SCRIPS: Supply Chain Resilience Issues, Problems and Solutions for the Homeland Security Enterprise

A Workshop for Defining Research Needs and Opportunities

Workshop Report

October 1-2, 2024

Washington, D.C.

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Executive Summary

Three DHS (US Department of Homeland Security) Centers of Excellence, the Center for Accelerating Operational Efficiency (CAOE), the Cross-Border Threat and Supply Chain Defense Center (CBTS) and the Command, Control and Interoperability Center for Advanced Data Analysis (CICADA), with support from the DHS Supply Chain Resilience Center (SCRC), hosted a workshop on October 1-2, 2024, in Washington D.C. to discuss the state of Supply Chain Resilience (SCR). Entitled SCRIPS: Supply Chain Resilience Issues, Problems and Solutions for the Homeland Security Enterprise, the workshop had two main objectives. First, to create a community of interested individuals spanning the academic research, problem domain owner and governmental policy communities that can collaborate to advance the state of supply chain resilience. Second, to develop a 3-5-year research agenda for enhancing the resilience of supply chains for critical industries necessary for the nation's security and economic vitality. The SCRIPS Workshop focused on the Food/Ag (Agriculture) industry, Port/Maritime operations and Semiconductor Manufacturing. General SCR issues that cut across those and other vital industries were also considered.

SCRIPS brought together approximately 50 individuals spanning academia, government and industry to discuss the current state of SCR, identify threats and define research opportunities. Due to the workshop coinciding with the start of the ILA (International Longshoremen's Association) strike closing 14 ports along the Eastern and Gulf coasts and the recent hurricanes affecting the southeastern United States, several DHS representatives were unable to attend at the last minute, however, the workshop still engaged a diverse set of individuals with broad and deep backgrounds in SCR. The focus was on information, data analytic and quantitative modeling needs to enhance SCR. To set the stage for discussions, following introductions the workshop commenced with keynote presentations delivered by Mr. John Caton from the DHS SCRC on the need for SCR and Dr. Anna Nagurney from the University of Massachusetts - Amherst on the opportunity of network modeling and recent advances on supporting SCR in the Food/Ag industry. Most of Day One was devoted to three breakout sessions with attendees divided into four groups – one for each of the main industry themes and a fourth for general SCR. In each session the groups were given a main topic to discuss with associated thought questions. Breakout #1 focused on Supply Chain Weaknesses, Threats and Needs. The second breakout addressed Research Needs, in particular, Science and Solution Gaps. The final breakout of the day was devoted to defining the science that could be advanced to address the gaps. Each group had an opportunity to report out their findings after each session. Day Two commenced with a welcome and motivational presentation by Rebecca Medina, Director of the DHS Office of University Programs (OUP). A general session was then held for open discussion summarizing the previous day's observations and searching for commonalities. Finally, each group returned to their breakout room to Prioritize Short- and Long-Term Research Needs in their area. A summary of key opportunities was produced by each group focusing on the Impact, Feasibility and Resource Requirement tradeoff.

Despite separate groups focusing on different industries, several common themes and research needs emerged across the breakout groups and assembled discussions.

Common Themes:

- Supply chains are **international and complex**. There are many different players that make sharing data and understanding all risks difficult. Current models do not adequately cover the complexity of interactions/dependencies and are limited by lack of data and sufficient system knowledge of interconnectedness. Frequently, specific components (materials) are limited to specific geographic regions which further exacerbates supply risk.
- Labor uncertainty is a concern with inadequate source or qualified workers in many cases. This results from insufficient training and demographic causes.
- Climate risks and the potential for political instability are major sources of concern.
- AI, quantitative modeling and automation are all important opportunities but have limitations due to limitations in data and process understanding.
- Governments have an important role in defining which industries are critical and when they can/should intervene to ensure resilience, but other responsibilities lie with individual firms.

Current Status:

- Current supply chains are at risk and resiliency is low. This is due to lack of data, regional concentrations and single sourcing of components, political and climate uncertainty and high complexity of global supply chains. Some of this has developed due to a push for economic competitiveness under normal operations but other factors are exogenous to the firm.
- Detailed understanding of supply chain risks is limited due to a lack of data, limited willingness to share the data that does exist, a lack of consistent definition for data elements and incomplete process mappings of the interconnected web of players and vulnerabilities.
- AI is growing in use, but this poses risks as AI systems are limited by data quantity and accuracy. Currently, AI may be useful for minor repetitive tasks but not for addressing major uncertainty.
- Blockchain solutions have yet to be proven effective due to cost and complexity of implementing trusted collaborative systems.

Commonly Identified Research Opportunities and Solution Approaches:

- Better models of supply systems are needed that provide a more comprehensive system description of interconnectedness of system entities and cascading impact potential in order to fully understand system vulnerabilities and allow prediction of the impact of various scenarios and recovery mechanisms. This might be referred to as more complete system mapping. Models should integrate sourcing and logistics networks and be suitable for use in disruption simulations.
- Comprehensive digital twins provide one possible avenue for understanding the impact of various disruption scenarios, but a better understanding of the full interconnected system and potential threat scenarios is needed to allow this.

- Better data collection and sharing are needed to populate those models. This includes clear definition of data elements. And, trust must be built among the global participants in the supply chain to facilitate data sharing.
- Metrics are needed for measuring system vulnerability and resilience effectiveness.
- Automation can help alleviate labor and other shortages for some disruptions. One example provided was that of oxygen generators that are typically manually assembled. Demand surged during the pandemic, but labor availability suffered due to infected workers.
- In other situations an integrated AI/Automation/Human solution is appropriate. Identifying such opportunities and building the collaborative systems is an opportunity given current technology. Understanding and incorporating human behavioral principles is a key element of this approach.
- Models for trading off operational "optimality" vs. reactive "optionality" are needed to enhance resilience. This involves long term sustainability vs. short term profit and determining how to exist in a competitive environment. Approaches such as stochastic optimization, chance constrained programming and multiobjective decision making may have applicability here.
- The role of governmental policy and support for building resilience enhancing options such as inventory investment and infrastructure expansion into critical supply chains should be addressed.
- Tools to aid small companies with limited IT and modeling expertise could be valuable in improving overall system resilience since these may often be the weakest link and least understood vulnerability. This could be especially important for lower level (Tier 3) suppliers.

Introduction

Background

Throughout history, supply chains have been instrumental in determining the health and advancement of societies. While for much of recorded history supply chains were primarily local, long distance trade routes nevertheless provided an avenue for incorporation of new materials and processes to enrich civilizations. In recent decades, advances in transportation, communication, technology and competitiveness created an opportunity for global labor markets and a need for rare materials leading to economic development in emerging markets and a rapid expansion of global supply chains. Such tight global coupling increased the sensitivity of society to disruptions from man-made and natural causes. Incidents such as the Covid-19 pandemic and Suez Canal blockage coinciding with Just-in-Time inventory policies impacted demand in addition to creating major shortages in supply of many goods. Recognizing the need to ensure human health and economic vitality in a tightly couple world, on February 24, 2021 the White House issued an Executive Order on America's Supply Chains focusing on assessing and strengthening America's supply chains particularly for critical industries. After that order, the Department of Homeland Security created a Supply Chain Resilience Center (SCRC) in 2023. To support this effort, the DHS Office of University Programs encouraged its Centers of Excellence to assist and the Center for Accelerating Operational Efficiency (CAOE) at Arizona State University proposed hosting a workshop on Supply Chain Resilience in conjunction with the Center for Cross-Border Threat Screening and Supply Chain Defense (CBTS) at Texas A&M University and the emeritus Command, Control and Interoperability Center for Advanced Data Analysis (CCICADA) at Rutgers University. This report covers the planning, actualization and findings of that workshop.

Objectives

The workshop had two primary objectives:

- To identify and bring together leaders from academia, government and industry to create a diverse community of researchers, policy analysts and problem domain owners united by common interest in the supply chain resiliency of critical industries; and
- To define a research agenda for the next 3-5 years that could advance relevant science and lead to measurable advances in the resiliency of critical industry supply chains.

Scope

Supply chains exist for all industries and there are many critical industries related to economic vitality, national security and human health. Given the broad nature of the task, in conjunction with the Steering Committee and SCRC the decision was made to focus on three key industries for the 2024 workshop: Semiconductor Manufacturing; Food/Agriculture Industry and Port/Maritime Operations.

Methodology

Workshop Preparation

Following the award to CAOE for organizing the workshop, an Organizing Committee was formed consisting of the following individuals:

Ronald Askin, CAOE, Organizing Committee Chair,
Greg Pompelli, CBTS,
Fred Roberts, CCICADA
Hilary Shackelford, DHS, OUP
John Caton, DHS SCRC
Tracie Hanson, DHS SCRC

The committee met biweekly starting in April 2024 and then weekly for the last two weeks before the workshop. Meetings were used to discuss the format, agenda, timing, location and set of participants for the workshop.

In preparation for the workshop, two additional activities were undertaken. First a Request for Research White Papers and a Request for Use Cases were distributed to the academic and government/practitioner communities respectively for input on prior work and relevant problems. These are shown in Appendix C along with evaluation criteria. Reviews on submitted white papers were conducted by the members of the Organizing Committee and several additional individuals recommended by Organizing Committee members. At least two reviews were obtained for each submission. The committee then collaborated on selecting the participants to be invited to SCRIPS based on the reviews. Selected white papers are provided in Appendix D.

Second, graduate student Digvijay Redekar was tasked with working with Dr. Askin to undertake a literature review of relevant supply chain resilience research papers and reports covering the three workshop tracks. The literature review along with the selected white papers were provided to the workshop participants prior to the event. The literature review appears in Appendix E.

Workshop Format

The scope and agenda for the SCRIPS Workshop were determined by the Organizing Committee. The agenda appears in Appendix A. The workshop can be seen as being composed of three phases – Introduction/Motivation, Thematic Discussions and Aggregation. The workshop began with participants introducing themselves and their interests to begin to develop a community of interested individuals. This was followed by a keynote from John Caton (DHS) on the importance of supply chain resilience and the workshop to DHS. Dr. Anna Nagurney, Eugene M. Isenberg Chair in Integrative Studies from the University of Massachusetts- Amherst then gave a research keynote entitled “Supply Chain Resilience Research: Insights from Agriculture & Food Supply

Chains" covering quantitative modeling and analysis of supply chains with emphasis on Dr. Nagurney's previous network modeling related to Food/Agriculture resilience.

The main portion of Day 1 was reserved for three breakout sessions. Workshop participants were divided into four groups representing the three focus industries and general SCR. Each group had a designated Discussion Leader and a Student Scribe for taking notes. Groups were instructed to select one member for briefly reporting their results to the full group following the breakout. Workshop participants are listed in Appendix B; breakout group assignments are shown in the Discussion section. The first breakout focused on creating a modified SWOT analysis for each area (Supply Chain Status/Weaknesses/research Opportunities/ Threats). Groups were asked to focus on the following questions:

What are the key components/steps in the supply chain?
What is the current health of the supply chain? Level of resilience?
What are the major areas of weakness?
What are the major threats/susceptibilities going forward:
What are the opportunities to strengthen the weak links?
Can we group and list problems?

After addressing these issues and reporting findings to the entire workshop, groups reconvened in their breakout groups to address Research Needs: Science and Solution Gaps. In this period, groups were asked to address the following:

What science is currently used to address SCR needs?
What are the knowledge gaps?
What science/knowledge is needed to address unresolved needs?
What knowledge is feasible in short term? Long term?
What data analytic tools/models could be developed to help?
Can we group these into topics/themes (Affinity exercise).

The final breakout of the day was designed to answer the question What Applicable Science can be Advanced and Applied? Groups were asked to consider:

What are the limits of data science for assisting supply chain resilience?
What problems can be attacked and what advances are needed?
For selected research avenues, what resources are needed and what outcomes are desired?

Day 2 began with a welcome from Rebecca Medina, Director of the DHS OUP. Director Medina expressed the importance of the mission and noted the value of bringing together multiple Centers of Excellence to address supply chain resiliency. This was followed by a general session with all four groups in attendance. The discussion focused on finding commonalities between groups based on the previous day's discussions and group summaries. Several themes emerged as discussed in the next section. The final breakout returned groups to their meeting rooms to summarize their findings and prioritize next steps. Groups were asked to develop a 3-D chart

documenting their research need recommendations along the axes of Feasibility, Impact and Resources Required. The Workshop concluded with a final session of breakout reports, discussion of next steps and a request to complete the workshop survey.

Report Preparation

Following the workshop, notes from the Scribes were collected along with flip charts from the breakout sessions. These were compiled and edited to create a draft report. The draft was then distributed to the Organizing Committee for comment and editing. Based on that feedback this final report was produced. Workshop participants were asked to complete a survey on their experience. Survey results are shown in Appendix F.

Discussion

A significant portion of the workshop was devoted to Breakout Group discussions. Four groups were convened focusing respectively on the three key industry themes and general supply chain resilience. This section documents those breakout discussions, critical insights generated and recommendations. These sections are closely adapted from notes taken by the session Scribes. Copies of the full reports produced by each scribe are available from CAOE.

