How Do We Increase Port Security Without Imperiling Maritime Commerce? Using Flight Simulators and Workshops to Begin the Discussion

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Abstract

Port security is an area of increasing national concern. Various security measures have been proposed in an effort to reduce perceived security threats. These measures have the potential to significantly change port operations, and may lead to significantly increased shipping cost and time. To help define and explore the tradeoffs between security and commerce, we have used system dynamics models to engage diverse representatives of business and government. In collaboration with domain experts, we have developed models of port performance on two relevant time scales. A short-term port operations model simulates the effects of a variety of security measures on port operations, under both normal conditions and when subject to several disruptions in supporting infrastructures. A long-term port economics model simulates the possible consequences in of port performance changes caused by security measures on the long-term competitiveness of the port. In workshops designed around these models, we have engaged government and business representatives in discussions about the ramifications of security policies. These workshops have catalyzed discussions among the diverse parties concerned with insuring secure and efficient shipping.

Problem Statement

Especially since the events of 9-11, container shipments through US ports are believed to be a potential pathway for introduction of weapons of mass destruction (WMD) into the United States. Currently only about 2% of all cargo containers are inspected. New security measures have been implemented, and others proposed, in an effort to reduce this perceived threat. These measures call for additional processes and equipment to be used in container shipment in an effort to better characterize and control cargo. Requiring new security measures can change important performance characteristics of the port such as the time and cost required to import and export goods. These performance changes can suppress overall demand for shipping, and change the relative attractiveness of ports to importers, exporters, and cargo carriers. The current inspection process was designed

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primarily to enforce tariffs and intercept illicit drugs and other contraband, and may not be well suited to interdicting WMD.

In addition to any long-term performance changes created by security measures, the transition from the current system to an inspection system tailored for security may impose additional costs and delays. Effective security measures must take account of the economic consequences they entail. The National Strategy for the Protection of Critical Infrastructures and Key Assets (2003) issued by the White House states that "security solutions to the container shipping challenge should recognize that, in many cases, commerce, including essential national security materials, must continue to flow…Stifling commerce to meet security needs simply swaps one consequence of a security threat for another." Successful port operations requires the coordinated action of many disparate people and organizations, including ship owners, port authorities, importers and exporters, labor unions, and government agencies. Negotiating the appropriate balance between security and cost requires considering the consequences of alternatives on these diverse interests.

Port operations also rely on reliable performance of various infrastructures, including electric power systems, telecommunications systems, petroleum refining and distribution systems. Disruptions to these infrastructures may stop or degrade port operations. Understanding the potential for infrastructure interactions is our line of business. We are therefore interested in how new security procedures might change the sensitivity of port performance to infrastructure disruptions. In this study, we used the Port of Seattle and the Port of Portland as the ports we considered in our analysis.

Analysis Objectives

We have set about to inform decisions about port security measures by answering the following questions:

- How might port security policies applied to container cargo affect shipping time and costs?

- Under what conditions are there infrastructure disruptions and how will those disruptions impact port operations? Can security measures exacerbate the impact of port disruptions or impede the recovery from disruptive events?

- What are the potential long-term economic impacts of increased security costs?

Security Policy Options

Over the past 18 months a variety of container security policy options have been proposed. Those currently being considered include:

- Increased manual inspections

- Port of departure inspections
- Cargo profiling
    - Early manifest reporting
    - Supply chain assurance
- Container seals
    - Physical
    - Electronic/smart
- Scanners
- Detectors
    - Radiological
    - Chemical/Biological
- Monitoring and Access Controls

The system dynamics flight simulators we have constructed consider the effects of all these security measures. The figure below shows some of the security equipment being considered for deployment.

Disruptions

Disruptions to port operations we consider include:

- Telecommunications – We consider the effect of a major telecommunications disruption. A fire destroys all the switches in a single building downtown. The cable vaults in the basement remain operational and unaffected office space in the building is converted to house the replacement switches. Our collaborators at Lucent developed a model of the Seattle network to simulate the performance of the telecommunications system following this disruption. Both wireline and wireless communications are severely impacted for 1 week. In the first day or so, this impacts the ability to assemble labor, pilots, tugs, linesmen, and others, but work arounds are implemented fairly quickly. However, this disruption more persistently affects the logistical communications needed to (1) deliver cargo by truck to the port; and, (2) truck import cargo off the terminal. Following the first week, telecommunications gradually recover over the next three weeks. In all, it is a month before telecommunications fully recover.
- Electric Power – In this scenario an avalanche in the Cascades takes out two major transmission lines. Rolling blackouts occur for 5 days reducing productivity of both the day and night shifts by about half.
- Labor – A strike or lockout occurs. In the first week, throughput is significantly affected as "work to rules" is imposed. Then, a strike or lockout occurs for the following 2 weeks.
- Port Security Threat/shutdown – A dirty bomb is discovered during a Customs inspection at another West Coast port. The users are able to specify the duration of port closure. If they like, they can increase the amount of customs inspections after the event.

