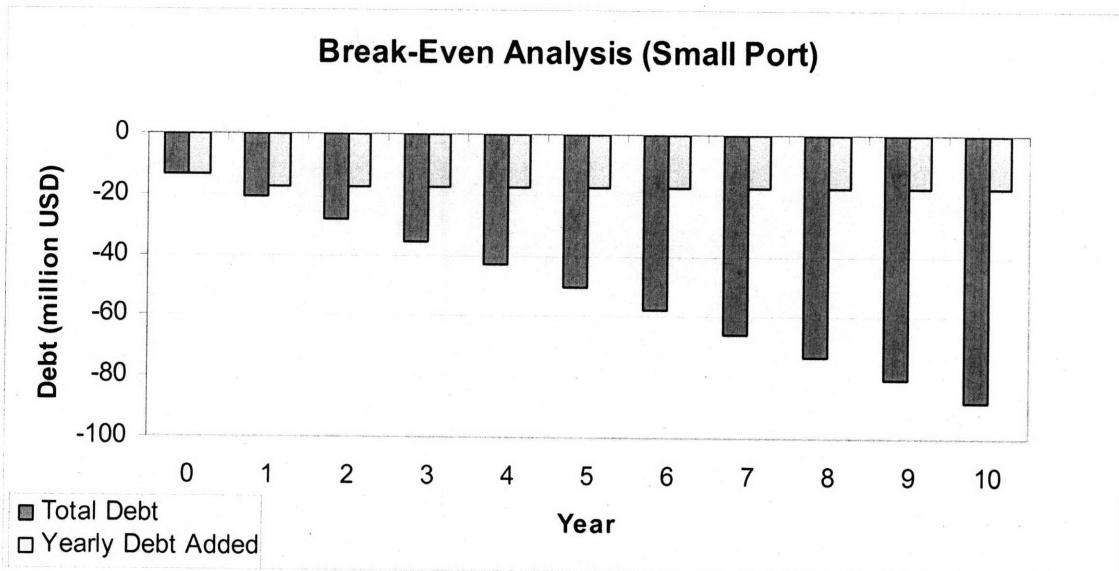


Figure 9: Timeline of debt repayment for a small port

The debt for a small port will only grow because the tax revenue from a \$75/TEU tax will not cover operating expenses. While the major port will be able to pay off their initial investment in less than 2 years with a \$75 tax, the small port will need to charge a tax of over \$120/TEU for 10 years in order to pay down their initial debt. This clearly puts the smaller ports in danger of losing business to larger ports, and it also raises the question of whether a small port would even be able to fund the technology and expenses necessary to scan 100% of the cargo leaving the country for the United States.

The likelihood of a global tax is unlikely for a variety of reasons, but mainly because it would be prohibitive of smaller ports staying operational. There is a much greater chance that each port will decide on a tax for their port based on their initial investment and how long they wish to recoup that investment. Figure 10 below shows, for each of the three scenarios, how many years it will take each sized port to recoup its initial investment based on the tax that it charges in \$10/TEU increments.