Food/Agriculture

Breakout Group Composition:

Participant	Affiliation
Greg Pompelli (Leader)	CBTS
Wenting Li (Scribe)	Arizona State University
Manish Bansal	Virginia Tech
Alok Baveja	Rutgers University
Matt Cochran	CBTS
Erica Gralla	George Washington University
Deniz Karakoc	Arizona State University
Justin Louchheim	DHS CISA
Anna Nagurney	Univ of Massachusetts
Hamidreza Sharifan	Univ. of Texas at El Paso
Isabella Sanders	West Point
Yimin Wang	Arizona State University

Breakout Session 1: "SWOT: Supply Chain Weaknesses/Threats/Needs"

The first breakout session focused on conducting a SWOT analysis of the agricultural supply chain, particularly analyzing weaknesses, threats, and unmet needs in the current system.

Weaknesses in the Supply Chain

Key weaknesses in the agricultural supply chain include:

- **External Supplier Dependency:** The heavy reliance on international suppliers for essential inputs, particularly fertilizers, makes the U.S. agricultural system vulnerable to disruptions.
- **Labor Shortages:** Agriculture's reliance on migrant labor, exacerbated by immigration policy changes and global pandemics, creates vulnerabilities in labor availability.
- **Climate Risks:** Climate variability, including droughts, floods, and temperature extremes, poses persistent threats to food production and the broader supply chain.

- .**Information Gaps:** The lack of real-time, integrated information across the supply chain prevents farmers, processors, and distributors from making informed, timely decisions.

Threats to Supply Chain Resilience

Major threats to the agricultural supply chain include:

- **Political Instability:** Geopolitical tensions, trade restrictions, and tariffs can severely affect the flow of goods, impacting global food systems.
- **Market Consolidation:** The consolidation of market power within agribusiness, leading to ”too big to fail” risks, where the collapse of key players has far-reaching impacts.
- **Natural Disasters and Pandemics:** Events such as the COVID-19 pandemic and natural disasters highlight the vulnerabilities in supply chains from production to distribution.

Unmet Needs in the Supply Chain

Critical unmet needs identified in the session included:

- **Improved Data Systems:** Integrated, real-time data systems are needed to allow better decision-making and faster responses to market, environmental, and logistical changes.
- **Workforce Solutions:** Addressing labor shortages through both workforce development and investments in automation technologies, including robotics and AI.
- **Sustainable Practices:** Increased adoption of regenerative agriculture, water conservation, and soil health management to mitigate climate-related risks.
- **Diversified Supply Chains:** Reducing dependency on single suppliers or regions for critical inputs would improve resilience to global disruptions.

Breakout Session 2: Research Needs: Science and Solution Gaps

The second breakout session explored research needs, with a focus on identifying the science and solutions required to bridge the gaps in today’s agricultural practices.

Data and Information Systems

- **Big Data Integration:** Integrating disparate data sources, including climate models, market trends, and production statistics, is crucial for a holistic view of agricultural systems.
- **Real-Time Monitoring:** Real-time tools that monitor soil health, crop conditions, and weather patterns enable more efficient resource management and better decision-making.
- **Supply Chain Transparency:** Blockchain and other technologies can enhance

transparency, ensuring traceability throughout the supply chain and reducing inefficiencies.

Methods and Tools for Resilience

- **Decision-Support Tools:** AI-driven tools that provide real-time guidance based on data analysis can improve decision-making at the farm and distribution levels.
- **Automation and Robotics:** Advances in robotics can help address labor short- ages by automating processes such as harvesting and processing.
- **Resilience Metrics:** Standardized metrics for resilience are needed to measure and improve the supply chain's ability to withstand disruptions.

Workforce Development

The session also emphasized the importance of developing a skilled workforce capable of managing modern agricultural technologies.

- **Training Programs:** Targeted training programs should be developed to equip workers with skills in data analytics, advanced machinery, and sustainable practices.
- **Educational Outreach:** Universities should partner with industries to create interdisciplinary curriculums that prepare students for the diverse demands of modern agriculture.
- **Retention Strategies:** Incentive programs are needed to retain skilled workers in rural areas where labor shortages are most acute.

Breakout Session 3: Defining Science that Can Be Advanced and Applied

This session focused on identifying the scientific advancements that can be applied to improve agriculture and food systems.

Agricultural Biotechnology

- **GMOs and CRISPR:** Genetically modified organisms and CRISPR technology were identified as critical tools for improving crop yield, pest resistance, and climate adaptation.
- **Synthetic Biology:** The application of synthetic biology to develop new crops with enhanced nutritional value and growth efficiency.

Automation and Robotics

- **Robotic Harvesting:** Robots are increasingly used to harvest labor-intensive crops, such as strawberries and lettuce, helping address labor shortages.
- **Drones and Precision Agriculture:** Drones equipped with sensors enable precision farming, optimizing the use of water and fertilizers.

- **AI-Driven Farm Management:** AI platforms that integrate data from multiple sources provide actionable insights, helping farmers optimize planting schedules and resource use.

Environmental Science and Climate Adaptation

- **Climate Modeling:** More localized and accurate climate models are needed to help farmers adapt to changing weather patterns.
- **Water Conservation:** Technologies like drip irrigation and soil moisture sensors are vital for improving water efficiency in agriculture.
- **Carbon Sequestration:** Regenerative farming practices that improve soil health and sequester carbon should be further researched to address climate change.

Breakout Session 4: Revisiting Day 1 and Affinity/Synthesis Analysis

This session revisited discussions from Day 1, synthesizing insights on how to improve agricultural resilience and adaptability.

Lessons from Day 1

- **Supply Chain Agility:** The ability to adapt quickly to crises, whether pandemics or natural disasters, was highlighted as a key element of a resilient supply chain.
- **Data Integration:** Integrated real-time data remains crucial for making informed decisions throughout the supply chain.
- **Cross-Sector Collaboration:** Collaboration between government, academia, and industry is essential for addressing the complex challenges facing agriculture.

Synthesis and Analysis

- **Diversification:** A diversified supply chain—reducing dependency on specific regions or suppliers—was seen as a crucial step toward greater resilience.
- **Balancing Efficiency and Resilience:** While efficiency drives profitability, resilience ensures the system can withstand disruptions.
- **Global vs. Local Dynamics:** While global trade offers benefits, encouraging local production where possible can provide more security during global disruptions.

Case Studies

Several case studies were discussed to highlight real-world examples of supply chain challenges and technological advancements in agriculture.

Case Study: COVID-19 and Agricultural Supply Chains

The COVID-19 pandemic revealed significant weaknesses in global supply chains, particularly in agriculture. Disruptions in transportation, labor shortages, and export bans caused widespread uncertainty in food availability. The pandemic highlighted the importance of supply chain flexibility and diversification.

Case Study: Climate Change Impact on Coffee Production

The global coffee industry faces significant threats from climate change, as rising temperatures and erratic weather patterns reduce suitable growing areas. Countries like Brazil and Vietnam, the largest coffee producers, have started adopting climate-resilient varieties and water-efficient farming practices to mitigate these impacts.

Research Recommendations

To address the challenges discussed during the sessions, several research recommendations were proposed.

Data Systems and AI Research

More research is needed to develop integrated, real-time data systems that can be easily accessed by all stakeholders in the supply chain. AI-based decision-support tools should be further developed to provide real-time insights based on weather, market trends, and crop conditions.

Biotechnology and Crop Resilience

Further research into CRISPR and other gene-editing technologies can help create crops that are more resilient to drought, pests, and climate variability. Additionally, synthetic biology can develop crops with enhanced nutritional content and faster growth cycles.

Sustainable Agricultural Practices

Research into regenerative farming practices that sequester carbon and improve soil health can both mitigate climate change and improve crop productivity. These practices need to be tested and scaled across different regions and crop types.

Conclusion

The two-day meeting provided a comprehensive look at the agricultural supply chain's current challenges and future opportunities. The breakout sessions highlighted the pressing needs for improved data systems, workforce development, and the adoption of advanced technologies such as automation, AI, and biotechnology. By diversifying supply chains, promoting

sustainability, and fostering collaboration across sectors, agriculture can become more resilient to global disruptions.

Building a more robust, data-driven, and diversified supply chain is essential for meeting the growing demands of global food security. These lessons can guide future research and policy decisions, ensuring that agriculture remains resilient in the face of evolving challenges.

Semiconductor Manufacturing

Breakout Group Composition:

Participant	Affiliation
Chip White (Lead)	Georgia Institute of Technology
Mobasshira Zaman (Scribe)	Arizona State University
E. A. Elsayed	Rutgers University
Erik Hadland	Semiconductor Industry Association
Jenny Margaros	DHS CISA (Cybersecurity and Infrastructure Agency)
Hokey Min	Bowling Green State University
Daniel Muller	LLNL
Dale Rogers	Arizona State University
Sara Saberi	Worcester Polytechnic Institute
Michael Sherwin	Duquesne University
Matthew Wayland	Semiconductor Industry Association

Breakout Session #1: SWOT Analysis of the Semiconductor Supply Chain

What are the key components/steps in the semiconductor supply chain?

- The supply chain involves the procurement of essential materials like silicon and rare minerals, concentrated primarily in specific countries.
- Key processes include front-end operations such as wafer fabrication and lithography, followed by back-end operations like assembly and testing.
- The final stages encompass packaging and testing for quality and performance standards, then logistics for global distribution.

What is the current health of the semiconductor supply chain? Level of resilience?

- The health of the supply chain is critically dependent on geopolitical stability, particularly with countries that are primary sources of raw materials and manufacturing hubs.
- The level of resilience is generally low, characterized by geographic concentration of current semiconductor production steps and limited alternatives for critical raw materials and manufacturing capabilities.

What are the major areas of weakness?

- Significant geographical concentration in Asian markets for raw materials and manufacturing.

- High complexity and multiple dependencies within the supply chain create vulnerabilities to even minor disturbances.
- Very expensive to add capacity (the CAPEX of a fab) and long lead times in fab construction.

What are the major threats/susceptibilities going forward?

- Political instability in key supplier countries can lead to significant disruptions.
- Natural disasters such as earthquakes and typhoons in the Asia-Pacific region can severely impact operations.
- Technological obsolescence poses a continuous risk, requiring ongoing innovation and investment.

What are the opportunities to strengthen the weak links?

- Opportunities include diversifying supply sources and localizing parts of the supply chain to enhance control and reduce dependencies.
- Advanced forecasting models, including AI and machine learning, can predict disruptions more accurately and allow for dynamic adaptation of operations.

In general? Through research?

- Generally, enhancing strategic planning and operational flexibility can improve resilience.
- Research opportunities include exploring substitutes for rare or politically sensitive materials to reduce supply risks and investing in technological innovations to improve manufacturing efficiency.

Can we Group and List Problems?

- Limited sourcing options and high reliance on geographically unstable regions.
- Inflexible manufacturing processes that are slow to adapt to changes in the market or technology.
- Economic cycles affect demand fluctuations, impacting inventory management and production planning.
- Compliance with international trade regulations and environmental standards may impose additional costs or restrict operations.

Breakout Session #2: Research Needs: Science and Solution Gaps

What science is currently used to address SCR (Supply Chain Resilience) needs?

- AI, Markov Decision Processes (MDPs), and partially observed Markov games (POMGs) provide a basis for predicting disruptions and managing responses within supply chains.
- Digital twins, perhaps based on MDPs and POMGs, simulate real systems to anticipate disruptions, optimize responses, and enhance overall resilience.
- Statistical and machine learning models are used to analyze trends and prepare for potential disruptions in the supply chain.

What are the knowledge gaps?

- There is a substantial gap in integrating sophisticated predictive models into everyday supply chain operations.
- Data necessary for training effective predictive models is often inaccessible, leading to challenges in model accuracy and applicability.
- Effective collaboration between academic researchers and industry practitioners is lacking, which impedes the practical application of research findings.

What science/knowledge is needed to address unresolved needs?

- The development of more sophisticated AI tools capable of handling the complexities and dynamics of modern supply chains is needed.
- Technologies capable of managing and processing real-time data are required to provide instantaneous feedback and adjustments in supply chain management.
- Research into sustainable, reusable, and adaptable supply chain practices is necessary to improve resilience, reduce cost and energy consumption and reduce environmental impact.

What knowledge is feasible in the short term? Long term?

- In the short term, deploying existing predictive models and AI tools in pilot projects can address immediate operational gaps.
- Conducting workshops and collaborative sessions between academia and industry can quickly bridge knowledge gaps.
- In the long term, comprehensive studies to evaluate the impact of digital twins and advanced predictive models on supply chain resilience are necessary.
- Developing robust AI technologies that can predict and mitigate complex and interconnected supply chain issues over time.

What data analytic tools/models could be developed to help?

- Further development is needed for simulation models like digital twins that can predict various disruption scenarios and their potential impact on the supply chain.

- Custom AI tools tailored to specific challenges within different segments of the supply chain such as logistics, manufacturing, or distribution should be developed.
- Advanced analytics tools designed to help quantify and manage risks, possibly integrated into a central platform accessible to different stakeholders, would be beneficial.
- Blending AI and Operations Research tools and techniques for Next Generation analysis and accelerated digital twin development for evaluation and stress testing.

Can we group these into topics/themes (Affinity exercise)?

- Predictive Analytics: Encompasses all activities related to AI and machine learning, including the development and implementation of predictive models to anticipate and react to disruptions.
- Collaboration and Knowledge Sharing: Focuses on enhancing the flow of information between academia and industry, improving access to necessary data, and fostering effective partnerships.
- Sustainability and Agility: Covers research into implementing sustainable practices, developing agile response strategies, and creating adaptive models to respond quickly to market and environmental changes.
- Tools and methods for quantifying risks and managing them effectively through sophisticated decision-making frameworks are needed to ensure that supply chains can withstand and quickly recover from disruptions.

