

The economics of cargo screening

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Introduction

For centuries, nations engaged in trade with other countries have needed to inspect incoming cargo, primarily to collect duties and to ensure that undesirable and illegal cargo is excluded from import. The techniques and technology, primarily manual inspection guided by intelligence, evolved little until the use of X-rays in the early 20th Century. X-rays allowed a look inside the container and provided a picture for comparison with declared contents. Exactly how the images are used depends on the country and the screening scenario but commonly, they are used to clear cargo and to refer any cargo with image anomalies for secondary screening.

A country may undertake intensive screening of cargo for many reasons. The type of screening, and techniques used, often depend on the perceived benefit. This paper discusses some of the benefits and estimates the costs of screening cargo with X-rays, and recommends processes that can yield the highest benefit to cost ratio.

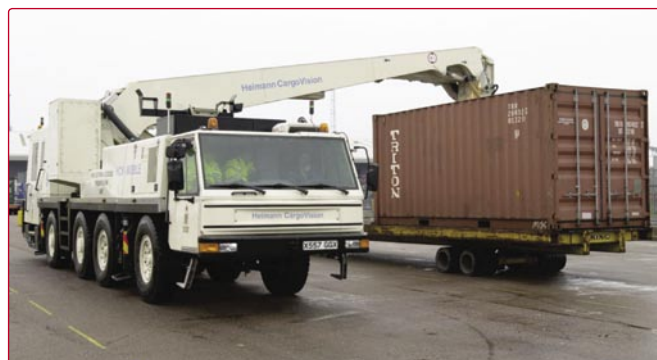
Benefits

There are three primary reasons to screen cargo: collection of duties and taxes, protection of society from culturally determined illicit materials, and protection of society from external threats. Each of these will be examined individually although X-ray systems are often utilised for some combination of these reasons.

Collection of duties and taxes: The most widespread use of high energy X-ray inspection systems is for the recovery of revenue from duties and taxes on undeclared or under-declared content. This is perhaps the easiest goal to achieve. The X-ray system provides an image of the cargo container's contents and the operator can compare the image to a record of the declared contents. The benefit is: more effective collection of duties and the protection of local industry from external competition.

Protection from illicit materials: The type of materials sought depends on social norms and laws but often includes narcotics, pornographic material, alcohol, and small weapons. The societal impacts of cargo screening, both in terms of security and cost, are difficult to quantify. Often the benefit to society is a matter of perception and, while important, also difficult to measure. As an example, interdiction of illegal drugs in the United States may increase the street price of these drugs and, to the extent there is economic compliance, can reduce the demand. In addition, there are important indirect social benefits associated with drug interdiction, such as reduced criminal activity and fewer costs to the healthcare system.

Protection from external threats: Each society may perceive external threats differently. Conventional weapons, weapons of mass destruction (WMD), and illegal immigration can all be perceived as significant threats. Traditional weapons can be used in street crime or for insurgency – very costly social problems – and there are significant social costs associated with illegal immigration, as well. The successful deployment of a single weapon of mass destruction, however, could enormously burden a society's economy, as well as world trade. Therefore there are immediate economic benefits to protection from this threat, with a corresponding psychological benefit to having the inspection system as a deterrent.



A mobile system in use for the detection of illicitly imported tobacco in the port of Felixstowe. Image courtesy of Smiths Detection.

The best way to deter potential threats is to find a self-, or nearly self-funding mechanism that also prevents terrorists from moving dangerous materials in order to conduct an attack. The concept is not to develop the perfect system, but rather to raise the obstacles to carrying out a successful attack beyond the will or ability of terrorists to surmount them. If, in addition to identifying threats, the security technology can be leveraged to increase the productivity of other inspection activities, it might be possible to add enough value to fund the screening programme. Of course, the optimum result for a successful screening programme is that an attack is deterred and never attempted.

