Transportation Security

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Erera, Spring School 2004
Outline

- Understanding transportation security
- Security regulations and programs
- Transportation security research: present
- Transportation security research: future
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  - Security regulations and programs
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  - Transportation security research: future
Security

- A “system state”
- Measured relative to threat(s)
  ✓ High security $\approx$ low vulnerability to a set of threats

- Transportation context…
Before 9/11…

- Transport security ≈ passenger aviation
  hijack/bomb prevention
- Known vulnerabilities
  - On-person, carry-on threats
  - Checked baggage
  - Access to secure airport areas
  - Access to secure ATC areas
- Horrific result
Immediately after 9/11...

- Transport security $\approx$ passenger aviation
  weaponize/hijack/bomb prevention

- Address vulnerabilities
  - Passenger screening (TSA)
  - Domestic baggage screening
  - Aircraft deterrence measures
    - Cockpit door bolts
    - Sky marshal expansion
    - Pilot handguns
  - Facility access control
Freight security before 9/11

- Freight security $\approx$ contraband interdiction
- Customs agencies
  - ✓ Border checks
  - ✓ Intercept illegal vehicles
  - ✓ Focus: narcotics, small-arms, illegal aliens, …
- Freight security $\approx$ theft prevention
  - ✓ Vehicle sealing
  - ✓ Track-and-trace
Freight security after 9/11

- Freight security $\approx$ prevention of weapon smuggling and weaponizing
- Primary perceived threat
  - Terrorists weaponize common transportation assets
The new world

- Passenger aviation security *not* enough!
- Freight systems under scrutiny *and* regulation
- New priority foci
  - Sea cargo and port facilities
  - Air cargo
  - Hazardous materials transport
Global economy built on information, telecommunications, and low-cost, long-haul transport by water, rail, and air.
Economic impact of security failures

- According to Fortune ("The Friction Economy," 18 February 2002), the impact on U.S. supply chains due to higher shipping costs, increased inventories, border closures, increased travel times and other changes as a direct result of the 11 September 2001 terrorist attacks is estimated to be $150 billion per year.
Regulators

✓ Security is primarily a “public good”
  • Corporate incentive is low, but societal incentive is high. Use regulation to enforce acceptable levels of security.

✓ U.S. examples: DHS (Customs and Border Protection, Coast Guard, TSA)

✓ Primary challenge
  • Develop systems and standards that provide acceptable security…
  • *without “excessive burden” on transportation systems operational cost or service provision*
Perspectives

- Shippers
  - *International* operations
  - Manufacturers, retailers, importers
  - Comply with security regulations
    - Cost-effectively
  - Supply chain inventory management
    - Security-related disruptions?
  - Is security only “regulation-compliance?”
    - Respond to customer/competitor pressure

What is the effect on Wal-Mart if one of *its* containers is used as a terrorist weapon?
Transportation service providers

- Port operators, ocean carriers, motor carriers, air cargo carriers, 3PLs...
- Comply with security regulations
  - Cost-efficiently
- Service challenges
  - Security-related disruptions
- Is security only “regulation-compliance?”
  - Respond to customer/competitor pressure
  - Opportunities for value-added service?
Primary themes

- Transportation systems should be secured against threats
  - How? Design and operation?
  - Win-win technology?

- Transportation systems will be regulated to provide security
  - Operational impact of regulations? Policy design?

- Transportation systems will remain vulnerable to security failures
  - Planning flexibility?
  - Operational recovery?
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Focus: International ocean containers

- 14MM container TEUs enter U.S. annually
- "Trust but do not verify"
  - Targeting, then "inspection"
  - Historical levels: 2%
  - Intrusive inspect: 0.1%, 15 man-hrs
- Exploitable?
  - Global intermodal container transportation system very large, very open, loosely regulated
Focus: Land border crossings

- NAFTA trade enormous
  - $375B: total trade with Canada and Mexico, 1995
  - $540B: total trade with Canada and Mexico, 2002
- Cross-border import truck flows
  - Laredo, TX: 3000 per day
  - El Paso, TX: 2000 per day
  - Ambassador, MI: 4500 per day
  - Blue Water, MI: 2300 per day
- Vital logistics nodes
- Much flow supports just-in-time (JIT) auto manufacture
Focus: Air cargo imports