Breakout Session #3: What Applicable Science can be Advanced and Applied?

What are the limits of data science for assisting supply chain resilience?

- The primary limitations involve the lack of accessible, high-quality data, which hampers effective analysis. Uncertainties about the existence and location of necessary data further complicate the use of data science. Moreover, challenges in data sharing due to privacy concerns, data sensitivity, and organizational silos within and between entities limit comprehensive analysis.

What problems can be attacked and what advances are needed?

- Addressing vulnerabilities in supply chains through detailed network mappings and stress testing to identify critical failure points can be significantly enhanced by data science. Advances in digital twins and synthetic data usage could provide valuable simulations and modeling for scenarios where actual data lacks depth or availability. Integrating AI and machine learning could improve predictive analysis, spot weaknesses, and facilitate system redesigns for enhanced resilience.

For selected research avenues, what resources are needed, and what outcomes are desired?

- Necessary resources include broader access to quality data from diverse sources, such as industry and government. Investments are needed in AI technologies and platforms capable of handling digital twins and synthetic data. Creating cooperative frameworks to enable seamless data sharing and collaboration among stakeholders is crucial.
- Desired outcomes focus on enhancing the ability to predict and understand the impact of potential disruptions, leading to stronger supply chain resilience. Strategies to facilitate knowledge sharing are crucial, aiming to establish platforms where lessons learned and best practices can be exchanged across sectors to collectively improve the management of supply chain challenges.

Breakout #4: Revisiting Day 1 and Affinity/Synthesis Analysis

- Day 1 Discussions Focus:
  - Summarized and explored research ideas, especially in collaboration with DHS.
  - Evaluated the feasibility of research efforts in enhancing Supply Chain Resilience (SCR).
- Key Topics Covered:
  - Supply Chain Data Collection:
    - Emphasis on improving systemized data collection and visibility for SCR.
    - Proposal to create a commodity-focused data repository for supply chain mapping.
    - DHS was suggested as a potential facilitator for ethical sourcing and data repository creation.
  - Challenges and Barriers:
    - Privacy and Compliance:
      - Privacy concerns, particularly in international trade, hinder widespread information sharing.
      - DHS CBP's CTPAT framework assists in validating compliance, but broader challenges remain.
    - Blockchain Adoption:
      - High-cost inefficiency and concerns over data ownership and quality present barriers.
    - Industry Resistance:
      - Sectors like semiconductors resist sharing inventory data and adopting automation due to perceived risks and inequities.
  - Supply Chain Visibility and Disruptions:
    - Need for better visibility of suppliers and material interdependencies (e.g., corn oil vs. ethanol).
    - Critical for managing supply disruptions amid fluctuating demand, climate change, and natural disasters.
  - Role of DHS:
    - DHS expected to define critical priority lists.
    - These lists could help researchers focus their proposals more effectively.

Breakout Session #5 Prioritizing Short and Long-Term Research Needs

What can be done in the Short Term (2-5 years)?

- Digital twin/ generative AI (stress test, "what if"), SC redesign, Strategies for avoiding geographical concentration of key semiconductor manufacturing steps (2)
- Data collection, information sharing (4)
- Map (with GAI) all weak points of links for raw material processes and all agencies involved (1)

- Recycling, culture mentality (3)

What can be done in the Long Term (> 5 years)?

- RnD for alternative materials (locally available) such as chips' raw materials
- Climate change consideration, extreme weather events, all-hazard terms
- PPP for data sharing
- Planning:
    - Fab locations/ factory location selection
    - Socio-political risks
    - Workforce, development of workforce
    - Water supply
    - STEM for improvement
    - Financial reward (intensive)
    - Modular design
    - Recycling minerals and chips
    - Data (public-private partnership from government.)
    - Environmental changes: Climate change consideration, extreme weather events, all-hazard terms Socio-political risks (1)

What short-term options are most critical and possible (high impact probability)?

- Map (with GAI) all weak points of links for raw material processes and all agencies involved;
- Digital twin/ generative AI (stress test, "what if" analysis), SC redesign, Strategy for avoiding geographical concentration of key semiconductor manufacturing steps
- Recycling, culture mentality
- Data collection, and information sharing
- What long-term options are most promising?
- After completing short-term terms focus on long terms

What would a successful team look like (resource needs) for prioritized projects?

- PPP (data sharing)
- Interdisciplinary knowledge
- Modeling knowledge
- Analysis-strategy (NLP)
- Based on the priority of short-term to do as needed

Port/Maritime Operations

Participant	Affiliation
Fred Roberts (Leader)	CCICADA
Digvijay Redekar (Scribe)	Arizona State University
Brian Bassham	MIT Lincoln Laboratory
Terri Clower	George Mason University
Maryam Hamidi	Lamar University
Edward Huang	Auburn University
Juan Pimentel	DHS CBP
Kayla Schultz	USCG
Andrew Tucci	USCG
Niels Veenema	Tradepoint Atlantic

1) Breakout Session #1: Supply Chain Status, Weaknesses, Research Opportunities, and Threats (SWOT)

Strengths

- US ports and maritime operations are able to move large quantities of goods. The US marine transportation system (MTS) is physically large, with many ports and terminals providing flexibility in most cases.
- Compared to other transportation modes, maritime is usually less expensive and more flexible.
- There is a large labor pool to pull from when needed, and it includes a large pool of well-trained and skilled labor. (For example, Trade Point Atlantic in Baltimore doubled its rollon-rolloff (ro-ro) workforce after the Francis Scott Key Bridge collapse in March and was quickly able to sign a contract and begin receiving debris from the bridge.)
- Government and industry work well together, especially in times of crisis such as a natural disaster or a bridge collapse.
- The system is resilient, able to adapt to major issues such as hurricanes, bridge collapses, etc., and re-route vessel traffic efficiently so that goods continue to come in.
- While natural disasters pose constant threats, improved forecasting and policies for rapid response and relief are strengths.

Weaknesses

- The port/waterway infrastructure is aging.

- Locations for ports are naturally limited to coastal locations and limited by various geographical and physical conditions. Also, major ports are limited in ways to increase their capacity by an inability to expand inland or place higher and higher stacks of containers.
- Market forces drive large ships, benefiting consumers with low prices, but decreasing resilience during disruptions by limiting places those ships can go. Those larger vessels cannot get into all ports without more dredging and improved aids to navigation.
- Labor disputes pose a challenge. The early October 2024 dockworkers strike shut down ports from Maine to Texas and stopped the import/export of goods along the East and Gulf Coast ports.
- Lack of automation puts US ports behind "smart ports" in Antwerp, Rotterdam, Hamburg, Singapore, Shanghai, etc. Unions are resisting automation; this was a major issue in the early October strike as the workers want protection against losing their jobs due to increased port automation.
- Dependence on imported equipment is in many cases a weakness.
- Cyber vulnerabilities present a threat. Consider for example Chinese ship to shore (STS) cranes. One concern is that China might track specific cargo, enabling a targeted disruption. Or, a third actor (state or non-state) might figure out how to exploit cyber vulnerabilities in STS cranes.
- Climate change is a growing problem, for example with sea level rise maybe growing faster than we thought.

Opportunities

- While port infrastructure is older and maybe weaker, there is an opportunity to improve, build new, state-of-the-art infrastructure, and to redesign for resilience.
- Technology and innovation can really improve port operations. For example, AI, Internet of Things, Blockchain, Digital Twins, and 5G. Improved information sharing, interconnectivity, and interoperability can significantly improve terminal operating systems, ship to port communications, unloading operations, container yard usage, and, in general, situational awareness.
- Dredging provides the possibility of supporting larger cargo vessels at more ports.
- Reducing dependence on imported equipment could be accomplished by reshoring equipment manufacturing.
- Vulnerability assessment programs can improve resilience. So can use of historical data to plan for and respond to future disruptions of any nature.
- Learning how European and Asian ports were able to become "smarter" may help the US do the same. For example, one can ask why Rotterdam, with its powerful unions, has achieved automation without conflict (through phased labor replacement strategies) and

how Singapore tried to eliminate labor, e.g., through use of automated vehicles, and what worked and what didn't.
- Proactively developing response policies that are targeted at different kinds of disruptions can improve the ability to recover from them.

Threats

- Cyber attacks.
- There is considerable lack of knowledge about how ports work, especially in the smaller ports in the US where people running/managing ports sometimes have little understanding of how ports or the entire supply chain process works.
- Ports are vulnerable to a wide variety of disruptions: natural disasters, strikes, accidents, equipment failures, international events, etc. International events are a case in point, illustrated by the effect on the MTS of the Houthi attacks in the Red Sea and the low water in the Panama Canal.
- Ports often lack the redundancy to repair damage quickly and they often don't understand what makes them vulnerable.
- Climate change leads to more and more severe storms, low water on waterways such as the Mississippi, heat events affecting dockworkers, and sea level rise.

2) Breakout Session #2: Research Needs Science and Solution Gaps

This session focused on identifying gaps in research and technology that could enhance Supply Chain Resilience (SCR).

Port Operations/Port Capacity

- Overall resilience could be improved by identifying means to improve collaboration, risk management, and for automating routine tasks.
- Knowledge gaps here include ways to train personnel on risks, and identifying which personnel to train.
- Tools to improve port operations include more use of sensors and video tracking to understand ongoing situations; AI and machine learning to predict faults before they occur; and use of digital twins to test out physical changes before they are made.
- Social networks play a large role in ensuring that ports operate effectively and efficiently. How can the role of social networks be enhanced? And has increased automation and other industry changes reduced the strength of those port social networks?
- Would building offshore ports result in improved port capacity and improved cargo handling efficiency? While they might allow for handling of large vessels in ports that

today cannot handle them, there are questions about how such offshore ports would operate that need to be addressed.

- Ports do not exist in isolation. They are affected by issues involving rail, trucking, warehouses, roadway congestion, and availability of power, water, and means of communication. How can we better understand the challenge to port operations and vulnerabilities of ports to vulnerabilities outside a port? For example, if the BART system in San Francisco floods, no one can get to the port.

Data

- Data is key to improving operations of ports and, more generally, the MTS. Collaboration in data sharing, whether local or international, is important, though it is important to overcome compliance issues that hinder such sharing. Tools such as blockchain and AI could be helpful in developing better collaborations.
- A challenge is to identify who has access to what data.
- Developing ways to train port personnel on data privacy is relevant.
- Data analytic tools are important in disaster management, especially in securing essential resources like power, fuel, communications, and PNT (position, navigation and timing).
- Tools to improve data availability, data access, data sharing and data privacy include the theory of secure multiparty computation from computer science.
- Can we make private sector data available to researchers?

Disaster Preparedness and Response

- Spare parts inventories are important in responding to/recovering from disasters. Strategies for managing such inventories are needed.
- Preparing for the effects of climate change, either short-term with more storms and heat events and situations with low water, or long-term with sea level rise, is needed.
- Tools to improve disaster preparedness and, therefore, response, include simulations to test resilience strategies and identify redundancies.
- Who bears the cost of pre-disruption countermeasures and post-disruption countermeasures?

Supply Chain Issues

- International agreements to share early warning signs of supply chain disruptions are important. CBT, USCG, and other federal agencies all have various agreements with foreign counterparts on sharing information on emergent threats, but they may not extend to supply chain concerns except where the supply chain issue is incidental to more typical security or terrorist threats. (CTPAT includes agreements with other countries that they notify CBP of security risks they identify.)

- How do you identify critical components of supply chains? How deeply do you need to dive into a supply chain to find those components? Large companies have deep, complex supply chains that are very difficult to understand and small companies with simpler supply chains may find their supply chains easier to map but may not have the resources to do it. (For example, floods from hurricane Helene in September 2024 affected the world's primary source of high quality quartz used in all manner of electronics. How many companies would have known that the quartz going into some electronic device they use comes from North Carolina?) Can DHS-supported research help here?
- Some commodities are traded by only a few small traders, which is a vulnerability, but also means that only a few players really understand the source and potential scarcity of those supplies. How can we make such knowledge more widely known?

3) Breakout Session #3: Applicable Science for Future Advancement

Data Science, Artificial Intelligence

- There is so much excitement about AI nowadays. What are the limits of AI? What problems can best be attacked using AI tools and what problems are best left to human decision makers?
- Current AI systems can handle routine tasks but are not advanced enough to manage scenarios that feature operational failures, collisions, etc. without human intervention. Human-AI collaboration will be increasingly important as AI is more and more widely used. Ways to enhance such collaboration, such as training of humans, developing safety features for multiple robots involved in the same spaces as humans, and understanding the best ways for humans to utilize UAVs, will be important.
- Data availability, accuracy, and the ability to share it are critical for improving port operations. The performance of AI models is highly dependent on the quality and integrity of data, which is often lacking, e.g., in disaster contexts. What resources are needed to best develop and utilize data science?
- How can simulation such as agent-based modeling help in identifying port/maritime problems under different scenarios? While existing simulations may be helpful for responding to known risks, new tools and approaches are necessary for ascertaining impacts for unexpected or unanticipated events.

Economics of Ports and Maritime

- How do we understand the costs and benefits of resilience, and in particular redundancy, in the port/maritime domain?
- The willingness of maritime businesses to invest in resilience, for example through insurance-like mechanisms, should be examined. For example, what are the costs and

benefits of exempting businesses from inventory tax to promote resilience? What economic incentives for maintaining resilience might be developed?