Costs

In order to compute a realistic cost-benefit ratio one must compute the true cost of ownership of an inspection system. The costs that must be considered are the cost of acquisition, installation, operation, and service, as well as fixed costs, including labour, the cost of capital, and utility costs. These costs vary depending on the site location and local cost structures but a reasonable attempt at an estimate is useful in identifying what lessons can be learned. The authors focus on two different types of inspection systems: mobile and fixed. In costing out both types, we will use an interest rate of seven per cent to compute the cost of money.

Mobile systems: As compared to fixed site systems, mobile systems are characterised by lower acquisition and site preparation costs, and relatively higher service costs because of the truck that is required. All numbers quoted in this paper are estimates only. The acquisition cost for a typical mobile system would be about \$3M, while the site preparation costs are low to negligible. A mobile system generally requires two operators: a driver and an image analyst. Some sites also require an additional outside coordinator. For this example we will assume three operators.

Usually a number of trucks are lined up and scanned simultaneously. This means that there is some time and effort associated with moving the trucks to the inspection site, lining them up, removing the drivers, scanning, allowing the drivers to return, and moving the containers back to their original locations. The time used per container for all these tasks is estimated at a conservative 20 man-minutes per truck/container. Other costs include the utilities required and the cost of fuel. Fuel is a highly variable cost in today's environment. A typical mobile system requires an amount of fuel costing approximately \$200/week.

The problem of false alarms is another little-discussed hidden cost of inspection. This will be considered in this paper as well.

An estimated annual cost of inspection could be calculated as follows:

Cost of money: acquisition cost times the interest rate;
 $\$3,000,000 \times 0.07 = \$210,000/\text{year}$

Amortization of the system over 10 years: $\$300,000/\text{year}$

Cost of service: estimated $\$100,000/\text{year}$. This will be significantly lower if multiple systems are in one locale, allowing the sharing of fixed costs.

Equipment operational costs: three persons/shift, two shifts/day or six man-years/year. Using a fully burdened rate of $\$150,000/\text{man-year}$, the total is $\$900,000/\text{year}$.

Port operational costs, movement of containers: 20 containers/hour, 16 hours/day, 300 days/year = 96,000 containers/year \times 20 minutes/container = 32,000 man-hours/year = 16 man-years/year at $\$150,000/\text{man-year} = \$2,400,000/\text{year}$ ($\$25$ per container inspected)

Utilities: $\$10,000$

So in summary one can expect the annual costs of a mobile system to be:

Equipment acquisition	\$ 610,000
Equipment operation	\$ 910,000
Port operations related costs	\$2,400,000

This amounts to $\$40.83$ per container inspected; $\$15.83$ are related to equipment costs and operation; $\$25.00$ are related to port operations (moving containers). If we compute costs for a higher rate of productivity, whereby 45 containers per hour are scanned, then the equipment-related costs drop to $\$7.04$ per container. Specific line items could certainly vary but when costs are broken out in this fashion it becomes clear that the dominant costs are related to container motions.

Fixed site: The overall costs of operating a fixed site are similar, with a few exceptions:

- Acquisition costs are higher ($\sim \$7,000,000$)
- There are some site preparation costs (which are variable depending on the port and design, but a fair estimate would be $\$2,000,000$)
- Service costs are lower because the mobile platform costs are reduced
- Operations costs are lower because the ground coordinator can usually be replaced with automated signage
- Depreciation can be taken over 20 years.
- Utility costs are somewhat higher because of HVAC costs for the buildings

It is also possible to achieve higher throughput with a fixed site although this is not common yet. The summary costs might be:

Equipment acquisition	\$1,605,000
Equipment operation	\$ 650,000
Port operations related costs	\$2,400,000

This amounts to $\$48.49$ per container; $\$23.49$ are related to equipment costs and operation; $\$25.00$ are related to port operations (moving containers). If one assumes the maximum rate achieved to date of 50 containers per hour then the equipment related costs drop to $\$9.40$ per container.