- Increasingly important system
- Recent statistics
  - Air cargo represents only 2% of international tonnage
  - Air cargo represents 35-40% of international value
  - Slowed growth, .com fallout
- Importance
  - High value goods, JIT manufacturing
  - High visibility target
- Security delays must be avoided
Focus: HazMat transport

- Vital economic importance
  - Energy, manufacturing, agriculture…
- Scale enormous
  - Millions of tons transported daily
  - U.S.: 800,000 shipments per day
- Safety prioritized
- Challenges
  - Many potential “rolling bombs”
Regulators: U.S. Example

- Department of Homeland Security (DHS)
  - Established in Homeland Security Act of 2002
  - Prevent terrorist attacks within U.S.
  - Reduce the vulnerability of U.S. to terrorism

- New umbrella for old regulatory agencies
  - “Border and Transportation Security” directorate
    - Customs and Border Protection (old Customs)
    - Transportation Security Administration
  - Coast Guard
Agency roles

- Customs and Border Protection
  - Old U.S. Customs Service + others
  - Primary mission
    • Prevent terrorists and weapons from entering the United States
    • Very different from historical...
  - Secondary missions
    • Enforce trade laws; apprehend illegal entrants; stem contraband flow; collect import duties; enforce international intellectual property laws
Agency roles

- Transportation Security Administration
  - Mission
    - Protect the nation’s transportation systems to ensure freedom of movement for people and commerce
  - Primary regulator for:
    - Airport and aviation security
    - Transportation employee credentialing
    - Hazardous materials transportation
Agency roles

- Coast Guard
  - Primary infrastructure protection
  - Mission includes
    - Protect ports, flow of commerce, and marine transport system against terrorism
    - Maintain maritime border security against illegal drugs, illegal aliens, firearms and WMD
  - Most shippers will never deal with the Coast Guard
    - …unless they get in the business of moving drugs in small fishing boats!
Global agencies

- International Maritime Organization
  - Promotes safe, clean, and now secure global trade via ocean

- Foreign government agencies
  - Some developing similar requirements (e.g., Australia)
  - Safe to say that United States remains most concerned
Example regulatory programs: U.S.

- Customs and Border Protection
  - ✓ C-TPAT
  - ✓ CSI + advanced manifest reporting rules
  - ✓ FAST

- TSA
  - ✓ HazMat guidelines
C-TPAT

- Customs-Trade Partnership Against Terrorism
- Voluntary joint initiative
  - Between CBP and [Shippers (importers), Carriers, Brokers, Consolidators, Forwarders, NVOCCs…]
- Agreement
  - Conduct a comprehensive self-assessment of supply chain security practices (including partners)
  - Develop and implement a plan to improve security practices according to C-TPAT guidelines
- Benefits
  - Reduced targeting? “Green lane”
  - Other benefit? “Public relations”
C-TPAT: security of chain

- Example global transportation chain
  - Chip production facility in Indonesia
  - Indonesian warehouse, drayage company
  - Malaysian-flagged ocean feeder container carrier
  - Malaysian hub port (PTP)
  - Dutch-flagged long-haul ocean container carrier
  - Port of Los Angeles
  - US trucking company
  - Mexican warehousing firm
  - Printer assembly facility in Mexico
  - Mexican trucking company
  - US trucking company
C-TPAT global implications

- C-TPAT suggests that you:
  - Understand all vulnerabilities
  - Work toward making improvements
  - Propagate guidelines to partners

- Potential indirect effects
  - Create demand for “secure 3/4PLs”? 
  - Offload responsibility to a specialist
CSI

- Customs Container Security Initiative
- Goal
  - Pre-screen ocean containers at foreign ports
  - Stop contraband/weapon before departure
  - “Distribute” screening processes
- The good
  - Uses (potential) idle time at foreign ports to conduct screening
- The bad
  - Information timing requirements
  - Disruptive effects on port export or transshipment operations?
CSI + 24 hour rule