- Supply chains are global and flexible; production can be moved to states or countries with fewer regulations and lower costs. Absent a global governance structure, public policies may have to rely on cooperation and persuasion. How can we build on concepts of voluntary regulation to design resiliency incentive structures? (Firms often regulate themselves, motivated by a desire for social legitimacy, social pressure from the public or customers, threat of regulation or eco-efficiencies. Can we tap into this?)
- How can we quantify the economic and political impacts of supply chain resilience strategies such as those based on local within-country incentive structures or regulations?
- Research on "behavioral economics" is lacking, particularly in areas like Red Team/Blue Team exercises. It is important to include human behavior considerations in port/maritime resiliency analysis.

Measurement

- It is important to understand how to measure the value of security in the port/maritime setting, as well as the cost of lack of security.
- In the port/maritime setting, how do we measure resilience? How do we quantify the tradeoff between cost and resilience? Would methods like those used by the Federal Highway Administration to estimate the value of a life assist with resilience quantification?
- How do we measure risk (threat, vulnerability, consequence), when we don't have a lot of experience with events, don't understand the threats, and we are dealing with low probability, high consequence events? Sometimes it suffices to start with qualitative comparisons rather than quantitative ones. It might help to understand how the insurance industry quantifies novel risks such as climate change. Or to understand how the SAFETY Act, which was designed to provide liability protection for certified products or facilities, might apply to ports.
- The value of clean air and water and other environmental considerations are very relevant issues for ports and maritime, both through state and federal regulations and international agreements. But how does one measure the value of clean air and other ecological benefits as these relate to port/maritime activities? For example, how does one measure investments in facilities to handle new types of fuels aimed at controlling greenhouse gases and vessel changes to utilize such fuels?

Electrification

- There is increasing use of battery-powered vehicles in ports. At what point do they become economical? And how resilient is the port at that point?

- As ports become more electrified, do they become more vulnerable to power outages? For example, would over-reliance on battery-powered vehicles in ports pose challenges to efficiency and resilience?
- Micro grids may promote resilience, but are opposed by large energy providers. What role can/will micro grids play in ports?
- Battery availability remains a key challenge for ports. Also relevant is how to handle delays for battery charging that make it much less attractive to use electrical vehicles in ports.

Fairness and Equity

- Distribution models have been widely studied, with the usual focus on cost minimization. However, methods to assess equity and fairness in distribution plans have only recently begun to be studied and more is needed. Can modeling and simulation help?
- Of particular interest are development of fairness metrics across different port stakeholders and in different contexts.
- Last-mile distribution is of special interest, especially in times of shortages or delays, for example in distribution of food after a natural disaster. What methods will allow rapid response that is also fair and equitable?
- Equity and fairness issues also need to be addressed in data sharing.

4) Breakout Session #4: Synthesizing Day 1 Revelations

This session focused on summarizing the Day 1 discussions, understanding the scope of research ideas, and evaluating the feasibility of research efforts in collaboration with DHS. Much of the discussion across the different teams gave rise to similar concepts. Some of those ideas that crossed over from food/agriculture, semiconductors, and ports/maritime were:

- Data sharing and data security are crucial.
- There is lots of data out there, but we need it to be useful and trusted. There is such an increasing risk of misinformation.
- Today's supply chains are not fully mapped, tracked, or understood. SCR can be enhanced through systematized data collection and improved visibility.
- Can we create a commodity-focused data repository with ethical sourcing for supply chain mapping, potentially facilitated by DHS.
- The complexity of today's supply chains and the wide variety of bad actors make visualizing supply chains and supply chain threats difficult.
- Blockchain's cost inefficiency, along with concerns over data ownership and quality, was noted as a significant barrier to its adoption.
- Resource needs include money, stakeholder engagement, and multi-disciplinary teams.
- Models of supply chains need a behavioral component.

- Network models need to be more multi-layered, multi-incident, and take into account cascading effects.
- There are so many independent actors in supply chains, which makes collaboration and trust difficult at times.
- Resistance from industries to share inventory data or adopt automation was linked to perceived risks and inequities. Improved visibility of suppliers and material interdependencies was deemed crucial for managing supply disruptions, especially amid fluctuating demand, climate change, and natural disasters.
- Tradeoffs between single- and multi-sourcing are still not fully clear.
- When we talk about resilience, for whom is that resilience?

Some more specific observations in this session were directly relevant to ports and maritime:

- Key needs in the ports/maritime area are improving infrastructure and initiating more automation.
- Labor disputes continue to roil the ports, and US labor unions continue to seek ways to protect jobs from automation.
- Resilience of ports and maritime operations is difficult to measure and understanding the costs and benefits of changes that enhance resilience is important. Ways to measure resilience are needed.
- Early-warning systems for disruptions to ports and maritime operations are needed and can build on private-private and private-public partnerships.
- Issues of privacy and compliance, particularly in international trade, are obstacles to widespread information sharing, despite initiatives like DHS CBP's CTPAT framework, which assists in validating compliance among collaborators.
- International partnerships are important. For example, CBP is building a system to communicate with foreign partners, including a model for exchanging data.
- International developments, such as low water in the Panama Canal and the Red Sea attacks by the Houthis affect the entire maritime supply chain.

5) Breakout Session #5: Prioritizing Short and Long-Term Research Needs

For the short term (2-5 years), the team identified several critical and feasible tasks, such as identifying concentrations of critical commodities (e.g., spare parts), categorizing disruptions to develop models and strategies, and addressing cyberattack mitigation. These actions were considered high-impact. Identifying critical component concentration and disruption categorization were judged to require relatively low to medium resources, making them suitable for immediate implementation. System automation and addressing aging infrastructure were also seen as critical topics that required more resources but were still achievable within

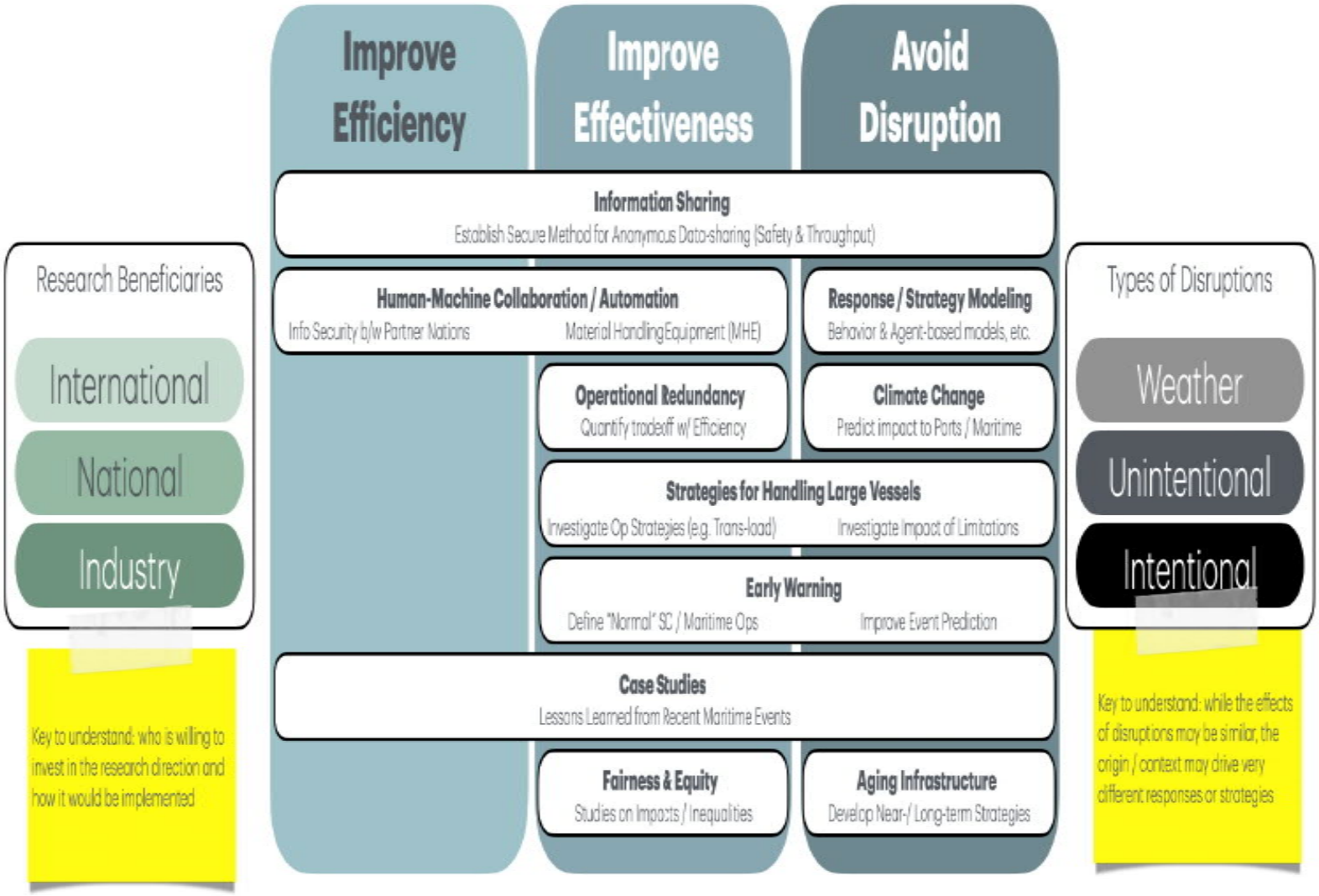
a short-to-medium-term window. In the long term (beyond 5 years), the team emphasized the importance of climate change mitigation, building infrastructure for larger vessels, and enhancing power, telecommunication and PNT (Positioning, Navigation and Timing) systems for smart ports. These efforts were deemed high-to-medium impact but resource-intensive, requiring more strategic planning and investment. Other research topics of somewhat lower impact but nevertheless important include new tools for information sharing, development of early warning systems, development of smart port automation (and related vulnerability assessment), and measurement of resilience. Other important topics, thought of even lower impact research, include developing tools for understanding and addressing concentration of container capacity, fairness and equity issues in distribution and data sharing, and identifying methods for judging the potential impact of international events. The team concluded that a successful project team might include experts in automation, cybersecurity, infrastructure, and policy, with sufficient resources for both technology upgrades and long-term infrastructure development. This would ensure that both short-term solutions and long-term resiliency strategies are effectively addressed. The following table shows the main topics considered by the team and their evaluation based on impact, feasibility of research and resources required to conduct research. It should be emphasized that judgments of impact, feasibility, and resources in the table are only rapid best guesses and should not be given a lot of weight.

Ports Resiliency Topics	Impact	Research Feasibility	Resource needs
Identifying concentration of critical commodities (spare parts)/stockpiling	High	High	Low
Categorizing/evaluating disruptions and identifying models, strategies/policies	High	High	Low
New tools for information sharing (company-company, company-government, with allies)	Medium	High	Medium
Fairness & equity (in data sharing, in post-disruption distribution)	Low	Medium	Low
System/information automation	High	Medium	Medium
Concentration of container capacity	Low	High	Medium
Early warning systems (including collaborative)	High	Medium	High
Climate change mitigation	High	Medium	High
Infrastructure required for large/growing vessel sizes	Medium	High	Low
Judging International events	Low	High	High
Cyber attacks (notification & mitigation)	High	High	High
Aging infrastructures	High	High	Medium
Smart ports: automation, vulnerability, resilience	Medium	High	Medium
Supporting infrastructure (power, telecom, PNT)	High	High	High
Tradeoff between resiliency and efficiency; measurement of resilience	Medium	High	Low

Team member Brian Bassham proposed the following figure for organizing the research topics discussed and identifying future research scope. Improvements to maritime port operations tend to address issues of efficiency, effectiveness, or disruptions. Impacts of several research applications could span one or more of these issues. It is also important to note the beneficiary of any research path. While localized improvements may benefit a local company, they may be of little use to the port authority or the end user. Thus, it is imperative to correctly identify the benefit—and potential

negative impacts—made to a “link” in the overall supply “chain.” Finally, disruptions to the supply chain are not all alike and may require very different response strategies to overcome.

Port Security / Supply Chain Resilience



(SCRIPS)

Breakout Group 4: General Supply Chain Resiliency

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Breakout Session 1

The breakout session participants covered a wide spectrum, including industrial engineering, cybersecurity, supply chain modeling, logistics, and resilience analysis. The discussion focused on the resilience of general supply chains, emphasizing identifying vulnerabilities, evaluating consequences, and examining strategies to enhance resilience against disruptions.

General Supply Chain Framework

The conversation revolved around the broad elements of a typical supply chain, which include:

1. Sourcing: Acquiring raw materials or products.
2. Transportation and Logistics: Moving resources from one stage to the next.
3. Production: Manufacturing or transforming products.
4. Distribution: Delivering finished products to consumers.

1. Vulnerabilities and Dependencies in Supply Chains

Participants discussed the importance of understanding vulnerabilities within the supply chain, which refers to the weak points or "single points of failure" that could cause a disruption.

- **Identification of Critical Nodes**: Supply chain resilience depends heavily on the identification of critical nodes that may serve as bottlenecks. For example, the availability of a specific raw material from a single supplier could be a vulnerability.
- **Interdependencies:** The interconnectedness of different elements in the supply chain was highlighted, where independent entities often pursue conflicting goals. This disconnect can lead to breakdowns during crises, as companies or sectors tend to optimize for their own objectives rather than the overall resilience of the supply chain.
- **Coordination and Collaboration:** Both domestic and international coordination were emphasized as essential for resilience. Globally, collaboration is crucial to understand the dynamics of foreign dependencies and mitigate risks effectively.