Cost of false alarms: This cost is variable depending on the site, the type of inspections being conducted, and other factors. However, one main characteristic of false alarms is their rising criticality as one moves from duty collection to protection from WMDs. Inspectors can afford to simply ignore an alarm when collecting duties. The only real negative effect would be the loss of revenue. In contrast, one can never afford to ignore an alarm that indicates the presence of a WMD. So assuming a false alarm rate of f , if the annual number of inspected containers is N and

the time to resolve each false alarm is T (in man hours), then the annual time to resolve false alarms is:

$$N \times f \times T$$

Assume that 96,000 containers are scanned per year, that the rate of false alarms is five per cent (which is quite high and would be typically found only in the duty collection scenario), and that it takes four man-hours to resolve a false alarm. (Note that this is a very low estimate, if one assumes even a partial devanning). In this scenario, the annual cost would be that of about 10 man-years or $\$1,500,000$.

The Domestic Nuclear Detection Office (DNDO), in a recent solicitation for the automatic detection of nuclear WMDs, has required a maximum false alarm rate of 0.5 per cent; this corresponds to about one man-year or $\$150,000$. These costs are significant but small compared to the operational costs, and amount to an additional $\$1.56$ to $\$15.60$ per container, depending on the actual false alarm rate.

Cost benefit ratios: The costs of inspection are clearly significant, but how do they compare to the benefits?

Duties and taxes: As noted above, the cost per container for inspection at a fixed site is around $\$50$, including false alarms. This compares to the average economic value of the containers that passed through Long Beach in 2003, which was $\$50,500$ per container [1]. If the costs of scanning were passed onto the shippers it would represent only 0.1 per cent of the value of the shipped goods. This seems a small price to pay for improved security. Another way of looking at this is if one per cent of the scanned containers were found to have undeclared, dutiable goods and if the duties and fines collected amounted to 10 per cent of the value of the cargo, then the inspection system would be self-funding. Both of these are conservative scenarios. In any country where fines for duty violations are used for running the inspection regime, it is likely that the checkpoint will be self-funding. In the United States, however, fines go to the Treasury Department, and Customs is left to lobby for its inspection budget independently of funds brought in.

The United Kingdom has committed to reducing cigarette duties and tax evasion. Their strategy has been to significantly increase the number of personnel involved in screening, and to add 10 X-ray scanners. The government reports: "In the first two years of the strategy, cross-Channel smuggling of cigarettes fell by over 70 per cent, while cross-border shopping increased by 50 per cent. In addition, the number of cigarettes successfully smuggled into the UK has been reduced by over five billion sticks per year, down by over a third since the introduction of the strategy, and around $\pounds 6$ billion in revenue has been protected." [2] Clearly in this case the benefit of inspection has been dramatic.

Drugs: Estimating the cost benefit ratio for a drug inspection scenario is difficult because there is no immediate monetary payback as in the case of duty enforcement. However, in a 2001 publication from The Office of National Drug Control Policy (ONDCP), the total annual costs of drug abuse to the country was estimated at $\sim \$160.7$ billion [3]. If a single inspection system could reduce the abuse problem by a mere 0.003 per cent then it will have paid for itself. Obviously a single inspection station would be ineffective, but the extremely low break even point suggests that a substantial deployment of inspection systems might have some significant effect (i.e. deployment of 1,000 systems could yield a three per cent reduction in abuse).

Weapons of mass destruction: Within the United States, it has been difficult to get agreement on an estimate of the value of deterrence, in the case of weapons of mass destruction. It's simply easier to justify expenditures in reaction to an event, rather than find the political will to prevent one. One has only to look at

the airline industry and the so-called 'Tombstone Technologies,' meaning that solutions to problems and threats usually already exist but are not implemented due to the perceived cost and the prospect of decreased profits. Then, when an accident happens, it is easier to justify the cost of implementing new technology. The rule of thumb is that the cost to the industry for each life lost in an accident is \$2m. If the accumulated loss exceeds the cost of implementing technology that might have prevented the accident in the first place, the technology is implemented.