- The controversy
  - Carriers and/or NVOCCs must submit cargo declaration 24-hours prior to loading a vessel at a foreign port

- Sticking points
  - Much earlier than previous (hours prior to arrival)
  - Freight description
    - “precise narrative” or 6-digit commodity code
    - No more: “freight-all-kinds”, “various retail products”, …
    - Difficult for consolidators?
  - Requires automated data transfer to CBP
  - Confidentiality

- Rule allows targeting of containers at CSI ports
Trade Act of 2002

- Expanding the controversy!
  - Requires advance import manifest information for all modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Inbound – Transmission Received By CBP In AMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel</td>
<td>24 hours (before lading)</td>
</tr>
<tr>
<td>Air</td>
<td>4 hours</td>
</tr>
<tr>
<td></td>
<td>Wheels up from NAFTA and Central and South America above the equator</td>
</tr>
<tr>
<td>Rail</td>
<td>2 hours</td>
</tr>
<tr>
<td>Truck</td>
<td>1 hour non-Free and Secure Trade (FAST)</td>
</tr>
<tr>
<td></td>
<td>30 minutes FAST</td>
</tr>
</tbody>
</table>

- Stakeholder participation
  - Importers, exporters, carriers, brokers, forwarders
  - Feedback
    - Importance of JIT inventory practices and conflict with advance information
    - “Shortest possible” advance reporting
    - Critical of “information before loading” for all modes
FAST initiative

- Customs Free and Secure Trade
  - Expedited release of cross-border imports
- US/Canada initiative
  - Vital importance of Canadian imports to auto industry
- Border inbound crossing times
  - Pre-9/11: 15-20 minutes
  - Post-9/11: 3-8 hours
  - Now: 24 minutes, but up to 70 minutes!
- *Just-in-time manufacturing requires timely arrival of parts*
How FAST works

- Dedicated lanes
- Clearance systems
  - NCAP/FAST
    - Paperless, with EDI and transponders
  - PAPS
    - Fax ahead to Customs broker
    - Attach a barcode for each shipment to invoice
    - Scan through at border
HazMat rules and guidelines

- Hazardous materials endorsement for CDL
  - “Security threat assessments” of applicants
  - FMSCA proposes that licenses can be restricted as a result
    - Interim rule, in public comment period

- HazMat Guidelines for shippers
  - Know your carrier
  - Verify documentation before release; ask driver questions!
  - Identify primary and alternate routes to destination
  - Plan routes to minimize stops; use relay teams if necessary
  - Use advanced track-and-trace systems to monitor en route
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### Primary themes

- **Transportation systems should be secured against threats**
  - ✓ How? Design and operation?
  - ✓ Win-win technology?

- **Transportation systems will be regulated to provide security**
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- **Transportation systems will remain vulnerable to security failures**
  - ✓ Planning flexibility?
  - ✓ Operational recovery?
Container inspection strategy design


- Inspection strategy design
- Multi-layer strategy
  - Shipper certification (C-TPAT)
  - Smart container seals
  - Targeting
  - Passive monitoring (neutron and gamma)
  - Active inspection (gamma radiography)
  - Manual inspections
  - Foreign (CSI) and domestic ports

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Container inspection strategy design


- **Optimization model**
  - Maximize detection probability
  - Constraints
    - Allowable port congestion (simple queuing)
    - Operating budget

- **Results**
  - Current policies yield low detection probabilities
  - Optimal policies utilize:
    - High-energy x-ray radiography
    - Passive neutron tests at overseas ports

9.75% detection for non-C-TPAT shipper
24% for C-TPAT
Security win-win analysis


- Quality analogy
  - End-of-line sampling inspections are wrong way to do quality assurance and security assurance
  - In-process control and prevention
- Continuous monitoring via smart container seals

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Smart container seal programs

- Bolt seal with RFID capability
  - Monitors presence and integrity of bolt seal, generates alarm upon bolt removal or breakage
  - Communication via RFID to readers at chokepoints (ports, yards…)
  - Minimizes theft, loss and tampering
  - Prices vary, but should eventually be very low (few dollars)