2. Data-Driven Approaches to Resilience

The discussion heavily touched on the role of data in improving supply chain resilience:

- **Data Collection and Analysis:** Participants agreed on the importance of data collection, specifically data that could minimize losses or ensure supply chain continuity. It was noted that much of the data currently available is the byproduct of other operations and not intentionally collected for resilience purposes.
- **Digital Twins and Simulations:** The use of digital twins—virtual models of supply chains—was discussed as a powerful approach for running simulations and stress tests. These digital models allow for better understanding of system behavior under various stress conditions and can help identify vulnerable points that need strengthening.
- **Data Gaps:** The challenges related to incomplete data sets were acknowledged. Many data sets may be incomplete or not real-time, making accurate resilience analysis difficult. Moreover, limited access to proprietary or restricted data adds additional layers of complexity.

3. Modeling Techniques

Modeling and simulation were highlighted as key tools to help predict and improve supply chain resilience:

- **Scenario Building:** Participants emphasized the need for creating different scenarios to model disruptions, such as natural disasters, economic downturns, or pandemics. Running scenarios through digital twin models can help determine which nodes in a supply chain are most vulnerable and where proactive interventions should be implemented.
- **Risk Assessment Tools:** The group noted the use of existing network theory and risk assessment tools for identifying vulnerabilities. Specifically, tools that analyze dependency graphs and vulnerability networks help identify which parts of a supply chain are most at risk.
- **Behavioral Modeling:** The importance of incorporating behavioral models was raised, focusing on how people or organizations would react to various disruptions. This aspect is crucial to understand unintended consequences of interventions, such as stockpiling or panic buying.

4. Threats, Consequences, and Interventions

The participants discussed the concept of "Risk" in terms of supply chain resilience, which comprises three elements: vulnerabilities, threats, and consequences.

- **Threat Sources:** Threats can come from both internal and external sources, including geopolitical tensions, market fluctuations, and natural disasters. Understanding where threats might originate helps frame the type of interventions needed.

- **Consequences Assessment:** It was emphasized that not all consequences can be reduced to financial terms. For example, delivery delays, integrity issues (e.g., contaminated products), or even loss of life cannot be fully assessed through financial metrics alone. Participants agreed that alternative metrics such as quality of life and human welfare are also necessary to capture the full scope of consequences.
- **Government Interventions:** There was significant debate about the role of government in supply chain resilience. It was argued that while the government should be prepared to intervene, they should also avoid taking over responsibilities that are best handled by the private sector. The key is to understand the authorities and leverage points that each stakeholder has and use them effectively.

5. Long-Term vs. Short-Term Resilience

The discussion also touched upon the tension between short-term problem-solving and long-term resilience planning.

- **Short-Term Resilience:** The group acknowledged that some supply chain disruptions require rapid response, often within days or weeks. In such cases, simulations and predefined models can help mitigate the impact.
- **Long-Term Resilience:** To build long-term resilience, supply chains need to identify underlying vulnerabilities and invest in strategies that can prevent such vulnerabilities from arising. This involves considering alternative suppliers, ensuring redundancy, and encouraging sectors to adopt long-term perspectives rather than focusing only on immediate profitability.

6. Challenges and Opportunities in Resilience Building

Several key challenges and opportunities were identified:

- **Global vs. Local Considerations:** The group emphasized that global supply chains pose unique challenges due to varying levels of cooperation and data availability. International collaboration is critical for strengthening global supply chains.
- **Prioritization of Resources:** Government and private entities need to identify which parts of the supply chain are critical for national security or economic health. Prioritizing resources towards strengthening these areas is crucial for resilience.
- **Adaptability to Changing Conditions:** Participants noted the challenge of preparing for low-probability but high-impact events. Techniques such as visualization, scenario planning, and simulation were suggested as ways to improve adaptability.

Key Takeaways and Actionable Items

Data Collection Strategy: Establishing what data should be collected, beyond operational byproducts, is critical. Data should be proactively gathered to inform resilience models and decision-making processes.

1. **Digital Twins Implementation:** Creating digital twins for key supply chains, even at a high level, can significantly help in stress testing the supply chain under hypothetical scenarios.
2. **Supply Chain Vulnerability Mapping:** Participants recommended implementing systems that can map out the entire supply chain—including suppliers and sub-suppliers—to better identify critical nodes and predict disruptions.
3. **Behavioral Analysis and Consequence Modeling:** There is a need to incorporate behavioral analysis into resilience planning. Understanding how human behaviors and policy decisions impact supply chains will improve preparedness for unforeseen events.
4. **Scenario Planning for Government Intervention:** The discussion highlighted the importance of delineating scenarios where government intervention is required versus those best handled by private actors. This will help streamline response efforts in a crisis.

Breakout Session 2

The discussion aimed to explore vulnerabilities within supply chains, evaluate their implications, and consider both short-term and long-term strategies to mitigate disruptions.

1. **General Supply Chain Vulnerabilities.** Critical weaknesses identified include
   - **Data Gaps:** Inadequate access to real-time and relevant data prevents effective risk assessment and diminishes resilience.
   - **Modeling Deficiencies:** Current models are insufficient for capturing the complexities of dynamic supply chains, particularly for shock assessments and risk mitigation .
   - **Single Points of Failure:** Many supply chains suffer from dependency on a single supplier for key materials or components. This presents a critical vulnerability.

2. **Supply Chain Complexity and Trust Issues:**
   - **Complexity and Collaboration:** Supply chain complexity and the involvement of multiple external actors are major challenges. Managing relationships and coordination between these actors is difficult, especially when they optimize for their own interests rather than the collective resilience of the supply chain.
   - **Trust in Sourcing:** Trust issues exist with international suppliers, particularly concerning goods like transformers for the power grid, which could be compromised with backdoors or vulnerabilities. Participants noted the lack of regulatory control in verifying the integrity of these products.

3. **Behavioral and Systemic Challenges:**
   - **Lack of System View:** There was a consensus that a holistic view of the entire supply chain is lacking. Participants emphasized the importance of understanding the interconnectedness of supply chain actors and fostering collaboration among stakeholders to establish a system-level understanding.

- **Human Behavior and Decision-Making:** Participants pointed out the disconnect between system-level models and behavioral aspects. The importance of incorporating human behavior modeling into supply chain risk assessment was highlighted, particularly in understanding decision-making under crisis.

Data-Driven Approaches

1. **Data Collection and Sharing:**
   - **Challenges in Data Collection:** Much of the data required for resilience analysis is not intentionally collected. Moreover, the available data often lacks completeness.
   - **Confidentiality and Trust Issues:** Data-sharing between companies, particularly competitors, is a challenge due to confidentiality and competitive advantage concerns. Railroads were noted as a critical part of the supply chain with limited data-sharing.

2. **Digital Twins and Modeling:**
   - **Role of Digital Twins:** The use of digital twins to create virtual models of supply chains for running stress tests and simulations to predict outcomes under disruption scenarios.
   - **Gaps in Existing Models:** Current supply chain models are often static and fail to capture dynamic changes or interdependencies effectively. Models that could evaluate the impact of disruptions, such as economic shocks, geopolitical instability, or pandemics, were seen as critical for improving resilience.

Strategies for Enhancing Resilience

1. **Scenario Planning and Threat Modeling:**
   - **Scenario Building and Planning:** Participants emphasized the need to create different disruption scenarios to identify vulnerabilities and plan mitigation strategies. This includes assessing risks from geopolitical tensions, cyberattacks, or natural disasters.
   - **Threat Modeling Framework:** A supply chain threat model similar to the MITRE ATT&CK framework for cybersecurity was suggested. This would help map out potential threats and aid in the development of countermeasures.

2. **Alternative Sourcing and Supply Chain Flexibility:**
   - **Alternative Sourcing Strategies:** Emphasis was placed on the need for diversification in sourcing to reduce reliance on single suppliers, especially for critical materials.
   - **Trust and Verification:** Improving verification processes for products entering supply chains was considered crucial for ensuring their integrity.

3. **Government Role and Interventions:**
   - **Public-Private Collaboration:** Participants discussed the importance of government intervention in building supply chain resilience, particularly in times of crisis.

Government agencies like DHS were seen as playing a key role in convening stakeholders and facilitating collaboration.

- **Long-Term vs. Short-Term Interventions:** The tension between short-term response efforts and long-term resilience planning was noted. Short-term measures often focus on immediate supply chain recovery, while long-term strategies should involve investing in redundancy, diversification, and continuous improvement.

Specific Recommendations and Models

1. **Knowledge and Research Gaps:**
   - **Incorporate Behavioral Insights:** There is a significant gap in integrating behavioral modeling with traditional supply chain models. Including human decision-making behaviors could provide better insights into supply chain disruptions and help anticipate the actions of different stakeholders during crises.
   - **Developing a Supply Chain Threat Model:** Establishing a standardized framework to identify, classify, and model different types of threats to supply chains. This framework could help organizations assess the vulnerabilities of their supply chains to both physical and digital threats.

2. **Operational Tools and Methods:**
   - **Advanced Optimization Models:** Participants highlighted the need for optimization models that could solve large-scale supply chain problems rapidly, allowing for real-time adjustments during disruptions.
   - **Data and Intelligence Sharing Platforms:** Creating platforms for secure data-sharing while maintaining confidentiality among supply chain stakeholders was recommended.

3. **Near Misses and Continuous Improvement:**
   - **Learning from Near Misses:** The importance of systematically recording and analyzing "near misses" was highlighted. Learning from these events could provide insights into vulnerabilities.

Key Takeaways

- The breakout session provided a comprehensive discussion on improving supply chain resilience through better data use, advanced modeling techniques, and a balance of government and private-sector interventions.
- The key focus was on identifying vulnerabilities, using digital twins and scenario planning for both short-term and long-term resilience, and understanding the full range of consequences, not just economic. Participants agreed on the need for greater collaboration among stakeholders, development of more robust data-driven tools, and integration of behavioral models to address the complexities of modern supply chains.

Breakout Session 3

The third breakout session explored the limitations and opportunities in modeling supply chain disruptions, especially when multiple or cascading disruptions occur. The participants discussed challenges related to multi-layered supply chain networks, integration of predictive and prescriptive models, and how best to utilize high-performance computing to address these challenges. They also delved into the difficulties of obtaining data, stakeholder engagement, and the current limitations of modeling tools in accurately assessing supply chain resilience.

Key Discussion Topics

1. **Modeling Multi-Layered Disruptions:**
   - **Complexity of Modeling Cascading Events:** Current models often assume a single disruption event. Participants stressed the need for models capable of handling cascading disruptions, such as infrastructure breakdowns and interdependencies between multiple supply chain actors. The importance of collaboration among stakeholders, such as energy providers, internet service providers, and water management authorities, was emphasized. These models may need high-performance computing (HPC) resources due to their increased complexity. This underscores the need for diverse stakeholder groups in emergency management and planning.

2. **Resource Allocation and System Resilience:**
   - **Proactive Deployment of Resources:** The discussion revolved around the optimal pre-deployment of resources for disruptions and the importance of designing supply chain networks to be resilient by ensuring that alternative pathways.
   - **Prediction and Prescription Integration:** There was a strong focus on integrating predictive modeling (e.g., identifying potential disruptions) with prescriptive models (e.g., determining the best course of action once a disruption is predicted). Avoid overdesigning or inefficient resource allocation by prescribing optimal responses that match predicted risks. Consider optionality rather than optimality as a criterion.

3. **Challenges in Accessing and Standardizing Data:**
   - **Data Access and Availability:** Participants pointed out the difficulties in accessing and sharing supply chain data. Unlike the healthcare industry, where data is systematically reported and aggregated, there is no equivalent for supply chain disruptions. A centralized repository of supply chain data could be invaluable, and participants expressed a need for a catalog of supply chain data for research purposes.
   - **Standardizing Data Formats:** Another key point was the lack of standardized formats for supply chain data, which hampers data analysis and sharing. The development of a starter data catalog for supply chain research and standardized data-sharing agreements across agencies was suggested to address these issues.

4. **Modeling Limitations and Future Directions:**
    - **Qualitative vs. Quantitative Modeling:** Some aspects of supply chain resilience are difficult to model quantitatively, such as geopolitical factors and stakeholder motivations. They suggested the need for structured qualitative approaches, like influence diagrams to complement quantitative models.
    - **Nested Modeling and Scalability:** The concept of developing "nested models" with scalable resource requirements was discussed. Participants noted that it is essential to have models that can operate at different levels of complexity and provide incremental insights as additional resources become available.

Resources and Implementation Needs

1. **Data and HPC Resources:**
    - **Funding and Stakeholder Engagement:** Participants highlighted the need for dedicated funding, stakeholder engagement, and establishing non-disclosure agreements (NDAs) to facilitate data sharing.
    - **Leveraging HPC:** Securing priority access to HPC resources, potentially through institutional support or alignment with DHS mission-critical needs, was emphasized.

2. **Knowledge and Expertise:**
    - **Cross-Disciplinary Teams:** It was noted that effective modeling requires multidisciplinary teams, including experts from academia, industry, and government agencies. Engaging industry stakeholders such as Walmart, Amazon, and Intel could provide real-world insights into supply chain vulnerabilities and help align academic research with practical needs.

Limitations of Data Science and Modeling

1. **Qualitative Factors:**
    - Political Dynamics: The unpredictability of political events and their impact on supply chains was identified as a factor that is challenging to model.
    - Stakeholder Behavior: Modeling the behavior of stakeholders in response to disruptions or incentives requires qualitative understanding.