Long-term Economic Factors

We have focused on the long-term economic viability of the port. There are several distinct interests that must be served by the port in order to remain competitive, including carriers, importers and exporters, and local businesses that support or rely upon port operations. Some key decision variables in our analysis include:

- Costs to carriers of making a port call
- Costs to importers of customs inspections and supplementary security measures
- Delays and unpredictability in shipping time created by alternative security measures
- Lease rates and other fees charged by the Port

Long-term performance will clearly depend on external factors as well. Our analysis allows alternative assumptions for interest rates and market growth.

Process

We have consulted with port operations specialists, port interests, and business representatives to learn about port operations. It was during an exercise in causal loop diagramming in which the modeling team began to articulate the important feedbacks in port operations that we observed that there seemed two primary time scales of interest in this problem. First, the mechanics of port operations and its performance in response to added security measures and/or disruptions operates on a time scale extending over days and weeks to months. Second, long-term competitiveness and economic viability of a port – especially in shouldering the burden of paying for increased security measures – seemed to play out over a time scale that extended over years to more than a decade. Here we hypothesized that, similar to many system dynamics problems (e.g., Forrester, 1971; Sterman, 2002), cause and effect may not be closely related in time. As detailed in the following sections, we used this understanding to develop three tools to help identify and communicate the tradeoffs between security and commerce:

- A port operations model to evaluate potential impacts of security measures on throughput
- A port economics model to evaluate long-term effects of security
- Workshops held in Portland and Seattle to test the port models and concepts, and begin the process of finding the appropriate balance between security and commerce.

Collaboration

We have worked with numerous individuals to design and parameterize the port models, identify analyses and workshop content. Collaborators and domain experts that helped us develop the model and workshops included:

- Pacific Northwest Economic Region
- Regional Maritime Security Coalition
- US Coast Guard
- Bonneville Power
- Ports of Seattle and Portland
- Cities of Seattle and Portland
- University of Washington
- Lucent Technologies
- Transportation Strategies International

Model Development

In discussing the processes that influence cargo flow through a port, under both normal and disrupted conditions, we concluded that the system exhibited important dynamics over a range of time scales, and that the system responses could best be captured by separating these dynamics into short-term operations, concentrating on the internal

dynamics of the port, and long-term responses, addressing the responses of the shippers, carriers, and port operators to changes in summary long-term operational characteristics.