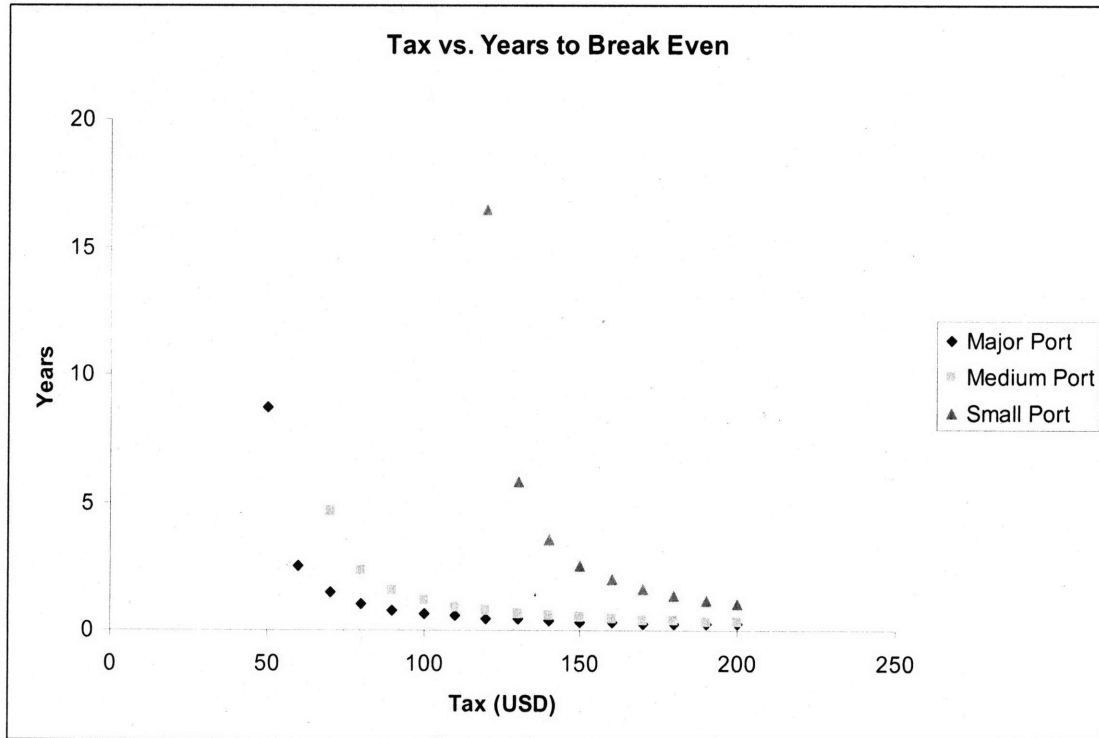


Figure 10: Years to recover initial investment based on tax

Each of the lines has an asymptote at the point where the operational expenses are greater than the tax revenues. Based on this graph, it is clear again that the major and medium sized ports have a sizeable advantage over the smaller ports because they will be able to recover their initial investment in a faster period with lower taxes. Using this graph, it is easy to determine the optimal tax based on how long the port wishes to have its initial investment recovered.

4.4 Economic Conclusion

Based on the economic analysis, one point is very clear: scanning 100% of cargo at the world's smaller ports will be very difficult economically. Not only will taxes be higher, but the period to recover their initial investment will be longer. This could potentially lead to shippers utilizing larger ports, especially for very small ports that ship

less than 150,000 TEUs to the United States annually. These ports will have taxes in excess of 10 times those of major ports, possibly making it more economically viable to transport cargo via rail or truck to larger ports in the vicinity of a smaller port.

Larger ports are able to utilize economies of scale much better than smaller ports. There are many expenses that will not vary based on the size of the port, including legal fees and network operations. These fees will be paid by every port regardless, and will obviously impact those ports with lower volume more than the larger ports.

The increase in the cost of goods to the consumer is also an area of debate. My analysis shows that the cost of goods could increase anywhere from 0.56% to 1.68%, although these estimates are on the higher extreme. This is only an expected average increase, because actual increases would vary widely depending on the good that is being shipped. This increase in the cost of goods could potentially be regulated by the government by preventing the cost of the tax from being passed onto the consumer, however this is unlikely, and an increase in cost of goods would most likely occur.

5.0 Performance Analysis

The second major issue that must be dealt with is the performance issues that will result from scanning 100% of the cargo prior to entering the U.S. The main issues deal with the backup that will be created from scanning millions more containers per year, and if that backup will have a significant effect on the flow of goods from international ports to the U.S. Aside from the actual time it takes to scan 100% of the containers, the time it takes to physically search any suspicious cargo will also attribute to the overall delay. After the economic issues previously discussed, the performance issues have the next most significant impact on the feasibility of 100% scanning of cargo.

This section will deal with two separate scenarios. The first scenario will be using the technology that is currently in use and available around the world. This scenario will be analyzed as if there are minimal changes to existing scanning equipment at ports. For all numbers that are calculated, a medium sized port will be used, which will assume shipment of 400,000 TEUs per year from the international port to the United States.

The second scenario will be a similar analysis with new equipment being used. This new equipment is currently in the developmental stages at various companies around the world. The economic analysis performed in the previous section was done with the assumption that this new equipment would need to be implemented in order to maintain the current throughput, and this analysis will examine this necessity deeper.

5.1 Current Technology without Upgrades

As impractical as the current system may be for 100% scanning, it needs to be examined in the case that purchasing new equipment is not economically feasible for a port. This section will examine how stepping up the number of cargo containers scanned will increase the throughput time, as well as how the increase in number of containers opened for a physical inspection will increase throughput time. This scenario will be examined for a port that processes 400,000 cargo containers annually to be shipped to the U.S.