- Operation Safe Commerce (OSC), Safe and Secure Tradelanes (SST)
  - Public-private partnerships to deploy technology
Global visibility systems

- **Integration with smart seals**
  - Seals can be read and status ascertained at certain “choke points”
    - Equipped ports, warehouse, factory facilities
    - Container ID, time stamps, status, seal integrity
  - Information feed to asset track-and-trace system
  - Security and integrity monitoring

- **Integration with Customs ACE**
  - Limited data sharing

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Security win-win analysis

- Inventory model analysis of SST seal program

\[ E(T) = E(x) + pE(y) \]

\[ \text{var}(T) = \text{var}(x) + p^2 \text{var}(y) + p(1 - p)E(y^2) \]

\[ p = \text{inspection probability} \]
\[ y = \text{inspection dwell time, random variable} \]
\[ x = \text{transit lead time, random variable} \]
\[ T = \text{total lead time} \]
Security win-win analysis

Lee and Whang (2003).

- **Safety stock**

  \[ \mu = \text{mean per period demand} \quad \sigma = \text{std dev per period demand} \]

  \[ R = \text{inter-replenishment time} \quad k = \text{safety stock factor} \]

  \[ p' = \text{reduced inspection probability} \quad \theta = \text{transit time variance reduction factor} \]

\[ S_{old} = k\sqrt{\mu^2 \var(T) + \sigma^2 E(T + R)} \]

\[ S_{new} = k \left( p'\sqrt{\mu^2 \theta \var(x) + \var(y)} + \sigma^2 [E(x) + E(y) + R] + (1 - p')\sqrt{\mu^2 \theta \var(x) + \sigma^2 [E(x) + R]} \right) \]

**Theorem:** \( S_{new} \leq S_{old} \)
Security win-win analysis

Lee and Whang (2003).

\[ \mu E(T) + S \]

order up-to level

on-hand inventory
system inventory

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Security win-win analysis

Computational study

✓ High-value containers ($300K), high ICC 23%

\[
\begin{align*}
\mu &= 4300 \text{ containers/365 days} \\
R &= 7 \text{ days} \\
E(x) &= 30 \text{ days} \\
p' &= 0.4\% \\
p &= 2\%
\end{align*}
\]

\[\sigma = \text{std dev per period demand (?)}\]

\[k = \text{norminv}(0.95)\]

\[\text{var}(x)^{1/2} = 6 \text{ days}\]

\[\theta = 0.81 \text{ (10\% reduction in std dev)}\]

✓ Results: large reported savings

• Annual inventory costs reduced from $13MM to $9MM

Lee and Whang (2003).
At the time we place order 2, we **do not** have the lead time for order 2. When we place order 2, we may or may not have the lead time for order 1 (and order 0, and order –1, and order –2, etc.).
Security win-win analysis questions?

- Timing of lead-time resolution from uncertain to certain is crucial
  - Advance information must arrive in time to take a valuable action

- Value of departure (CSI) inspections vs. arrival inspections

Luedtke and White; ongoing research (2004).
Security win-win analysis questions?

- Assumptions
  - Order decisions made periodically, orders do not “cross”
  - Departure and arrival inspections *stochastically identical*
  - For departure inspections, time when containers leave origin port is known
  - Expected holding and shortage costs convex; ordering results in fixed cost per order and linear cost per item

- Dynamic programming approach

Luedtke and White; ongoing research (2004).
Security win-win analysis questions?

Luedtke and White; ongoing research (2004).

