Title: Risk Mitigation and Food Supply Chain Design and Control

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Center of Excellence: Food Protection and Defense Institute (FPDI)
COE Lead/Co-Lead Institution: University of Minnesota

Project Start Date: 09/2010

Project Completion Date: 12/2016

Project Status: Complete

Research Theme: Risk Analysis

Participating State(s): Georgia, Minnesota, North Carolina

Participating Minority Serving Institution(s) (MSI): North Carolina State A&T Univ

Amount Awarded to Date: $876,237

Award Number: 2010-ST-061-FD0001

Abstract: The primary goal of this research is to create and deploy improved risk analysis methods for food supply chains. The research proposed for July 2014 - June 2015 is specifically aimed at actively engaging the user community to translate the fundamental research that has been developed by the PI and co-PI under prior research awards from the NCFPD into useful tools for risk analysis. Specifically, our fundamental research improves the state-of-the-art in risk analysis by: (1) using a decision optimization framework to model likely behavior of an intelligent and adaptive adversary seeking to attack a food supply chain with the intent of creating a catastrophic outcome, (2) incorporating sequential decision-making with incomplete information into a game-theoretic optimization-based approach for risk analysis, where decision makers may have multiple objectives, and (3) developing systematic estimates of the likelihood and consequences of scenario outcomes using the framework, thus improving risk analysis measures. Research to be completed by June 2015 has initiated this translational research phase. The objectives for the July 2014 - June 2015 performance period therefore were: (1) build risk analysis tools for food supply chains facing catastrophic intentional contamination risk with two to three stakeholder users, preferably both an industry and government user represented and test risk analysis tools in partnership with stakeholder users to validate the approaches and availability of required input data and to determine the effectiveness and robustness of the new methods. The deliverables for this project year will be prototype risk analysis tools tailored to user requirements, documentation for their use, and reports detailing the findings of the test cases analyzed.

Project Type: Research

End User Engagement:

- Academic Community
- DHS U.S. Customs and Border Protection
- Federal Bureau of Investigation
- Food and Agriculture Industries
- Intelligence Community

Executive Summary (2016): The objective of the research was to consider the situation where an intelligent and adaptive adversary is intent on contaminating the food produced by a food supply chain. We also assumed that the manager of the supply chain is intelligent, adaptive, and intent on balancing two objectives: maximize supply chain productivity while minimizing the expected consequences of a successful contamination. Our research has shown that by assuming that both agents receive data, can extract information from the data, and then select actions based on new information, system

performance from the perspective of the food supply chain manager can improve, although vulnerability to an attack may be time dependent. In so doing, we have improved the state-of-the-art in risk analysis by: â€¢ Using a decision optimization framework to predict likely behavior of an intelligent and adaptive adversary seeking to attack a food supply chain with the intent of creating a catastrophic outcome; â€¢ Incorporating sequential decision-making with incomplete information into a game-theoretic optimization-based approach for risk analysis, where decision makers may have multiple objectives; â€¢ Developing systematic estimates of the likelihood and consequences of scenario outcomes using the framework, thus improving risk analysis measures. Methods utilized were decision, risk, and reliability analysis, partially observed stochastic games, partially observed Markov decision processes, multi-objective genetic algorithms, and multi-objective decision analysis. During the period 2010 through June 2015, we developed a general decision support system methodology, applied this methodology in two case studies (liquid egg production, Foot and Mouth Disease risk mitigation), and since June 2015 applied the methodology to cargo theft. The methodological contributions and the two case studies have been reported in earlier annual reports; we now provide further detail about application of the methodology to cargo theft. The research accomplished during the period June 2015 â€“ December 2016 was aimed at quantifying the risk of cargo theft on transportation routes and determining non-dominated routes based on this measure of risk and cost under two possible scenarios: (1) The transportation manager provides a set of routes from origin to destination and (2) The software system determines the set of all routes from origin to destination. Both scenarios required the development of a method to compute route risk scores. We then determined the non-dominated set of routes from the set of all routes under consideration. Details are presented in Part II, Section D, of this report. The deliverables for this project year is the software that supports the determination of the non-dominated set of routes for each scenario and the procedures for their implementation. This methodology addresses how to measure the risk of intentional contamination in a food supply chain and how best to mitigate this risk and has the potential of supporting this need for a broad range of food and other supply chain risk scenarios beyond the two case studies and cargo theft accomplished during this six-year study.

Peer-reviewed journal articles produced from this project

Citation
Lewis, Brian M., Alan L. Erera, Maciek A. Nowak, and White Chelsea C. â€œManaging Inventory in Global Supply Chains Facing Port-of-Entry Disruption Risks.â€ Transportation Science 47, no. 2 (April 5, 2012): 162â€“80. doi:10.1287/trsc.1120.0406.
Cheong, Taesu, and Chelsea C. White Iii. â€œInventory Replenishment Control under Supply Uncertainty.â€ Annals of Operations Research 208, no. 1 (July 6, 2011): 581â€“92. doi:10.1007/s10479-011-0929-9.
White III, Chelsea C., and Taesu Cheong. â€œIn-Transit Perishable Product Inspection.â€ Transportation Research Part E: Logistics and Transportation Review, Select Papers from the 19th International Symposium on Transportation and Traffic Theory, 48, no. 1 (January 2012): 310â€“30. doi:10.1016/j.tre.2011.08.006.
Chang, Yanling, Alan Erera, and Chelsea White III. A Leader-follower Partially Observed, Multiobjective Markov Game. Annals of Operations Research 235, no. 1(2015): 103-28. doi: 10.1007/s10479-015-1935-0.
Chang, Yanling, Alan Erera, and Chelsea White III. Value of Information for a Leader-follower Partially Observed Markov Game. Annals of Operations Research 235, no. 1(2015): 129-53. doi: 10.1007/s10479-015-1905-6.
Teasley, Raquel, Jessye Bemley, Lauren B. Davis, Alan Erera, and Yanling Chang. â€œA Markov Chain Model for Quantifying Consumer Risk in Food Supply Chains.â€ Health Systems, December 4, 2015. doi:10.1057/hs.2015.16.

Chang, Yanling, Alan L. Erera, and Chelsea C. Ill White. â€œRisk Assessment of Deliberate Contamination of Food Production Facilities.â€ IEEE Transactions on Systems, Man, and Cybernetics: Systems 47, no. 3 (March 2017): 381â€“93. doi:10.1109/TSMC.2015.2500822.

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