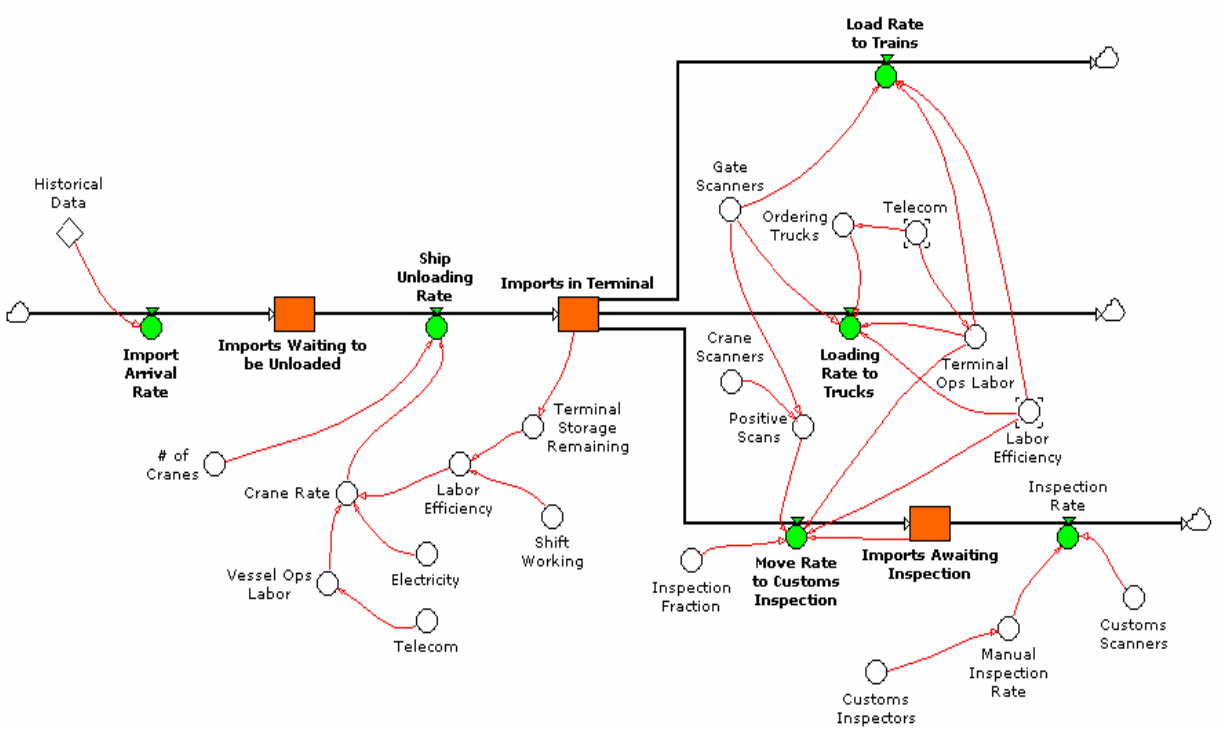
Short-Term Operational Model

Our first goal was to explore the tradeoffs between security and port performance by evaluating performance under a variety of alternative security policies. We designed a short-term simulator of port operations to help us assess port performance under various conditions, including imposition of diverse security policies. There are many possible security policies, each combining some subset of available technologies. Each policy will have some associated performance characteristics. In the short term, the tradeoffs between security and performance are shown schematically in the following figure:

In this figure, each dot represents a different potential security policy option. Conceivably, there could be an infinite number of security policies, but in this schematic we show that there are many possible policies. It is possible (though probably unlikely) that a low cost, high security option could be identified. This is represented by the red dot to the upper left of the graph. There are also many inferior options shown as orange dots. For each of these options there exist other preferable options that provide either (1) more security for the same cost, or (2) the same security at less cost. We anticipate there will exist a continuum of preferable options (shown here as the blue dots connected by the green line) where there will be direct tradeoffs between shipping performance and enhanced security.

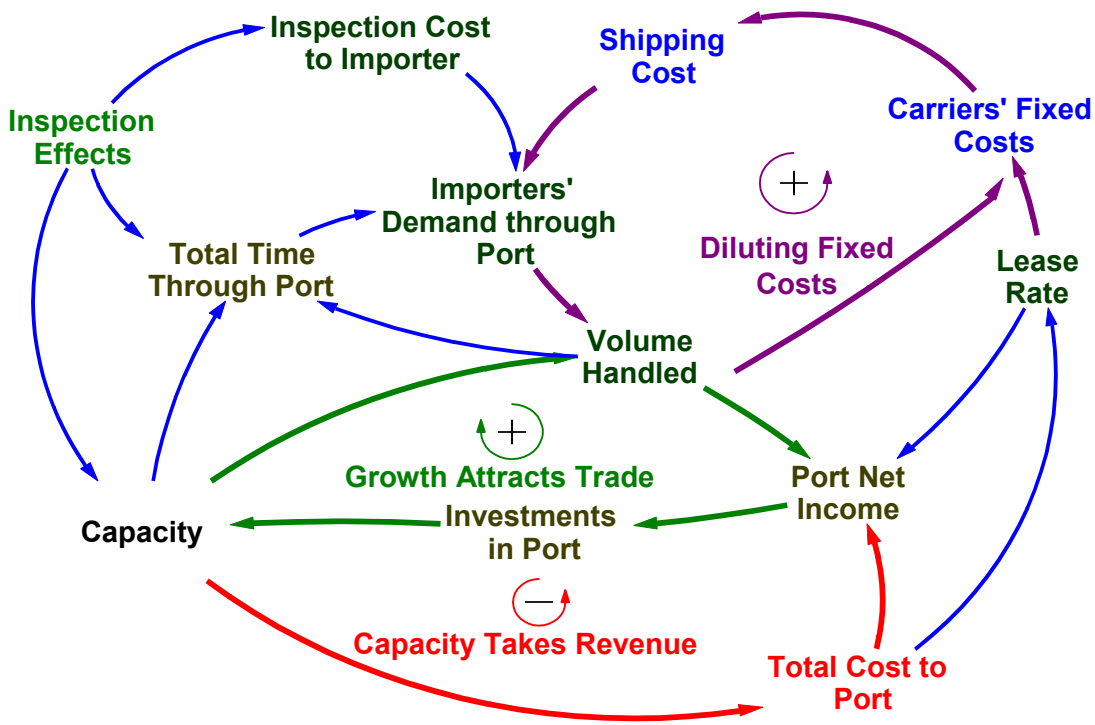
The short-term model was also designed to provide an understanding the robustness of port to disruptions under different conditions, and to evaluate the effects of security measures on the ability of the port to recover from such disruptions.