5.1.1 False Positives

With the current technologies in place, approximately 6% of cargo containers are scanned, with 4% of those containers having to be opened and physically inspected [21]. The process of opening a container and performing a physical inspection can take hours to perform, depending on the materials that are being shipped within it. The process involves moving the cargo to a separate area to be inspected, unloading the cargo from the container, performing any kinds of scanning or tests deemed necessary, and repacking the container. This process can take hours [21] to complete and is difficult to estimate because times can vary by port and by what cargo is contained in the container. For instance, unpacking a container shipping a couple of automobiles will not take as long as unpacking a container with thousands of small, oddly shaped boxes.

For this analysis, I compared the current technologies capabilities of handling partial scanning (~6% of cargo) and complete scanning (100% of cargo). Table 4 below illustrates the amount of extra time added to throughput for each situation. I have estimated that the average time to unpack a container, search for contraband such as

fissile material, and repack it to be 3 hours. Also, the typical alarm rate for the current generation of cargo scanners is 4%, with approximately 1% of containers having some kind of contraband in them, although rarely a fissile device [22].

	Partial Scanning	Complete Scanning
Containers processed	400000	400000
Containers scanned	24000	400000
Containers opened	960	16000
Time to physically inspect (hrs)	3	3
Time added to throughput/year (hrs)	2880	48000

Table 4: Increased false positive time for current technology

It is clear that scanning 100% of cargo containers with current technologies will add a significant amount of time if no other adjustments are made. With only partial scanning, 2,880 hours are added onto throughput time annually. This is a manageable amount of time because it is only an average of less than 10 hours per day. This is easily achievable with only a few workers dedicated to this process. However, 100% scanning adds on a total of 48,000 hours annually, an average of 160 hours per day. Plain and simple, this is not possible without other adjustments to either decreasing the number of false positives or increasing the number of man hours being devoted towards physical inspection.

The workforce would need to increase by 1600% in order to maintain the current level of throughput, and the total space devoted to physical inspection would need to increase tremendously. At many ports, there is simply not enough room to accommodate these extra inspections without a serious overhaul to the port, which would probably be cost prohibitive.

5.1.2 Increase in Scanning Time

In addition to false positives causing backups at ports, the actual time it takes to scan hundreds of thousands of additional cargo containers annually will contribute to the increase in delays of throughput. Many of the current technologies are designed to process only 6-10 containers per hour [22], which may not be adequate for complete scanning of cargo. This section of the analysis will show how the current technologies, with no amendments made at ports, would handle the requirements set forth by the new law.

Based on the assumption liberal assumption that 10 containers can be scanned per hour, a port would be able to scan a maximum of 48,000 containers per year if they were to operate 300 days per year, 16 hours per day. Therefore, one active scanner would be sufficient for partial scanning at a port. Tables 5 below shows the delays added to throughput times for the current technologies in the current setup for partial (~6%) scanning and complete (100%) scanning.

	Partial Scanning	Complete Scanning
Containers processed	400000	400000
Containers scanned	24000	400000
Time to scan 1 container (min)	6	6
Time added to throughput/year (hrs)	2400	40000

Table 5: Increased scanning time for current technology

As this data shows, there is a significant amount of time added per year for scanning all cargo exiting a country for the United States. Currently, by scanning approximately 6%, there is 2,400 hours added to the throughput of containers annually. This works out to approximately 8 hours per day of scanning (assuming 300 work days per year). However, complete scanning would require a total of 40,000 additional hours per year of scanning, or over 130 hours per day of screening. Again, this is not possible

without other modifications to the port. Even if we were to take into consideration that a port of this size would most likely have two or more scanners on site in case of a malfunction, this still leave an extra 65 hours per day that need to be fit into a 24 hour day. Without increased throughputs of machines, more workers, or more machines, 100% scanning is not feasible.

5.1.3 Conclusion for Current Technologies

Figure 11 below puts these delays into perspective. Partial scanning only creates total delays of 5,280 hours per year. However, scanning 100% of cargo with the currently available technologies with no changes to the current port setups would cause 88,000 hours of delays over the year, or almost 300 hours per day. Clearly, this is not feasible.