For example, a Congressional Research Service report estimated that, if an event in a medium sized port did occur, the cost of the loss of human life would be \$200 billion on top of the property and commerce disruption costs, which could run as high as \$500 billion or more [4]. The total cost of implementing a screening system in every large and medium-sized port in the US as well as the major ports overseas that export containers to the US would be a fraction of this amount, even assuming that none of the self-funding mechanisms discussed in this paper are implemented. If the self-funding mechanisms were utilised, the net cost to protect the country from a WMD arriving in a container could be negligible.

The likelihood of a WMD being smuggled into a port and detonated is hopefully extremely remote, but the consequences would be immense. To estimate possible impacts consider the economic impact of the October 2002 West Coast dock worker's strike. It has been estimated that the strike cost \$2 billion per day in lost economic activity. If a device were detonated in the Port of Long Beach, this port and the Port of Los Angeles would be taken out of service for many months. Furthermore, it is highly probable that all port activity would cease, certainly on the west coast but probably nationwide for an extended period while the threat and possible responses were evaluated. This scenario mirrors the sequence of events that unfolded after the 9/11 terrorist attacks on the World Trade Center, which impacted air travel, passenger screening and financial markets for a long time. It is clear that the impact of such an event could quickly mount up to hundreds of billions of dollars. Yet it would take only 25-30 scanners, in the most optimistic scenario, to inspect 100 per cent of the containers coming through the Port of Long Beach. With today's state of the art, this would be difficult. Land is too scarce in the area and logistics would be complicated. However, with enough development to integrate the inspection routine so that it fits within the normal cargo flow through the port, it would be possible to prevent this nightmare scenario at a cost of less than \$50 per container.

Conclusions

Although this economic analysis is rather basic, it demonstrates two major points: 1) the cost of ownership of X-ray scanning equipment appears high but the benefits accrued are much higher, and 2) the ongoing operational costs are higher than the inspection technology acquisition costs. Point one clearly argues in favour of extensive implementation of X-ray inspection. Point two suggests that in order to increase the benefit/cost ratio one must reduce the operational costs, even at the expense of increasing acquisition costs. In other words it would be economically advantageous to invest in a completely new design for an X-ray system if it can be made to reduce the operational costs. Possible areas for innovation would be: automation of the cargo motion, automation of the image analysis, and system integration with the port cargo flow. At any site where there are multiple inspection systems the images could be transmitted to a central site for interpretation and analysis. This would reduce the amount of imaging operational manpower by a fraction of a person up to a maximum of a full person if the ground coordinator is shared. Certain inspection analysis tasks could be fully automated and this would remove the analyst from the cost equation. The DNDO is now funding efforts to fully automate the inspection for secreted nuclear weapons of mass destruction. But perhaps the most useful time and cost savings technique will be to integrate the inspection into the standard flow of cargo through the port to minimize the interruption of cargo flow. System/port integration will be examined in an upcoming article.

REFERENCES

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ABOUT THE AUTHORS AND THE COMPANY

Paul Bjorkholm, PhD, Varian Security & Inspection Products' Senior Scientist, has spent his career designing and building X-ray imaging equipment of all types. He has created images using X-rays from 250 eV to 15 MeV with size scales from parsecs to microns. Recently he has concentrated on the application of high energy X-ray imaging of cargo containers for security, contraband interdiction and manifest verification. He invented backscatter imaging, helped develop nine MeV inspection systems for Schiphol airport, and was essential in the development of 2.5 MeV mobile scanners. Dr. Bjorkholm has 16 patents to his name. Dr. Bjorkholm graduated from Princeton University and received a PhD from the University of Wisconsin, Madison.

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Varian Medical Systems is a world leader in the design and manufacture of equipment and software for treating cancer and other medical conditions with radiation therapy, as well as a premier supplier of X-ray tubes and flat-panel digital technology for imaging in medical, scientific, and industrial applications. The company is also a market leader in high-energy X-ray devices for non-destructive testing and cargo screening.

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