The figure below shows a simplified stock and flow structure for moving import cargo containers through a port. There is also a corresponding outflow of export materials (not shown).



Long-Term Economic Viability Model

Our second goal was to understand whether the consequences of additional security measures on port operations, particularly the cost and time required to ship cargo, might initiate a death spiral due to the large capital costs involved port and carrier operations. The essential aspects of the causal structure governing long-term performance are shown in the following diagram:



Ports have large fixed costs for facilities and equipment, and may have large recurring maintenance costs (e.g. for dredging) that do not vary with port traffic. In the long term, the greater the traffic through the port the lower the unit cost. Large traffic volume may allow Ports to lower the rates they charge to carriers, which make the port more attractive, and thereby attracts more trade. Conversely, a decrease in traffic can increase the unit cost, making the port less attractive, and diminishing trade. Long-term port operations exhibit other classical feedbacks: higher traffic volume increases income and permits more investment in equipment and facilities, allowing even higher traffic; repair and maintenance of existing capacity diminishes income and hinders capacity expansion.

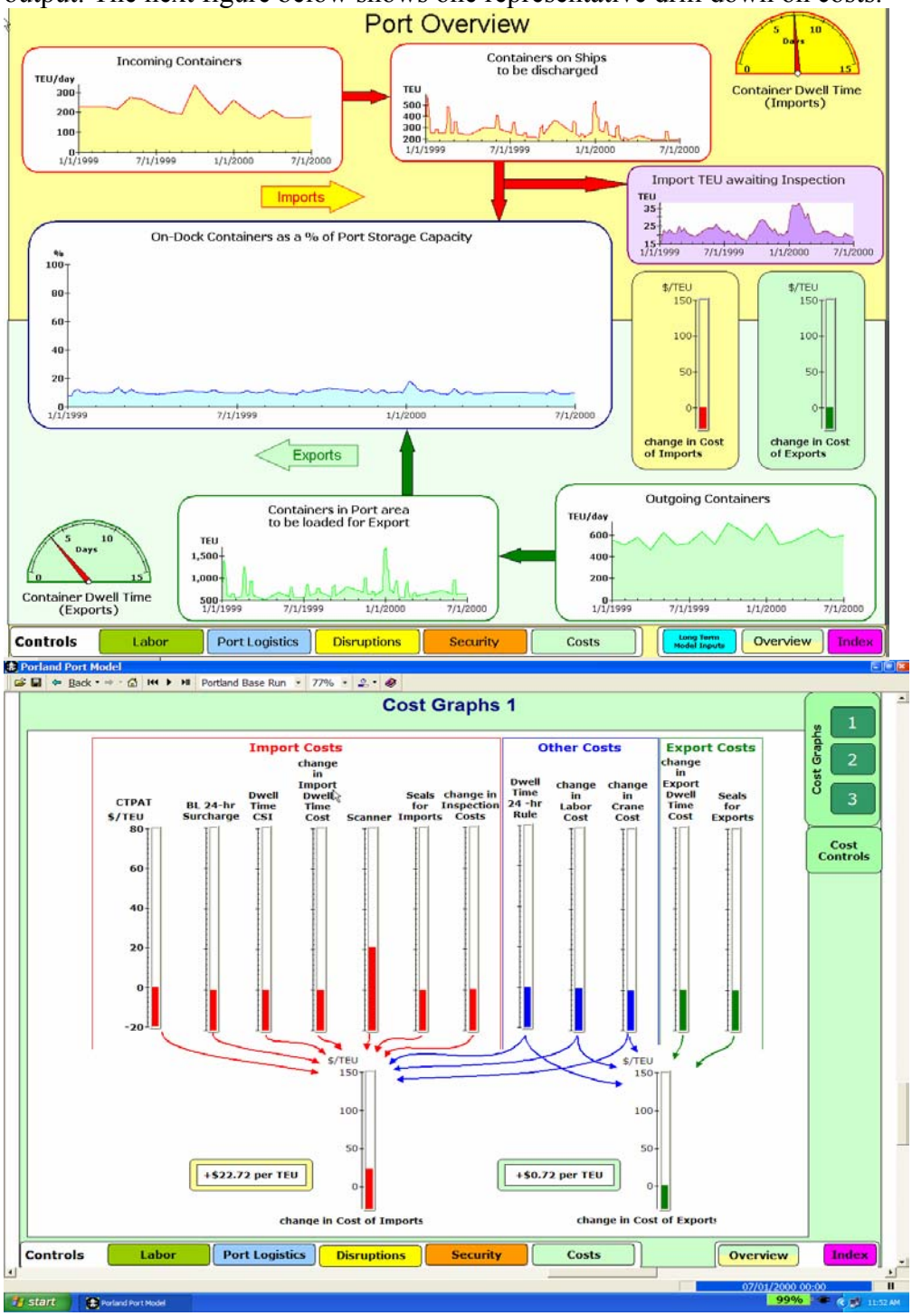
The model structures in both the short-term operations model and the long-term economic viability model were constructed to be generally applicable to many ports. It is the parameter values make them port-specific. The model and process can thereby be used with little additional work to evaluate other ports.