2. **Current Limits and Opportunities:**
    - Unforeseen Events: The group acknowledged that there would always be elements that models cannot predict, particularly rare or unprecedented events. However, improving data analytics capabilities can expand what is possible.
    - Life-Cycle Considerations: There was a focus on incorporating long-term, life cycle thinking into supply chain design to ensure that networks remain resilient over extended periods. Participants suggested that long-term planning should consider

infrastructure investments and the need for flexibility in adapting to future changes, such as climate impacts on port facilities.

Key Takeaways

- The breakout session addressed multiple facets of supply chain modeling, focusing on the complexities of cascading disruptions, data access and standardization, stakeholder engagement, and the integration of predictive and prescriptive models.
- Key takeaways included the need for high-performance computing resources, the development of qualitative methods to complement quantitative models, and a greater emphasis on collaboration across disciplines and between public and private sectors.

Breakout Session 4

The general session was focused on summarizing key points from the previous day's discussions and looking for commonalities across group discussions. It explored the current state of supply chain systems, identifying critical resilience gaps, and brainstormed solutions that could enhance national and global supply chain stability. It delved into the role of small and large companies, government initiatives, stakeholder engagement, and future directions for better resilience.

1. **Supply Chain Complexity and Vulnerability:**
   - Modern supply chains are complex and involve numerous sub-systems and geopolitical influences.
   - There is significant risk associated with geopolitical stability and labor shortages. Resilient supply chains must address material sourcing, labor, and automation.

2. **Supply Chain Mapping and Re-Shoring:**
   - The idea of mapping supply chains to better identify weak points and dependencies was a recurring theme. Challenges involve ensuring transparency across multiple supply chain tiers and the need for collaboration to enable efficient re-shoring or near-shoring.
   - Need mapping initiatives to help both small and large companies visualize their upstream and downstream dependencies to better understand vulnerabilities.

3. **Automation, Labor, and Trust Issues:**
   - Automation was discussed as a solution to mitigate labor shortages and improve operational efficiency but has challenges of implementation and labor displacement.
   - The participants also raised the issue of data trust and collaboration between private companies and government bodies. This is critical for information sharing and a need to establish a framework for increasing trust between stakeholders, including government, private sector, and international partners, was identified.

4. **Cross-Sector and International Collaboration:**

- International collaboration was identified as essential for improving supply chain resilience. DHS and other agencies must work with global partners to ensure that critical information is exchanged securely.
- The collaboration between sectors was highlighted as necessary to form a more systemic understanding of supply chain risks. It was suggested that establishing common standards, definitions, and protocols could enhance collaboration.

5. **Supply Chain Threat Analysis:**
   - A supply chain threat framework, similar to MITRE ATT&CK for cyber threats, was proposed to provide a structured approach to identifying and mitigating risks within the supply chain.
   - Early warning systems were suggested as an important tool for preemptively identifying supply chain disruptions, such as shortages or risks to critical components, before they result in large-scale disruptions.

6. **Supply Chain Resilience Metrics:**
   - The concept of resilience metrics was discussed in depth, where participants debated the lack of established metrics to measure the resilience of supply chains.
   - Metrics could include recovery time objectives, time to restore supply chain operations after an event, and a clear understanding of the dependencies that could impact performance during a crisis.

7. **Scenario-Based Simulations:**
   - Participants considered the use of scenario-based simulations to understand the cascading effects of different types of disruptions. This included natural disasters like hurricanes, geopolitical events, and the impact of industrial shutdowns. Simulations would help organizations be better prepared for unpredictable events and provide insight into which supply chain components are most vulnerable to these disruptions.

8. **Blockchains and Data Privacy in Supply Chains:**
   - Blockchain was discussed as a tool to ensure secure, traceable data sharing across supply chains. However, concerns were raised regarding the cost and complexity of implementing blockchain on a global scale, particularly regarding reaching consensus among multiple stakeholders. There are practical challenges to global implementation.

9. **Role of Small and Medium Enterprises (SMEs):**
   - A recurring topic was the vulnerability of small companies within the broader supply chain network. Small suppliers typically lack visibility and resources to mitigate risks, which makes them susceptible to disruptions.

- There was discussion around developing AI tools or assistance programs to help small companies analyze and manage their supply chain risks. However, it was also noted that providing these companies with resilience plans is only half the battle—execution requires additional resources that small companies may lack.

10. Climate Change and Sustainability:

- Climate change was identified as an important factor that will increasingly impact supply chains. Participants discussed the role of climate-related events in supply chain disruptions and the need for supply chain models to integrate climate risk.
- Sustainability considerations were also touched upon, as companies are under increasing pressure to reduce carbon emissions. Building resilient and sustainable supply chains will require balancing efficiency, environmental impact, and resilience.

11. Prioritization of Supply Chain Criticality:

- A key discussion revolved around identifying which supply chains are critical from a homeland security perspective and require prioritized government intervention. Prioritization would help allocate resources effectively, especially when addressing complex supply chain networks. Participants suggested that the focus should be on commodities that are crucial for national security and infrastructure resilience.

Key Takeaways

- The session highlighted multiple avenues for improving supply chain resilience, including developing new frameworks for threat analysis, enhancing trust and collaboration between private and public entities, and implementing scenario-based planning for better preparedness. While the discussions acknowledged the potential role of technology—like blockchain and AI—in supply chain risk management, the practical challenges of implementing these technologies at scale were also emphasized.
- Moving forward, it was suggested that initiatives focus on developing resilience metrics, mapping supply chain dependencies, fostering multi-stakeholder collaborations, and using simulation-based approaches to prepare for future risks.
- There was also consensus on the need to prioritize certain supply chains, especially those critical for national security, while considering sustainability and climate impacts.

Breakout Session 5

The final breakout session returned to the thematic groups and addressed the prioritization of proposed initiatives based on impact, feasibility and resource requirements. The group plotted these initiatives and discussed implementation challenges, potential stakeholders, and practical approaches to these initiatives.

Assessment of Proposed Initiatives:

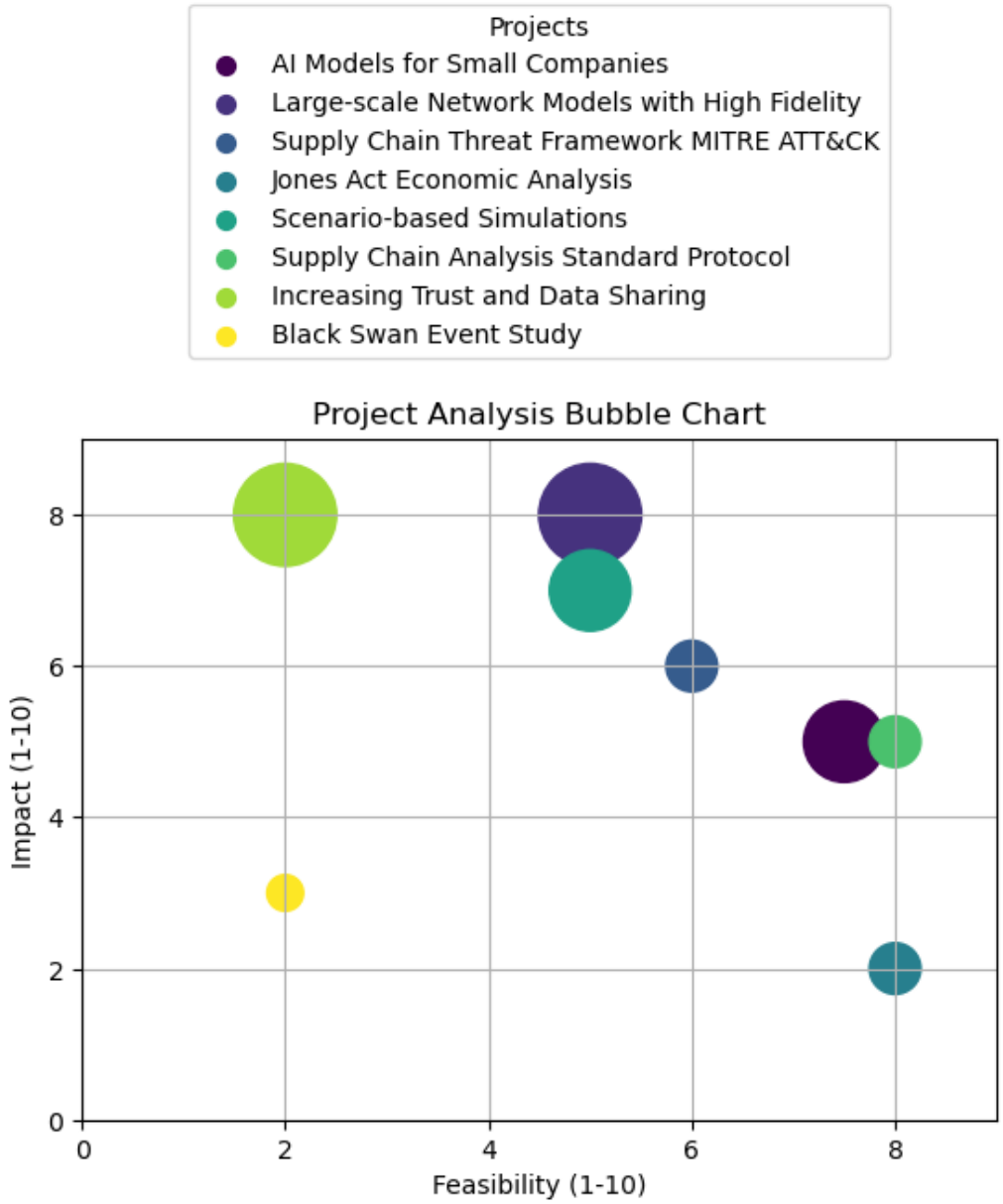
1. **Initiative Identification:**
   - The group identified eight key initiatives:
     - AI Models for Small Companies
     - Large-Scale Network Models with High Fidelity
     - Supply Chain Threat Framework (akin to MITRE ATT&CK)
     - Jones Act Economic Analysis
     - Scenario-Based Simulations
     - Supply Chain Analysis Standard Protocol
     - Increasing Trust and Data Sharing
     - Black Swan Event Study

   - **Plotting Impact vs. Feasibility:** Each of the eight initiatives was assessed and plotted on the chart shown below. The resource intensity of each initiative was visually represented by the **size of the plotted points**. Initiatives like the large-scale network models were expected to have high resource requirements, while initiatives such as the Jones Act analysis and scenario-based simulations had comparatively lower resource requirements.

2. **Individual Initiative Discussions:**
   - **AI Models for Small Companies:** The idea was to develop a tool to help small companies assess their supply chain resilience. It was assessed as having medium impact and high feasibility. The group also acknowledged that these AI models could suggest practical recommendations for resource allocation in smaller supply chains.
   - **Large-Scale Network Models with High Fidelity**: This initiative aimed at developing detailed multi-layered models incorporating different infrastructure layers and interdependencies (e.g., energy, communications, transportation). It was noted as having high impact but lower feasibility due to its complexity, requiring significant resources and collaboration.
   - **Supply Chain Threat Framework (MITRE ATT&CK-like):** The development of a comprehensive threat framework for supply chains was viewed as a high-impact initiative that could be feasible if implemented in phases. Phase one would establish a basic framework, potentially setting the stage for long-term scalability.
   - **Jones Act Economic Analysis:** The goal was to evaluate the economic implications of waiving the Jones Act in disaster scenarios. This initiative was assigned medium impact and high feasibility, with a relatively low requirement for resources. The analysis could leverage existing shipping data to assess the Jones Act's impact on disaster response.
   - **Scenario-Based Simulations:** This initiative aimed at running scenario-based simulations to understand the implications of potential disruptive events (e.g., cascading impacts, geopolitical disruptions). It was considered to have medium to high

impact but medium feasibility. Such simulations could help identify indicators of extreme events and enable proactive mitigation.

- **Supply Chain Analysis Standard Protocol:** The idea was to create a standardized format for supply chain analysis reports, similar to a public policy case study. This was seen as having a potentially significant impact if it facilitated a common understanding of supply chain issues across organizations. Feasibility was considered high due to the lower complexity and resource requirements.
- **Increasing Trust and Data Sharing:** Establishing rules of engagement and mechanisms to promote data sharing across entities, with a focus on improving data accessibility, was discussed. This initiative was considered to have high resource requirements and medium feasibility, as the challenge of fostering trust between stakeholders is substantial.
- **Black Swan Event Study:** The study aimed to understand how highly unlikely but impactful events could be modeled and anticipated. The group discussed approaches like multidisciplinary collaboration to create practical frameworks. However, the initiative was considered to have medium impact and low feasibility due to the inherent unpredictability of such events and the difficulty in deriving actionable insights.



3. **Cross-Disciplinary Collaboration:**
   - **Diverse Stakeholder Involvement:** The discussion highlighted the importance of involving diverse groups in developing and evaluating initiatives, including both governmental bodies and private sector representatives like Amazon and Walmart. Collaborative efforts were seen as critical to improving supply chain resilience.
   - **Behavioral Science and Trust Issues:** Participants emphasized the need to incorporate behavioral science perspectives to improve data-sharing agreements. Building trust between stakeholders could significantly enhance data sharing and collaboration, which was seen as key to tackling many of the identified challenges.