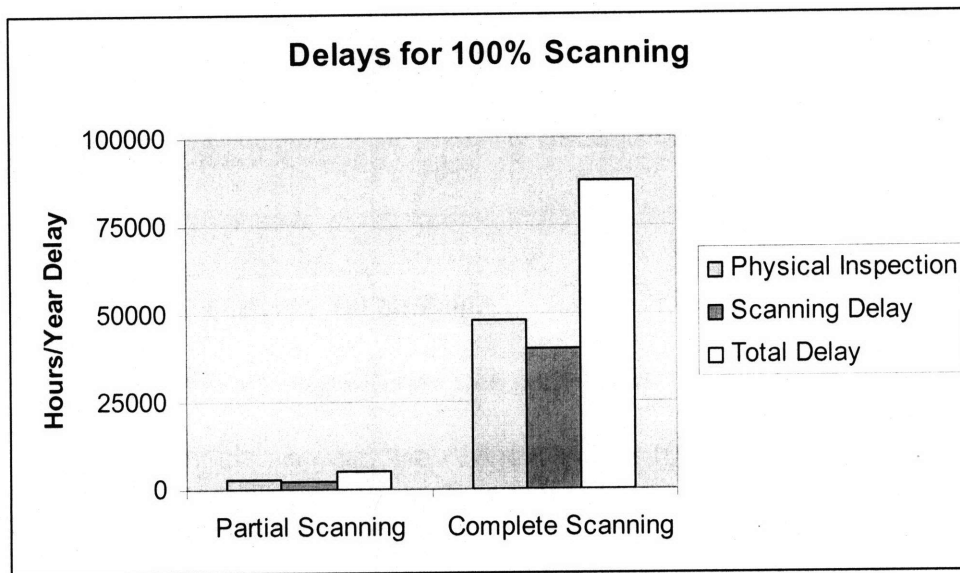


Figure 11: Graphical representation of delays for scanning with current equipment

Without a major upgrade to the technologies used or the number of scanners used, there is no possible way for 100% cargo to be scanned at a port prior to being shipped to

the United States. The most logical steps to rectify this would be to upgrade to a system that provides faster throughput, or to increase the number of scanners and the number of workers performing the scanning and searches.

5.2 Developing Technologies

New and developing technologies have the possibility of increasing both the efficiency and speed of cargo scanning. By combining fewer false positives with a greater throughput, scanning 100% of the cargo bound for the United States may actually be feasible. This section of the analysis will examine how feasible it would be with the upgrades that were mentioned in the previous economic section.

5.2.1 False Positives

Based on testing and specifications of scanners in development, government officials believe that the total number of containers flagged for a physical inspection will drop from 821,000 per year to 15,000 per year with new systems [16]. This is a decrease of over 5600%, meaning that there will be a serious decrease in time spent unloading and reloading cargo containers that must be physically inspected.

Current generation scanners often alarm when there is no need for alarm. For instance, kitty litter and granite emit low levels of radiation, which can alarm a radiation sensor, while pesticides can be mistaken for explosives and cause alarms in explosive detectors [23]. Next generation detectors are able to differentiate between real threats and innocuous items to lower the false positive rate, and therefore increase the throughput.

By taking the alarm rate as .1% [24] (as opposed to the 4% for current technologies), we are able to analyze and estimate the amount of time that will be added by scanning 100% of cargo. Table 6 shows the current technology scanners and their delay as a result of alarms for partial scanning against the next generation scanners and their delay as a result of alarms for complete scanning.

	Partial Scanning (current technology)	Complete Scanning (new technology)
Containers processed	400000	400000
Containers scanned	24000	400000
Containers opened	960	280
Time to physically inspect (hrs)	3	3
Time added to throughput/year (hrs)	2880	840

Table 6: False positive scanning time change for developing technology

It is clear to see that an investment in new technology will make the time needed for physical inspection insignificant. This is the result of the highly efficient technology that could be deployed to these ports to scan. This new technology would actually lead to a decrease in the amount of time needed necessary to physically inspect any containers that cause an alarm.

What is not illustrated in this diagram would be the potential increase in necessary workers to perform the scanning. This is, however, incorporated into the economic analysis section. With an increase in volume of cargo, there will be a necessary increase in labor to adequately handle this cargo.

5.2.2 Throughput times

Since scanning of every cargo container bound for the U.S. means a huge increase in volume, the biggest issue with performance is going to be the delays that result from scanning millions more containers annually. At a port that ships 400,000 containers to the U.S. annually, 376,000 more containers will need to be scanned annually. This could present a potentially significant backup.

Scanning technologies currently in development will have the capacity to scan 40-60 containers per hour, with the potential for even more [22]. Already this represents almost a tenfold increase in the throughput of the current systems in place. For the purpose of this analysis, I will assume that the throughput is 40 containers per hour at a port that is run for 16 hours per day, 300 days per year. Table 7 below shows the current technology used for partial scanning against developing technology that could be used for complete scanning.