Interface Design

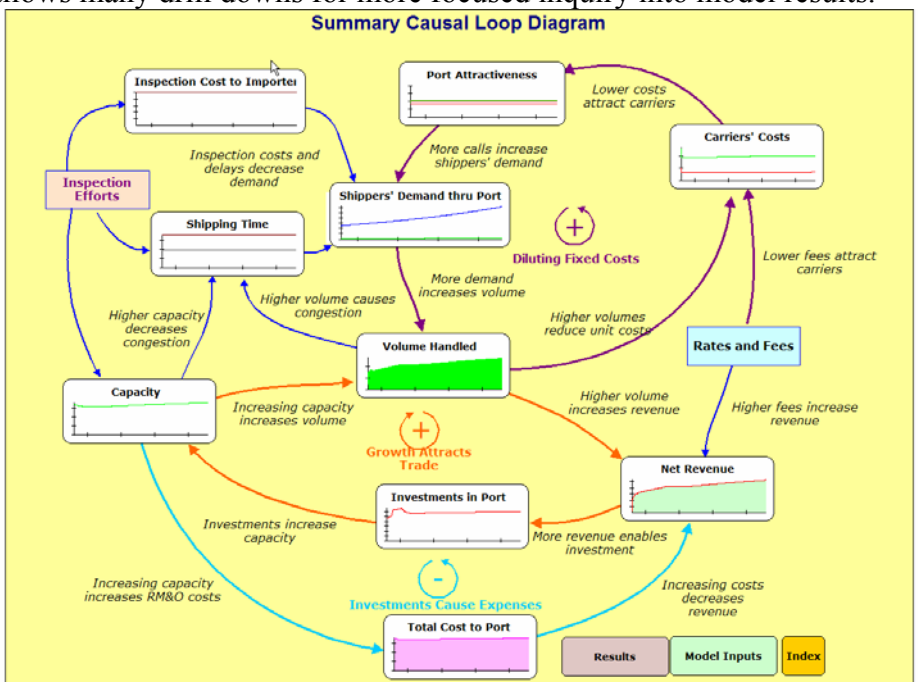
Interface design for the models was especially challenging because of the need to quickly and effectively present diverse users, usually with little prior exposure to simulation models, with a clear representation of the way their system was modeled and convenient access to model controls and results. The structure of the underlying models is quite complex, creating further challenges for interface design. Our goal was to make the

model details available to interested users, while not confronting them initially with overwhelming complexity.

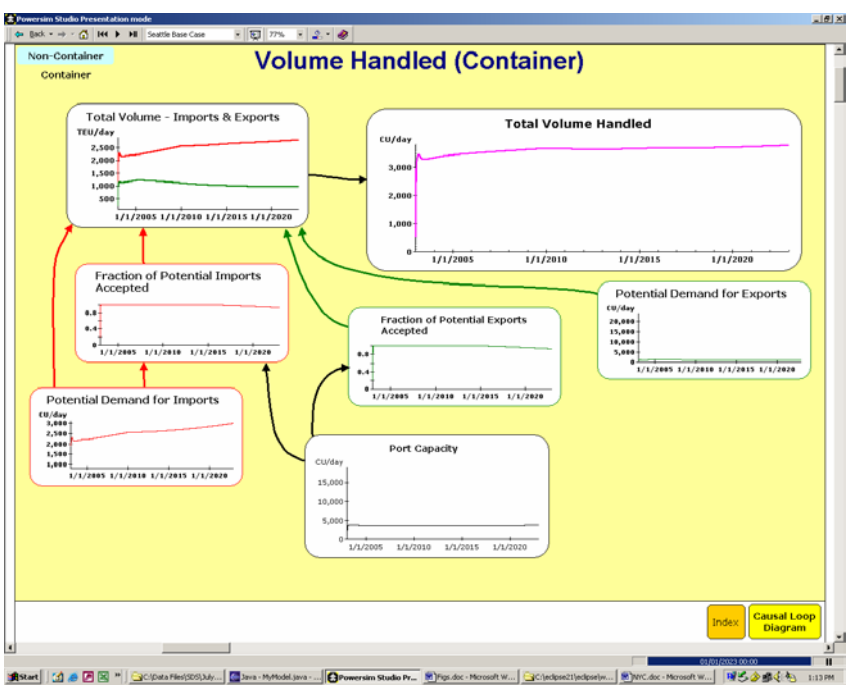
The following figure shows the overview results screen. Each graph contains a hyperlink allowing the users to drill down deeper to get more detail on various aspects of the model output. The next figure below shows one representative drill down on costs.