4. **Scenario-Based Approaches and Black Swan Events:**
    - **Approach to Scenario-Based Simulations:** The group discussed generating potential scenarios (e.g., geopolitical disruptions, natural disasters, supply chain attacks) to assess how supply chains react under different stressors. The value of scenario-based planning was recognized to build resilience and establish contingency plans for a wide range of events.
    - **Black Swan Event Considerations:** Participants explored how to integrate black swan events into strategic planning. They discussed the need to consider potential chain reactions, even when the initiating events are unlikely. The importance of multi-disciplinary input (e.g., political science, behavioral science) was highlighted.

5. **Short-Term vs. Long-Term Perspective:**
    - **Time-Bound Scope:** A crucial consideration was the time-bound nature of the center's funding. Participants stressed that initiatives must be scoped such that meaningful progress could be made within a three-year period.
    - **Phased Research Approach:** Several initiatives were framed in terms of initial phases, with proof-of-concept or pilot studies being emphasized for completion within three years.

Common Threads

Despite separate groups focusing on different industries, several common themes and research needs emerged across the breakout groups.

Common Themes:

- Supply chains are **international and complex**. There are many different players that make sharing data and understanding all risks difficult. Current models do not adequately cover the complexity of interactions/dependencies and are limited by lack of data and sufficient system knowledge of interconnectedness. Frequently, specific components (materials) are limited to specific geographic regions which further exacerbates supply risk.
- Labor uncertainty is a concern with inadequate source of qualified workers in many cases. This results from insufficient training and demographic causes.
- Climate risks and the potential for political instability are major sources of concern.
- AI, quantitative modeling and automation are all important opportunities but have limitations due to limitations in data and process understanding.
- There is an important role for government in defining which industries are critical and when government can/should intervene to ensure resilience, but other responsibilities lie with individual firms. Efficiency and resilience objectives may conflict and models/rules/policies are needed for guiding what resources should be provided pre and

post disruption to enhance resiliency. Similar issues exist for green infrastructure investments.

Current Status:

- Current supply chains are at risk and resiliency is low. This is due to lack of data, regional concentrations and single sourcing of components, political and climate uncertainty and high complexity of global supply chains. Some of this has developed due to a push for economic competitiveness under normal operations but other factors are exogenous to the firm.
- Detailed understanding of supply chain risks is limited due to a lack of data, limited willingness to share the data that does exist, a lack of consistent definition for data elements and incomplete process mappings of the interconnected web of players and vulnerabilities.
- AI is growing in use, but this poses risks as AI systems are limited by data quantity and accuracy. Currently, AI may be useful for minor repetitive tasks but not for addressing major uncertainty.
- Blockchain solutions have yet to be proven effective due to cost and complexity of implementing trusted collaborative systems.

Commonly Identified Research Opportunities and Solution Approaches:

- Better models of supply systems are needed that provide a more comprehensive system description of interconnectedness of system entities and cascading impact potential in order to fully understand system vulnerabilities and allow prediction of the impact of various scenarios and recovery mechanisms. This might be referred to as more complete system mapping. Models should integrate sourcing and logistics networks and be suitable for use in disruption simulations.
- Comprehensive digital twins provide one possible avenue for understanding the impact of various disruption scenarios, but a better understanding of the full interconnected system and potential threat scenarios is needed to allow this.
- Better data collection and sharing are needed to populate those models. This includes clear definition of data elements. And, trust must be built among the global participants in the supply chain to facilitate data sharing.
- Metrics are needed for measuring system vulnerability and resilience effectiveness.
- Automation can help alleviate labor and other shortages for some disruptions. One example provided was that of oxygen generators that are typically manually assembled. Demand surged during the pandemic, but labor availability suffered due to infected workers.
- In other situations an integrated AI/Automation/Human solution is appropriate. Identifying such opportunities and building the collaborative systems is an opportunity given current technology. Understanding and incorporating human behavioral principles is a key element of this approach.

- Models for trading off operational “optimality” vs. reactive “optionality” are needed to enhance resilience. This involves long term sustainability vs. short term profit and determining how to exist in a competitive environment. Approaches such as stochastic optimization, chance constrained programming and multiobjective decision making may have applicability here.
- The role of governmental policy and support for building resilience enhancing options such as inventory investment and infrastructure expansion into critical supply chains should be addressed.
- Tools to aid small companies with limited IT and modeling expertise could be valuable in improving overall system resilience since these may often be the weakest link and least understood vulnerability. This could be especially important for lower level (Tier 3) suppliers.

Workshop Evaluation

Workshop participants were encouraged to complete an online survey. Results are shown in Appendix F. Results were largely positive with participant comments particularly noting that they appreciated the chance to interact with other interested individuals from different roles and backgrounds and to build a network, and they gained an appreciation for the complexity of addressing supply chain resilience. Interestingly, the comments related to the breakouts were split between those wanting shorter sessions and those wanting longer sessions

About This Report

Grant Acknowledgement

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About the Center for Accelerating Operational Efficiency

The Center for Accelerating Operational Efficiency (CAOE) led by Arizona State University, develops and applies advanced analytical tools and technologies to enhance planning, information sharing and real-time decision making in homeland security operations. CAOE focuses on Data Science, Operations Research/Systems Engineering, Economic Analysis and Risk Sciences methods useful across the homeland security enterprise.

General Acknowledgements

The project team would like to thank Dr. Ross Maciejewski, Amy Bennett, Casey Lownes, Cynthia Gerber and Zachery Spencer from the CAOE for their support in this effort. We would also like to thank Hilary Shackelford from DHS OUP for her support of the workshop. Finally, we express our appreciation to the student scribes from ASU, namely Digvijay Redakar, Karthikeyan Chitrarasu, Mobasshira Zaman and Wenting Li for their note taking assistance.

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Appendix A: Workshop Agenda

SCRIPS: A Workshop on Supply Chain Resilience Issues, Problems and Solutions for the Homeland Security Enterprise

Agenda
October 1-2, 2024
Texas A&M University Bush School of Government & Public Service
1620 L Street NW
Washington D.C. 20036

Tuesday October 1, 2024

8:00 – 8:30am	Continental breakfast available and Registration
8:30 – 8:50am	Welcome and Setting Expectations Ross Maciejewski, CAOE Director Greg Pompelli, CBTS Director Ron Askin, CAOE Exec. Director and Workshop Chair Hilary Shackelford, CAOE Program Manager
8:50 - 9:10	Introductions
9:10 - 9:40	DHS Keynote: Asst. Secretary Christa Brzozowski and John Caton
9:40 - 10:30	Research Keynote: "Supply Chain Resilience Research: Insights from Agricultural & Food Supply Chains" Prof. Anna Nagurney
10:30 – 10:45	Break
10:45 – 11:00	Breakout Organizing and Instructions
11:00 – 12:00	Breakout # 1: "SWOT*: Supply Chain Weaknesses/Threats/Needs"
12:00 – 12:15	Brief Breakout Reports
12:15 – 1:15pm	Lunch
1:15 – 2:30	Breakout # 2: Research Needs: Science and Solution Gaps - Data, Methods. Workforce, Tools, Platforms
2:30 -2:45pm	Brief Breakout Reports
2:45 – 3:00pm	Break
3:00 – 4:00pm	Breakout #3: Defining Science that can be Advanced and Applied
4:00 – 4:30pm	Breakout Reports
4:30 - 4:45pm	Wrap Up
5:00 -	No Host Networking Reception

Wednesday October 2, 2024

8:30 – 9:00	Continental Breakfast available
9:00 – 9:10	Welcome by Rebecca Medina, Director DHS OUP
9:10 – 9:55	Breakout #4: Revisiting Day 1 and Affinity/Synthesis Analysis
9:55– 10:10	Breakout Reports
10:10 - 10:20	Break
10:20 – 11:20	Breakout #5: Prioritizing Short & Long Term Research Needs: Importance/Feasibility
11:20 – 11:40	Breakout Reports
11:40 – 12:20	Final Wrap Up, Synthesis and Plan Going Forward
12:20– 1:00	Lunch

Breakout Groups

- Agricultural Supply Chains
- Semiconductor Manufacturing Supply Chains
- Maritime/Port Supply Chains (Roberts and Rose)
- Supply Chain Resilience – General HSE Issues

SWOT* modified to Status/Weaknesses/research Opportunities/Threats

Appendix B: Workshop Participants

Last Name	First Name	Title	Company/Organization
Askin	Ron	Executive Director	Arizona State Univ
Bansal	Manish	Associate Professor	Virginia Tech
Bassham	Brian	Tech Staff, Transportation Safety & Logistics	MIT Lincoln Lab
Baveja	Alok	Professor	Rutgers University
Bennett	Amy	Assistant Director	Arizona State Univ
Betak	John	Consultant	
Caton	John	Policy Analyst	DHS HQ:SCRCr
Chitrarasu	Karthikeyan	Student	Arizona State Univ
Clower	Terry	Professor	George Mason Univ
Cochran	Matt	Research Director	TAMU-CBTS
Conrado	Aaron	Program Coordinator	DHS Office of Univ Programs
Elsayed	Elsayed	Distinguished Professor	Rutgers University
Gerber	Cynthia	Communications Specialist	CAOE
Gralla	Erica	Associate Professor	George Washington Univ
Greening	Lacy	Assistant Professor	Arizona State University
Hadland	Erik	Director of Technology Policy	Semiconductor Industry Assoc
Hamidi	Maryam	Associate Professor	Lamar University
Hanson	Robert	Associate Program Leader for National Security Infrastructure	Lawrence Livermore Nat'l Lab
Huang	Edward	Associate Professor	Auburn University
Jones	Beth	Managing Director	CAOE, ASU
Karakoc	Deniz Berfin	Assistant Professor	Arizona State Univ
Kincaid	Chris	Policy Analyst	DHS, SCRC
Kolasky	Bob	Senior Vice President	Exiger
Li	Wenting	PhD student	Arizona State Univ
Louchheim	Justin	Food and Agriculture Liaison	DHS CISA
Lownes	Casey	Project Manager Associate	CAOE
Maciejewski	Ross	Director	CAOE, SCAI
March	Peter	University Professor	Rutgers Univ
Margaros	Jenny	Section Chief	DHS/CISA

Medina	Rebecca	Director, Office of University Programs	DHS
Min	Hokey	Professor	Bowling Green State Univ
Muller	Dan	Security Researcher	Lawrence Livermore Nat'l Lab
Nagurney	Anna	Eugene M. Isenberg Chair in Integrative Studies	University of Mass-Amherst
Pimentel	Juan	Branch Chief	DHS CBP
Pompelli	Gregory	Director	CBTS
Redekar	Digvijay	Research Assistant	Arizona State Univ
Roberts	Fred	Professor of Mathematics and Director of CCICADA	Rutgers University
Rogers	Dale	ON Semiconductor Professor of Business	Arizona State Univ
Saberi	Sara	Associate Professor	Worcester Polytechnic Institute
Sanders	Isabella	Assistant Professor	United States Military Academy
Schultz	Kayla	CG-NAV-1	US Coast Guard
Shackelford	Hilary	Program Manager	DHS Ofice of Univ Programs
Sharifan	Hamidreza	Assistant Professor	University of Texas at El Paso
Sherwin	Michael	Assistant Professor	Duquesne Univ
Spencer	Zachary	Administrative Specialist	CAOE
Stubbs	John	Senior Cyber Operations Analyst	TSA
Tucci	Andrew	Owner	Tempest Marine LLC
Uster	Halit	DR	Southern Methodist Univ
Veenema	Niels	Director of Marine Operations	Tradepoint Atlantic
Wang	Yimin	Associate Professor	Arizona State University
Wayland	Matthew	Global Policy Associate	Semiconductor Industry Assoc
White	Chelsea	Professor	Georgia Institute of Tech
Zaman	Mobasshira	Student	Arizona State Univ
Zhuang	Jun	Associate Dean for Research, Morton C. Frank Professor	University at Buffalo

Appendix C: Call for White Papers

Call for Research White Papers

Call for White Papers and Workshop Participation

Supply Chain Resilience Research Needs for Homeland Security

The Center for Accelerating Operational Efficiency (CAOE) at Arizona State University, a Department of Homeland Security (DHS) Center of Excellence, will host a Workshop entitled *SCRIPS: Supply Chain Resilience Issues, Problems and Solutions for the Homeland Security Enterprise* in Washington D.C. October 1-2, 2024. SCRIPS will bring together leaders from academia, government and industry to identify research needs to ensure the resiliency of critical supply chains. In particular, the workshop will focus on three areas: **Ag/Food industry**; **Semiconductor Manufacturing**; and **Maritime/Port Operations**. In preparation for that event, CAOE is soliciting the research community for white papers covering innovative supply chain resilience research ideas and solution methods as they relate to Homeland Security.

Individuals and research groups with relevant interest and expertise are invited to provide white papers as described below. A limited number of respondents will be invited to attend the workshop to further develop prioritized research problem statements and solution approaches. The workshop's results are anticipated to be used in the development of a Request For Research Proposals (RFP) to be distributed in Spring 2025. Travel expenses will be provided for a limited number of invited participants from accredited academic institutions in the United States.

Submissions will be evaluated based on demonstrated expertise, importance of the problem addressed and the scientific merit and applicability of the solution methodology proposed. Research agendas should have a maximum three-year horizon. Selected contributors will be invited to participate in the October 1-2 workshop.

White Paper Requirements and Acknowledgements:

- White Papers are limited to at most two (2) pages in at least 11 pt font;
- White Paper format should follow the Research Needs/Models/Tools/Solution Template;
- White Papers must be submitted by 11:59pm EDT June 30, 2024 to the following: https://easychair.org/conferences/?conf=scrips2024
- Submissions must be available for distribution to workshop attendees, publication on workshop website, use in final workshop report and summarization in subsequent RFP. Submission implies such consent.
- Workshop attendance will be by invitation only. Invited participants will be notified by July 31, 2024.