- Interesting result
  - Sufficient statistic under departure inspection scenario identical to that of arrival inspection scenario
  - Optimal decisions identical
  - No value to advance information in this scenario
  - Key: no order cross-over

- Further research
  - Expediting, multiple-sourcing problems
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Container inspection operational impacts

- Understand productivity impacts on mega-ports providing inspections
  - Transshipment port (e.g. Singapore)
- How will % of containers to be inspected affect
  - Number of container moves required during transshipment
  - Unload/load times and their variability

Transshipment container terminals

  - Comprehensive; 200 references
- Operational planning problems
  - Berth-to-vessel allocation
  - Quay crane assignment
  - Yard storage allocation
  - Yard crane management
  - Container unload/load sequencing*
Container sequencing

- Minimize $\sum_{j \in V} w_j C_j$

- Scheduling: release times, precedence
## Container sequencing

- Stowage plans create precedence

<table>
<thead>
<tr>
<th>Vessel 1 Inbound</th>
<th>Vessel 1 Outbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1329</td>
<td>19</td>
</tr>
<tr>
<td>524</td>
<td>419</td>
</tr>
<tr>
<td>365</td>
<td>1024</td>
</tr>
<tr>
<td>31</td>
<td>778</td>
</tr>
</tbody>
</table>

$$t_{31} \geq t_{365} + c(\Delta)$$

$$t_{778}^\Gamma \geq t_{31} + c(\Delta)$$
Container sequencing

- Container inspection impacts

- Example screening station
  - Deterministic single-server FIFO queue: 15 min per
  - Assume no “rework”
Container sequencing

- Container inspection impacts

- Example screening station
  - Deterministic single-server FIFO queue: 15 min per
  - Assume no “rework”
Container inspection operational impacts


- Direct move
- Yard storage
- Harbor
- Quay

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Container inspection operational impacts


- Inputs
  - Container stowage plans for inbound and outbound vessels for a transshipment cycle
  - Arrival times of inbound ships
  - Containers that must be moved to/from security station

- Decision variables
  - Times when containers are moved
  - Indicators: is the container moved direct?

- Objective
  - Minimize total transshipment time
Container inspection operational impacts


- Highly-simplified
  - No yard equipment, no storage area models, outbound ships wait for containers under inspection
- MIP
- Heuristic approach
  - Greedy approaches determine containers to move direct vs. through storage
  - LP to determine minimum transshipment time
- Results
  - 1000 container problems
Container inspection operational impacts


Histogram of Transshipment Time
(100 Instances at Inspection Level 5%, x-ray scanning system)

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“Workshop on Supply Chain Security and Productivity: Research and Education Implications”

✓ Sponsors: NSF, GT, The Logistics Institute

Idea consensus

✓ Enhance and develop methodology for design of robust flexible SC systems, with focus on high-impact low-probability events
✓ Real-time operational decision support, including tools for robust response to disruptions
✓ System-wide respond/recovery support
✓ Security risk metrics
✓ Leverage investment in asset visibility systems
✓ Pursue models for collaborative supply chains
✓ Inform policy analysis and debate
A broader view

- Threats to transportation systems and the supply chains they support are broader than terrorism
- International supply chains serving the global economy particularly vulnerable
  - Chain lengths
  - Chain jurisdictional “coverage”

“Security” defined as reducing vulnerability to terrorist threat only part of the picture
Robust, flexible SC systems


- “Special events” variability
  - Many sources, some are indirect
  - Each has low probability and (likely) difficult to estimate

- Vulnerability
  - What can go wrong?
  - What is likelihood then of disruption?
  - What are consequences and then response actions?

- Measurement of vulnerability
  - Two-dimensional: likelihood of disruption and ability to respond (resilience)
Robust, flexible SC systems

Robust, flexible SC systems

- Disruption
  - Aggregating influences to reach a probability assessment
    \[ 1 - \prod_{i} (1 - P_i) \]

- Resilience
  - Ability to recover; a response over time
    \[ R = \int_{t_{F}}^{t_{R}} (100 - L(t)) \, dt \]

Robust, flexible SC systems

- Mitigating disruption
  - Strategic planning
  - Awareness
- Enhancing resilience
  - Redundancy (but how to be lean, and redundant?)
  - Flexibility (low-cost reconfigurability)

Last thoughts

- Vulnerability is a “new” cross-cutting dimension
- May impact strategic decisions
  - What should be the global extent of our supply chain?
  - Should we maintain reliable domestic suppliers?
  - Should we locate near CSI ports?
  - Should we outsource more logistics functions?
Questions