Likewise the long-term model starts from an overview screen (shown below) that also allows many drill downs for more focused inquiry into model results.



One drill down expands the volume of goods moving through the port, showing the potential market for both imported and exported containers, and the amount of that potential market currently served. The import and export markets are further subdivided into "local" and "distant" components, which are distinguished by the mode of surface transportation that serves them. Non-container traffic, include imports and exports from both local and distant markets, are also tracked in the model.



Workshop Process

There is a long history of using management simulators to teach System Dynamics and Systems Thinking. Senge and Lannon (1990) describe the value of simulators or "microworlds" as tools for organizational learning. Certain simulators such as People Express have had extensive use for general management training and have been studied by Sterman (1988a,b) for their effect on learning. Simulators have been developed in specific fields such as health care to help those in the field understand the implications of major changes (see Hirsch and Immediato(1998), Hirsch and Kemeny(1989)). Particular design issues such as the desired degree of transparency in simulators have been studied by Grossler (1998) and by Machuca et al. (1998).

We conducted ½ day workshops in both Portland and Seattle. We intend the workshops to be the beginning of our collective discussion, not the end. During the workshop, representatives from industry (including labor) and government (including the newly formed Department of Homeland Security) used the models to perform several analyses:

- Run through short-term model base case together
- Disruption Scenario

–Anticipate disruption effects
–Attempt to mitigate disruption effects
–Groups present results

- Security Policy Options

–Implement single security policy, anticipate effects, (repeat)
–Implement comprehensive security policy, anticipate effects
–Groups present results

- Long Term Model

–Examine base case, understand behavior, manage port
–Examine security policy from short term model
–Groups present results

- Summing up

The photo below shows workshop participants in action.

Some Initial Findings

About the System

Initial insights about how the port system operates come from some preliminary model analysis and model runs conducted at the workshops. Much more systematic model analysis will be conducted in the coming weeks and we will present some of these results at the New York meeting (July 2003).

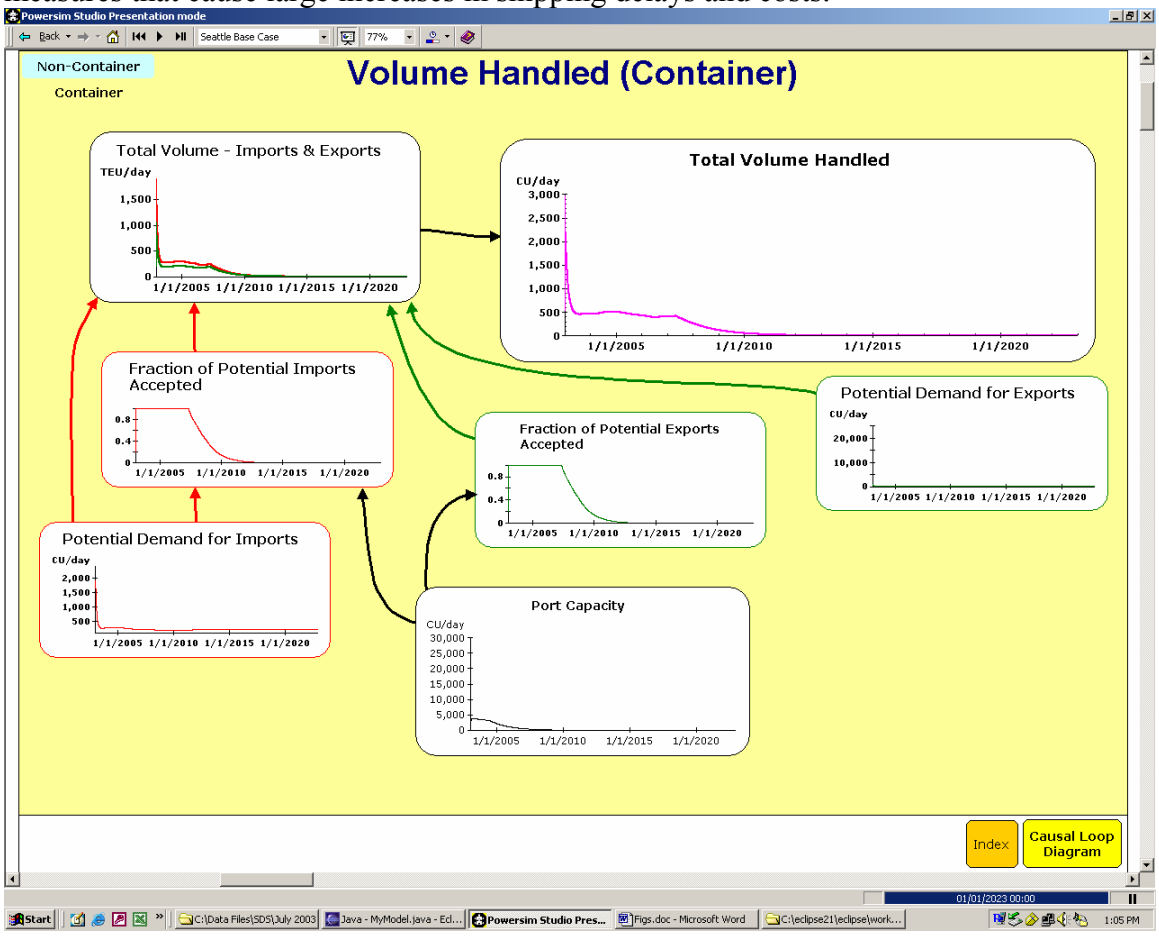
1. Some security measures can create substantial increases in the demand for customs inspectors. If not properly anticipated, backups at customs might have paralyzing consequences for port operations.