	Partial Scanning	Complete Scanning
Containers processed	400000	400000
Containers scanned	24000	400000
Time to scan 1 container (min)	6	1.5
Time added to throughput/year (hrs)	2400	10000

Table 7: Increased scanning time for developing technology

However, the economic analysis in the previous section calls for four of the new scanners to be on site at any time, with the idea that two will always function and two will serve as backups in the case of malfunctions or in during the busiest times for the port. Therefore, by having two scanners operating at all times, the total time added annually would only be 5,000 hours, as opposed to 2,400 for the previous technology. This amounts to only about 16.5 hours added daily for this given port. The backup scanners can also serve to alleviate delays and backups that may occur during busy hours or periods during the year.

5.2.3 Conclusion for Developing Technologies

If a port were to invest in this developing scanning technology, it is clear that the delays would be far less significant than if they tried to maintain their current equipment to scan 100% of the cargo containers to the U.S. But how do these delays compare with the delays that the industry already works with, where 6% of cargo containers are scanned? Figure 12 below shows this relationship, under the assumption that two of the new scanners are used at this particular port.

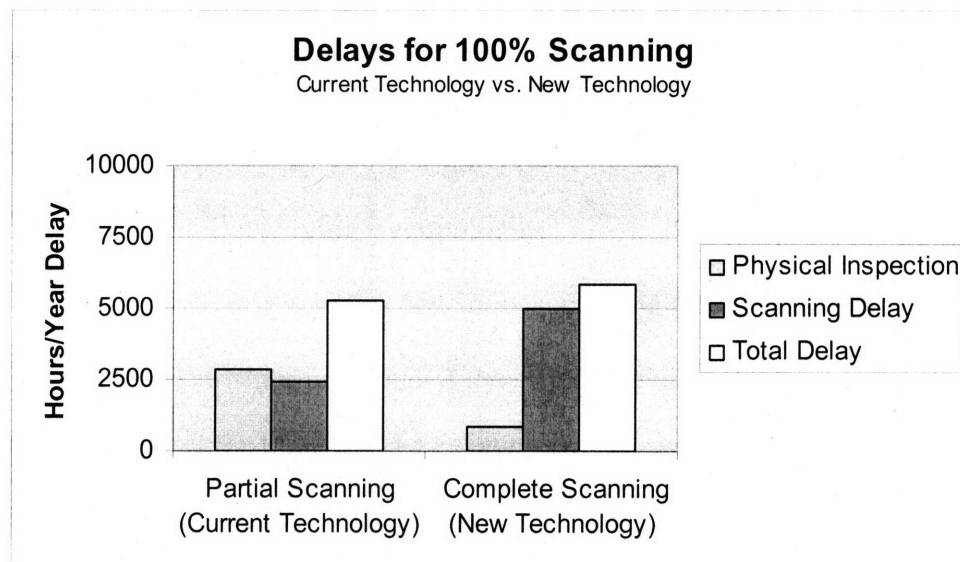


Figure 12: Graphical representation of delays for scanning with developing equipment

The new technology would only require 5,840 hours per year of time in addition to unloading the cargo off of the ships and onto their next mode of transportation. This is in comparison to 5,280 hours per year with the current system, meaning that there is only a need for an increase of 560 hours per year total. These hours can be made up with increased labor, longer hours, or machines with faster throughput.

5.3 Performance Analysis Conclusion

The analysis clearly shows that 100% scanning is not feasible if the technology is not upgraded. Without updating the technology, there would be an increase of 88,000 hours annually for the port discussed in this scenario, and there simply aren't enough hours in the day to accommodate that.

On the other hand, an investment into developing technologies that are capable of scanning at least 40 containers per hour would be feasible when it comes to maintaining performance. There would be a negligible increase in hours delayed from the current system in place (540 hours annually). The issues now are whether an upgrade in equipment is feasible for a specific port. More space will be needed to house the new equipment, significantly more workers will be needed to maintain and operate the equipment, and major capital will be needed to install and maintain the systems. If a specific port is equipped to handle these issues, then performance should not suffer when switching to scanning 100% of cargo bound for the United States.

6.0 Logistical Analysis

According to the economic and performance analyses, it is feasible for ports under certain circumstances to completely scan container cargo before it enters the U.S. However, there are a variety of political and logistical problems that vary widely from port to port that have a chance of preventing this law from being enforced. This section will discuss the problems that the United States government will need to confront before there is a real possibility of having all cargo screened before reaching a U.S. port.

6.1 Funding

The Congressional Budget Office estimates that implementing H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007 would result in new discretionary spending of \$21 billion between 2007 and 2012. However, none of this funding has been allocated to fund the scanning systems at foreign ports [9]. Regardless of the economics involved, this is sure to be met with opposition by foreign governments and foreign ports alike.