Research White Paper Submission Template

Supply Chain Resilience Research Needs/Models/Tools/Solutions Template

Contact Information:

Name: **E-mail:**

Organization: **Position/Title:**

Acknowledgement:

I, _____ (*full name*) acknowledge that the content of this white paper has not been previously copyrighted and the CAOE and DHS are granted a nonexclusive right to reprint and/or distribute its content for noncommercial purposes including the SCRIPS Workshop, workshop report and subsequent RFP.

- **Indicate whether you would like to be considered for participation in the SCRIPS Workshop**;

_____ Yes, I am interested in being considered for attendance at the SCRIPS Workshop.

_____ No, I am not interested in being considered for attendance at the SCRIPS Workshop.

Title:

Problem Addressed (250 words max):

Existing Relevant Research (list publicly available papers, reports, etc.)

Research Gap and Possible Solution Approach (500 words max):

Research Statement White Paper Reviewer Template

SCRIPS Research Statement Submission Review Report

Submission Number:

Title:
Authors:
Reviewer:

EVALUATION

Problem Statement Evaluation:

__ 4: Recommended for workshop discussion;

__ 3. Possibly of interest, consider for workshop discussion;

__ 2. Somewhat relevant, but not sufficient relevancy or importance;

__ 1. No further consideration warranted.

Please rate each of the following on a scale:

1 (low/poor) to 3 (minimally acceptable) to 5 (very high/excellent):

____ Clarity of problem and methodology description;

____ Thoroughness of description (ability to operationalize at workshop);

____ Relevance of the problem to DHS supply chain concerns;

_____ Likelihood of occurrence of problem;

_____ Criticality/Potential severity of Impact;

_____ Feasibility of solution approach;

_____ Novelty/Originality/Scientific Contribution of solution approach

Comments (Please provide justification for ratings and include strengths and weaknesses of the submission):

Strengths:

-

Weaknesses

-

Researcher Evaluation:

___ 4: Recommended for workshop invitation;

___ 3. Consider for workshop invitation if space available;

___ 2. Somewhat relevant, but not highly recommended for invitation;

___ 1. No further consideration warranted.

Please rate each of the following on the scale:

1 (low/poor) to 3 (minimally acceptable) to 5 (very high/excellent) or leave blank if unknown.

____ Relevance of the researcher background, knowledge and interest;

_____ Capability of researcher to produce relevant, useful results;

_____ Capability of researcher to provide significant scientific contribution;

Comments (Please provide justification for ratings and include strengths and weaknesses of the submission):

Strengths:

-

Weaknesses:

-

Call for Use Cases

Call for Problem Statements and Workshop Participation

Supply Chain Resilience Problem Statements ("use cases") for Homeland Security

The Center for Accelerating Operational Efficiency (CAOE) at Arizona State University, a Department of Homeland Security (DHS) Center of Excellence, will host a Workshop entitled *SCRIPS: Supply Chain Resilience Issues, Problems and Solutions for the Homeland Security Enterprise* in Washington D.C. October 1-2, 2024. SCRIPS will bring together leaders from academia, government and industry to identify key concerns and research needs to ensure the resiliency of critical supply chains. In particular, the workshop will focus on three areas: **Ag/Food industry**; **Semiconductor Manufacturing**; and **Maritime/Port Operations**. In preparation for that event, CAOE is soliciting problem statements/use cases describing existing and anticipated threats to safety and economic activity due to supply chain disruption in the above industries.

Government and industrial entities concerned with supply chain resilience are invited to provide problem statements for discussion and research consideration as described below. A limited number of respondents will be invited to attend the workshop to further develop prioritized research problem statements and solution approaches. It is anticipated that the results of the workshop will be used in the development of a Request For Research Proposals (RFP) to be distributed in Spring 2025.

Submissions will be evaluated based on importance of the problem addressed and potential for meaningful recourse through the use of data analysis, quantitative modeling and information science approaches. Significant solutions should be developable within a maximum three-year horizon. Selected contributors will be invited to participate in the October 1-2 workshop.

Problem Statement Requirements and Acknowledgements:

- Problem Statements are limited to at most two (2) pages in at least 11 pt font;
- Problem Statement format should follow the Problem Statement Template;
- Problem Statements must be submitted by 11:59pm EDT July 12, 2024 to the following: https://easychair.org/conferences/?conf=scrips2024
- Submissions must be available for distribution to workshop attendees, publication on workshop website, use in final workshop report and summarization in subsequent RFP. Submission implies such consent.
- Workshop attendance will be by invitation only due to space limitations. Those requesting attendance will be notified by July 31, 2024.

Use Case Submission Template

Supply Chain Resilience Problem Statement ("use case") Template

Contact Information:

Name: **E-mail:**

Organization: **Position/Title:**

Acknowledgement:

____ I _____ (*full name*) acknowledge that the content of this use case has not been previously copyrighted and the CAOE and DHS are granted a nonexclusive right to reprint and/or distribute its content for noncommercial purposes including the SCRIPS Workshop, workshop report and subsequent RFP.

- Indicate whether you would like to be considered for participation in the SCRIPS Workshop;

_____ Yes, I am interested in being considered for attendance at the SCRIPS Workshop,

_____ No, I am not interested in being considered for attendance at the SCRIPS Workshop.

Use Case Title:

DHS Component Agency and Potential Customer for Solution:

Brief Description of Problem/Threat/Weakness (250 word max):

Potential Severity of Threat (1 = Minor, 5 = Severe, i.e. many lives/$x bn economic loss):

Likelihood of Threat Occurrence (1 = Unlikely (<1%); 3 = Possible (33-50%); 5 Highly Likely (>80%):

Current Approach/Mitigation Strategy and Expected Effectiveness (500 word max):

Use Case Reviewer Template

SCRIPS Use Case Submission Review Report

Submission Number:

Title:

Authors:

Reviewer:

EVALUATION

Overall evaluation:

__ 4: Recommended for workshop discussion and invitation;

__ 3. Possibly of interest, consider for workshop discussion and invitation;

__ 2. Somewhat relevant, but not sufficient relevancy or importance;

__ 1. No further consideration warranted.

Please rate each of the following on a scale 1 (low/poor) to 4 (very high/excellent):

____ Clarity of case description;

____ Thoroughness of description (ability to operationalize at workshop);

____ Relevance of the problem described;

____ Likelihood of occurrence of problem;

____ Criticality/Potential severity of Impact;

Comments (Please provide justification for ratings and include strengths and weaknesses of the submission):

Strengths:

-

Weaknesses:

Appendix D: Selected Submissions

A total of 36 white papers were submitted. All submissions were reviewed by at least two reviewers. Following those reviews, 27 were selected by the organizing committee for inclusion in the workshop. The lead authors were invited to participate in the workshop and all selected submission were provided to workshop attendees prior to the workshop.

Selected Food/Agriculture Submissions

See attached *SCRIPS Food Ag* file

Selected Ports/Maritime Operations Submissions

See attached *SCRIPS Ports* file

Selected Semiconductor Manufacturing Submissions

See attached *SCRIPS Semiconductor* file

Selected General Supply Chain Resilience Submissions

See attached *SCRIPS General* file

Appendix E: Supply Chain Resilience Literature Review

See attached

Appendix F: Participant Survey Results

Participants were asked to complete the following survey. For questions 1 through 7 and 9 response options were on a five point scale of the type "Very dissatisfied/Strongly disagree", "Dissatisfied/Disagree", "Neutral", "Satisfied/Agree" "Very Satisfied/Strongly agree".

SCRIPS Post-Event Survey

1. How satisfied were you with the SCRIPS event overall?*
Select

2. The information provided was clear and easy to understand.*
Select

3. How satisfied were you with the talks delivered by the keynote speakers?*
Select

Additional comments (optional)
Please provide any additional comments about the talks delivered by the keynote speakers.

4. How useful was the information content discussed during the event for your professional application or research?*
Select

5. There was sufficient time for adequate discussion and consideration of the topics during the event.*
Select

6. The event provided good opportunities for networking with other attendees.*
Select

7. The breakout sessions were relevant and added value to the overall event.*
Select

8. What was your biggest takeaway from the SCRIPS event?*

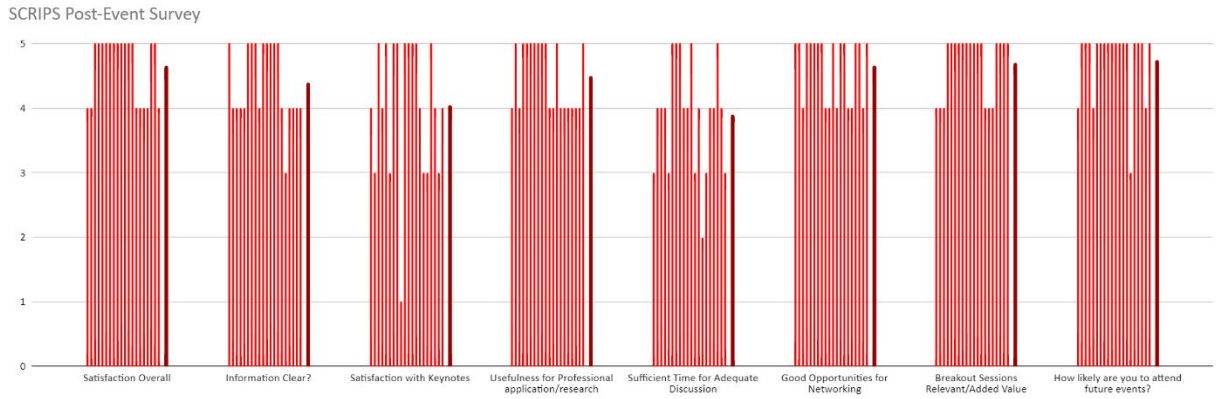
9. Based on your experience, how likely are you to attend future events?*
Select

10. Do you have any general comments, suggestions, or ideas for how we can improve future events? (Please write your response below.)*

Would you like to receive information about CAOE in the future?*

Yes

No



Comments received:

Additional comments (optional) I missed the first day, but the second day was really interesting and I enjoyed it This was a great open forum for collaboration and information sharing!! Dr. Nagourny's focused on her talk on her own accomplishments rather than providing context for workshop participants. I enjoyed Anna's talk! It was very interesting. It could be better if the sessions were shorter I feel it rather strange to evaluate my presentation but I appreciated the comments made to me afterwards. Keynote speaker was a little heavy on the math, but heck, I'm a knucklehead, so maybe it made sense to others. The keynote speaker was very informative.
Biggest Takeaway Ron is awesome! Networking and gaining a better understanding of topics within the context of DHS Better understanding of DHS research need Common interest Collaboration Resilient planning and meeting new people further insights into resilience and research ideas to think about. New ideas for projects and development of future projects to request from CISA and DHS Both the complexity and vulnerability of supply chains. An appreciation of various factors that impact supply chain resilience The need for supply chain research How important it is to have such a workshop! The maritime trend of larger container ships may be reducing supply chain resilience. Supply chains are enormously complex. Finding weak links and nodes that are relevant to DHS is even more complex. There are some individuals with whom I will have further conversations. Networking with HSD officials The opportunity to learn and discuss various topics from individuals of the private sector and academia. The ideas that were presented and debated makes this event an excellent venue to bring everyone to the table with the objectives and concerns about Supply Chain Security. networking Supply Chain Resiliency is a very broad subject and it will be challenging to narrow down the subjects,

targeted for research. Need for study/measure of supply chain resilience from a whole-system rather than company perspective
General comments, Suggestions, or Ideas Thank you! Great to expand efforts going forward Allocating more time for breakout sessions It was good It was well run and productive. thanks Great networking for new ideas and out of the box thinking It would be nice if we could also invite some industry people to hear their perspectives. The sessions may be more efficient to be shorter "I thought that the workshop was excellently organized but, perhaps, it could have used two full days. The discussions were very insightful and useful. The professional support and staff were outstanding and the lunches delicious! I very much enjoyed the interactions but would have benefited from additional opportunities to meet folks outside of my breakout session. It might have been nice to have a few more presentations. Thanks for the hard work on the workshop and congratulations on its success. I look forward to the additional outcomes." It's difficult to assimilate breakouts in a few minutes for a report out. Post meeting activities will be needed for the final report to show how the information provided gets distilled/organized/structured/assimilated and turned into something really useful for DHS. The purpose of the event was unclear, which impacted all of our activities. We would have benefited from some opening discussions that defined, or at least discussed, how supply chain resilience is relevant to DHS and the private sector. This would have helped the workshops focus our work and prioritize topics and solutions. Perhaps lengthening the breakout group by shortening the time of keynote speaker presentations. That requires some of the speakers to be more focused and concise in terms of the message they are trying to deliver. Need to extend the invitation of practitioners. Parking is difficult. Perhaps, a 3 days event with speakers from all perspectives: Government, Academia and Private Sector. For this event, the speaker focused on the research conducted to enable resilience, but it would crucial to also provide a operational point of view, as well as the challenges that are faced by the private sector in the day-to-day operation. For future events, I believe it would be very interesting to hear from senior members of DHS, discussing their ideas for improving supply chain resiliency based on their experience in their various roles. The breakout sessions could have been more structured with a clearer plan for facilitation. They often ended up a conversation, which was interesting and valuable, but did not clearly lead to actionable outcomes.