2. Specific port characteristics (unused container storage, cargo volume over which to spread increased capital costs for security) lead to different operational consequences from imposing security measures at different ports. This finding implies that new, across-the-board, requirements for security enhancements may impact some ports far more than others. Allowing some flexibility in the manner in which individual ports achieve increased security might be warranted.

3. One group at the Portland workshop demonstrated that by imposing higher scanning and inspection rates dynamically and intermittently in response to high alerts and certain

seasonal periods (such as before the July 4th holiday when imports of fireworks skyrocket) that the overall perception of security could be enhanced while minimizing inspection backlogs.

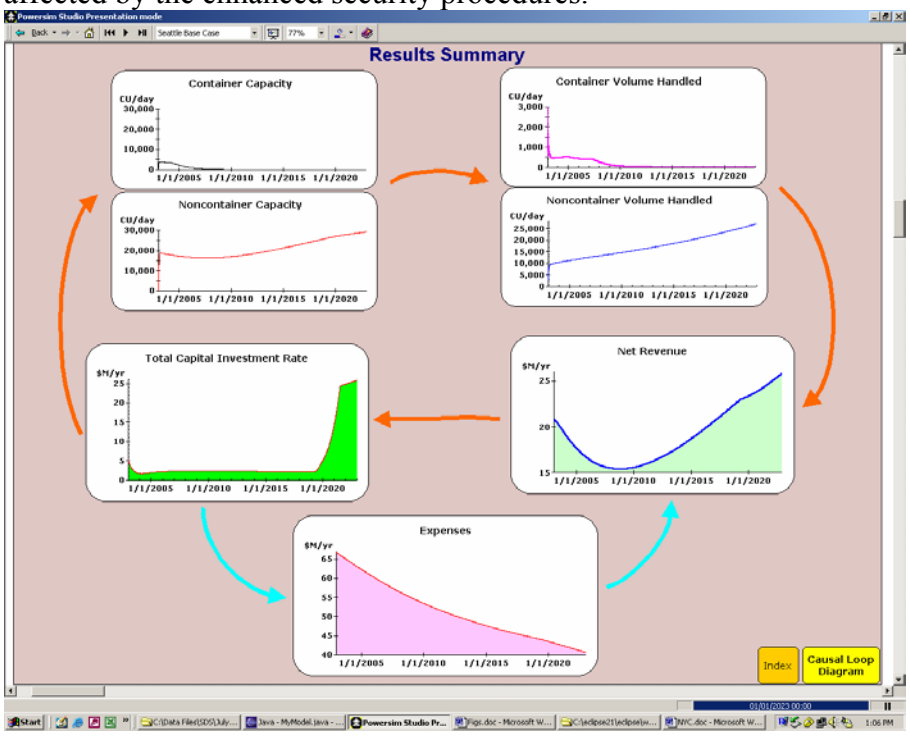
4. Many security measures can be designed which impose costs and dwell time impacts well within the normal range of variation seen in current operations. However, initial simulations with the long-term model indicated that imposition of some of the more costly security measures may make the port non-competitive. Loss of traffic has the potential to lead to collapse of container-handling business through the positive feedback loop labeled "Diluting Fixed Costs" on the causal loop diagram shown previously. The figure below shows the collapse of container traffic that can follow imposition of security measures that cause large increases in shipping delays and costs.