The economic analysis done previously showed that it will take a minimal investment from a port to establish the necessary technology to completely scan cargo bound to the United States, and it would take a similar annual cost to maintain the systems. Although this could be covered by minimal taxes to shippers, foreign ports may lack to liquid assets to initially fund the systems or may be hesitant to front a large sum for something that does little to directly support their economy. If a nuclear weapon were to detonate in the United States, the country that it originated from would suffer severe ramifications, both politically and economically. Trade relations would be severed with

the U.S. and many of its allies, and there would be the potential for retaliation from the United States. Although it may seem like a small price to pay to prevent this, some foreign governments may be hesitant to support this investment.

A potential solution for both sides would be for the U.S. government to provide low or no interest loans to the ports for their initial funding. This way, the burden of investing tens of millions of dollars at once is eased, and the investment can be paid back over a period of decades. This would also be beneficial to the U.S. government because they would have more oversight as to the equipment and technology that is used, and they would possibly lower taxes to shippers, which would then keep the price of goods from increasing in the United States.

6.2 Foreign Retaliation

The possibility of retaliation by foreign governments also exists. They may begin to impose similar laws, where all goods imported into their country would need to be scanned prior to leaving the home port. This would be particularly detrimental to the United States because of the number of major ports that are located on the coasts. Each port would need to make similar investments in the technology necessary to completely screen cargo.

There are 83 seaports in the United States [25]. If each of these seaports were required to make an investment into this technology, that would be over \$1.6 billion (assuming an average investment of \$20 million per seaport). In addition, this would require over \$2 billion annually operating and maintaining the new equipment. Although

these amounts could be recouped through taxes, the initial investment from seaports would possibly be felt throughout the local economy.

Retaliation may just be inevitable for the United States. If the government expects other countries to invest in scanning equipment for all cargo bound for the United States, then they must be prepared for the same. The government could either financially support the new technology and operation needed at ports, or provide them with interest free loans for the initial investment, much like what was proposed for foreign ports. This would allow ports to tax shipments over decades to recover their investments, meaning that the end consumer, both locally and abroad, would feel the increase less.

6.3 Maintenance and Operations of Ports

Finally, I will discuss the difficulties that remain when it comes to the actual logistics of running and maintaining the port. The bill is very ambiguous when it comes to whose responsibility it is to maintain and operate these improved scanning areas at international ports. The questions that are raised here are who is responsible for hiring, training, and maintaining qualified workers to perform the scanning and inspection duties? Also, what metrics will be established that each port will have to meet? Will there be a required throughput that will need to be met at all ports in order to maintain the flow of goods to the country? And finally, who has the final say in decisions made at the port?

Branches of the U.S. government will certainly have oversight authority on all ports. However, at a major port, a significant amount of workers will be needed to maintain operations, and it is more economically feasible to hire workers from the port

country in order to keep costs down. The most successful scenario would probably be an “outsourcing” type of operation, where almost all positions, from laborer to management, are given to the port, with the U.S. government providing oversight to the port. This is also more feasible because it would be needlessly difficult to hire thousands of U.S. workers to work internationally at these ports where the same quality of worker can be obtained domestically.

The lack of metrics may also lead to problems in implementing the bill. Without some kind of set of parameters to make sure that throughput is not being affected at ports around the world, ports are free to use any technologies that they wish with varying throughput times and as a result, varying delay times. This could be detrimental to the U.S. economy as it could cause shortages of goods if the trade flow is disrupted. On the other hand, the United States has no authority in foreign ports, and cannot legally enforce any kind of throughput parameters for ports. Another issue would be with establishing what technologies are satisfactory for completely scanning container cargo. There are a variety of different technologies and companies that produce scanners around the world, all with different advantages and disadvantages. The U.S. government will need to examine each of these technologies and determine which are acceptable for scanning cargo, taking into account throughput times and costs among other factors. A possible solution to these problems would be penalties imposed by the U.S. on home countries of the ports based on performance at the ports. These penalties would ideally encourage ports to invest in technology that is sufficient for scanning at that particular port and will not cause any significant delay times.

Finally, the issue that is likely to cause the most problems is who has the final say over the running of these scanners. Since it is a U.S. law, the United States government will want the final say. Their argument is that the cargo is entering the U.S., and the mandate is a U.S. law, therefore they should have total oversight of the operations and retain all decision-making rights. The ports and host countries, however, certainly will disagree with this. The scanners will be in these countries, and these countries will resist any kind of U.S. governance on their soil. However, the U.S. must maintain oversight in this process. Without this oversight, there is no way that the law can be enforced effectively. Again, it could threaten and enforce penalties against these ports if they refuse to comply with U.S. oversight at the ports.

7.0 Conclusion

Smuggling a nuclear weapon into the United States is a very real possibility. For today's transnational terrorists, a nuclear strike would cripple the United States' infrastructure in every way possible: physically, economically, and politically. According to a 2003 study done by ABT Associates, a nuclear strike could potentially kill over 1 million people and cause trillions of dollars in damage [17]. Despite this, there are still vulnerabilities in the security of the United States that make this scenario a possibility. The weakest point of security, and the point that a nuclear weapon would most likely be channeled through, is our nation's maritime trade with foreign countries. Currently, approximately 6% of cargo containers entering the United States are scanned for contraband, including fissile material. The remaining 94% go uncontested across our borders and into our country.

In August of 2007, President George W. Bush signed into law H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007, which mandates the scanning of 100% of cargo before leaving international ports bound for the United States by 2012. This law is a huge step in increasing homeland security; however serious issues have been raised over the feasibility of implementing this law.

Economically, major ports are more likely to be able to absorb the initial investments and operating costs than smaller ports. I have projected that a major port will require a \$26,562,500 investment, with annual operating and maintenance costs of \$34,452,000. On the other hand, a small port will require a \$13,437,500 initial investment with annual costs of \$17,184,000. Assuming that the costs will be passed onto the shippers, this leads to tax of approximately \$49.48 for a major port for every

TEU shipped, and a tax of \$123.52 for a small port. As the volume of containers shipped to the United States decreases, the tax per TEU increases exponentially, and will eventually become cost prohibitive.

Another major issue is how the increased volume will cause more delays in the shipping chains. By not upgrading the current equipment used for scanning at ports, a port with a volume of 400,000 containers shipped annually to the United States will incur more than 80,000 hours of delays per year. This delay is not feasible, as it amounts to more than 24 hours per day. Therefore, in order for a port to handle the increased volume of scanning, it must upgrade to new equipment or increase equipment and manpower drastically. By upgrading to next generation scanners, a port would be able to increase throughput tenfold, and incur delays of only 560 hours per year greater than the delays from the current technologies. By making the investments laid out in the economic analysis, a port would easily be able to accommodate complete scanning of cargo in a timely manner.

The United States government must maintain control over these foreign port operations. Without proper oversight, it is possible for the level of security to deteriorate. Parameters and guidelines need to be set forth and enforced by the U.S. government in order for this law to have any impact on the safety of American citizens. To aid in the installment of these systems, the United States government should make available low interest or interest free loans to these countries in order to encourage development of safer ports and minimize costs to shippers and end consumers.

While this law is a huge step in keeping American citizen's safe, it is a very complicated process to enforce. Initially, the law should be applied to only the highest

risk ports. Countries with known terrorist connections and access to fissile materials should be of particular interest initially because these are the most likely areas that a nuclear weapon could potentially originate from. Economically, 100% scanning is far more feasible in larger ports. Ports that ship less than 150,000 containers annually to the United States are unlikely to have the capital to invest in new technologies or the means of supporting their operation without cost prohibitive taxes. The United States government will need to take a closer look in the coming years as to how to rectify this problem, although the most likely scenario would be some kind of subsidy to these smaller ports. For ports that ship larger volumes of cargo, the most significant barriers for this law are the political and logistical barriers that must be overcome between the host country and the United States. If these can be overcome, then the scanning of 100% of cargo containers at these ports is feasible with the technology that is currently being developed.

7.0 References

- [1] Gallagher, Shawn P. (2005). A system for the detection of concealed nuclear weapons and fissile material aboard cargo cotainerships. Unpublished master's thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.
- [2] Spencer, Alexander (2006). Questioning the Concept of 'New Terrorism.' [Electronic Version]. Peace Conflict & Development, Issue 8, January 2006.
- [3] Broderick, Brett P. (2004). Systems-based analysis of a ship borne approach for the detection of fissile material concealed in cargo containers. Unpublished master's thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.
- [4] U.S. National Commission on Terrorist Attacks upon the United States. "Overview of the Enemy," Staff Statement No. 15, c. June 2004, p. 12. Available at [http://www.9-11commission.gov/hearings/hearing12/staff_statement_15.pdf].
- [5] Albright, David & Higgins, Holly (2003). A bomb for the Ummah. Bulletin for the Atomic Sciences, March/April 2003. Available at [<http://www.thebulletin.org/issues/2003/ma03/ma03albright.html>].
- [6] Khan 'gave N Korea centrifuges.' (25 August 2005). BBC News. Retrieved March 2, 2008. Available at [http://news.bbc.co.uk/1/hi/world/south_asia/4180286.stm].
- [7] Fetter, Steve, Frolov, Valery A., Prilutsky, Oleg F., & Sagdeev, Roald Z. (1990). Detecting Nuclear Warheads. [Electronic Version]. Science & Global Security, 1990, Volume 1, pp 224-302.
- [8] Vessel Calls at U.S. & World Ports 2005. Retrieved March 3. 2008. Available at [<http://www.marad.dot.gov/marad%5Fstatistics/2005%20STATISTICS/Vessel%20Calls%20at%20U%20S%20&%20World%20Ports%202005.pdf>].