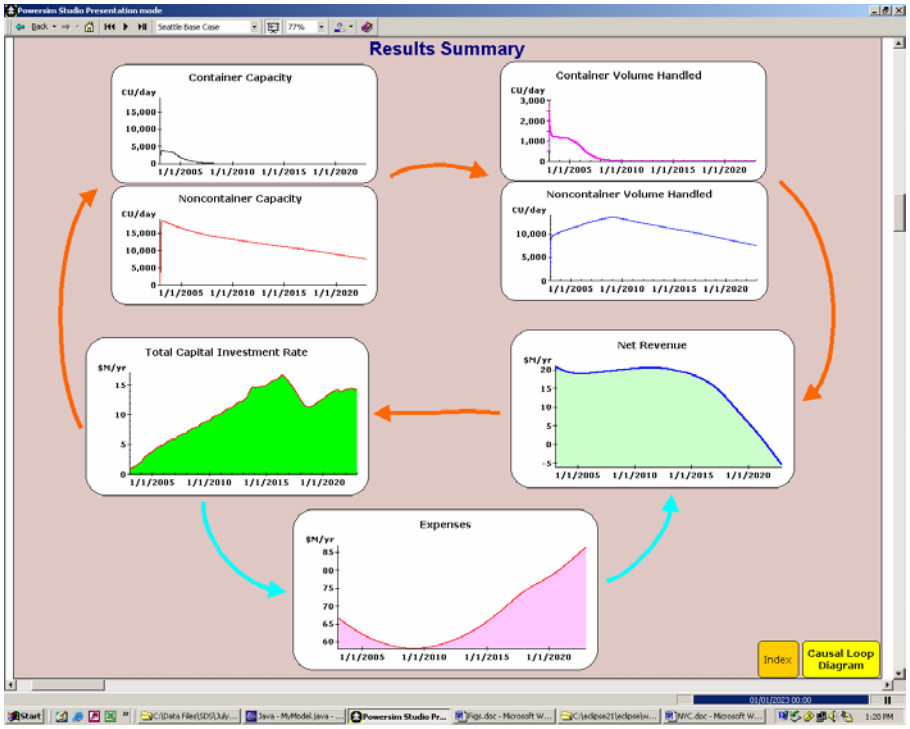
We emphasize that these results do not reflect our expectations about the effects of particular measures at any port. The model is still being reviewed and modified in response to comments received at the workshops. We include these results to present the kinds of responses the model can produce, and to illustrate the assessment of mitigations.

To continue on with this example imposing high cost security measures, the next figure shows that although container traffic has collapsed, non-container traffic continues to

grow throughout the 20 year simulation period. Bulk shipments and automobiles are not affected by the enhanced security procedures.



As a possible mitigation, a port operator might subsidize their container-handling business by raising rates and fees for non-container carriers. The next figure shows that this strategy delays but does not prevent the collapse of container traffic, and also produces a decline in bulk trade.



About the Process

Model development and use catalyzed discussions among diverse interests. This occurred throughout the process. Data collection and systemization provided new insights to operators about how their overall system works. The process of designing, presenting, and using the models surfaced implicit assumptions about system behavior for validation and refinement. Workshop participants readily engaged with one another and with the simulators to understand the model responses, evaluate them against their experience and intuitions, and to propose imaginative solutions to the problems that developed. They volunteered valuable recommendations for improving the model structures (such as explicit inclusion of customs training delays) and were generally eager to continue to use the models as an aid to decision making.

Here are some example written comments provided by workshop participants:
"Very worthwhile – hands on aspect was particularly helpful"

Would use these tools to:
"…to collaboratively work towards addressing imminent issues."
"As simulations for disaster conditions…"
"For enhancing viability of international business in our region."

Summary and Conclusions

We found the workshops to be successful both in promoting discussion between the participants and for providing valuable feedback into how we can improve the models. Our next steps are to revise the models to include suggestions from the workshop participants and to use the models to perform additional analyses of port-security issues. We anticipate presenting some results of these analyses at the conference in New York.

Our experience with the models to date suggests some tentative conclusions concerning the impact of port-security policies. In designing the port operational model, we anticipated that increasing security measures could increase costs, increase the average time to move cargo through a port, or both. Simulations to date suggest that the main impact of increased security measures would be mainly increased cost. When we input those increased costs to the long-term economic model, we found that often these added costs tend to be small compared to the normal variations in cost due to other factors. However, we have shown also that relatively high cost burdens for a port can initiate a spiral of decreasing competitiveness resulting in significant loss of market share.

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