- [9] H.R. 1: Implementing Recommendations of the 9/11 Commission Act of 2007. House Resolution 1, 108th Congress, 1st Sess. (2007)
- [10] Opposition Gathers to H.R. 1 Security Regulations. (February 2007). Logistics Today, February, 2007, pg. 14.
- [11] New port-screening requirement divides D.C. (23 Aug 2007). MSNBC News. Available at [<http://www.msnbc.msn.com/id/20413112/from/ET>]
- [12] DHS Exhibit 300 Public Release BY08 / DNDO – Cargo Advanced Automated Radiography System (CAARS) – Active Radiography Detection Systems (2008). 12 Feb 2007. Available at [<http://www.dhs.gov/xlibrary/assets/mgmt/e300-dndo-caars2008.pdf>]
- [13] Bertozzi, William & Ledoux, Robert J. Nuclear Resonance Fluorescence Imaging in Non-Intrusive Cargo Inspection. Available at [http://www.passportsystems.com/pr/CAARI_Presentation.pdf]
- [14] Chen, Gongyin, Bennett, Gordon & Peticone, David (2007). Dual-energy X-ray radiography for automatic high-Z material detection. Nineteenth International Conference on The Application of Accelerators in Research and Industry. April 20-25, 2006. Fort Worth, Texas, USA.
- [15] Omniview Gantry Inspection System Multi-View, High Energy Cargo and Vehicle Inspection System. Retrieved 11 March 2008. Available at [http://www.as-e.com/products_solutions/omniview_gantry.asp].
- [16] Fox, Jon (2006, July 17). DHS plans new nuclear detectors at port. Global Security Newswire. Retrieved 11 March 2008. Available at [<http://www.govexec.com/dailyfed/0706/071706gsn1.htm>].

- [17] ABT Associates, "The Economic Impact of Nuclear Terrorist Attacks on Freight Transport Systems in an Age of Seaport Vulnerability," executive summary, April 30, 2003, p. 7, [http://www.abtassociates.com/reports/ES-Economic_Impact_of_Nuclear_Terrorist_Attacks.pdf].
- [18] Law orders all cargo screened. Associated Press. Retrieved 12 March 2008. Available at [<http://www.heraldnet.com/article/20070824/NEWS02/108240070/-1/headlines2>].
- [19] Internal Revenue Service, United States Department of the Treasury (2005). Retail Industry ATG - Chapter 4: Examination Techniques for the Food and Beverages Industries (Mobile Food Vendors). Retrieved March 15, 2007. Available at [<http://www.irs.gov/businesses/small/article/0,,id=141485,00.html>].
- [20] Congressman Ed Markey Official Homepage January 9, 2007 -HOUSE PASSES MARKEY MEASURES TO SCREEN 100% OF AIR AND SHIP CARGO IN 9/11 BILL. Retrieved 14 March 2008. Available at [http://markey.house.gov/index.php?option=com_content&task=view&id=2515&Itemid=141#].
- [21] Gillett, Nick. Tradeoffs when selecting a cargo X-ray system. Port Technology International.
- [22] L-3 Communications (2007), Cargo Security Systems. Product line Brochure.
- [23] The MITRE Corporation. Uncommon Sensors May Help Secure Our Ports and Borders. October 2007. Retrieved April 5, 2008. Available at [http://www.mitre.org/news/digest/advanced_research/10_07/a_sensors.html].
- [24] Robinson, Sean M., et al. (2006). A Simulation Framework for Evaluating

Detector Performance in Cargo Screening Applications. 2006 IEEE Nuclear Science Symposium Conference Record (307-313). 29 Oct – 4 Nov 2006. San Diego, California.

[25] AAPA Port Profiles (2007). Retrieved 28 Apr 2008. Available at
[http://www.aapadirectory.com/portprofiles_list.cgi?region=US]