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## Tier 1 Highway Security Sensitive Material Dynamic Risk Management

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TIER 1 HIGHWAY SECURITY SENSITIVE MATERIAL DYNAMIC RISK MANAGEMENT

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DISSERTATION

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Engineering at the University of Kentucky

By

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2016

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## ABSTRACT OF DISSERTATION

### TIER 1 HIGHWAY SECURITY SENSITIVE MATERIAL DYNAMIC RISK MANAGEMENT

Each year, over 2 billion tons of hazardous materials are shipped in the United States, with over half of that being moved on commercial vehicles. Given their relatively poor or nonexistent defenses and inconspicuousness, commercial vehicles transporting hazardous materials are an easy target for terrorists. Before carriers or security agencies recognize that something is amiss, their contents could be detonated or released. From 2006 to 2015, the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) recorded 144,643 incidents involving a release of hazardous materials. Although there were no known instances of terrorism being the cause, accidental releases involving trucks carrying hazardous materials are not an uncommon occurrence. At this time, no systems have been developed and operationalized to monitor the movement of vehicles transporting hazardous materials. The purpose of this dissertation is to propose a comprehensive risk management system for monitoring Tier 1 Highway Security Sensitive Materials (HSSMs) which are shipped aboard commercial vehicles in the U.S.

Chapter 2 examines the history and current state of hazardous materials transportation. Since the late 19th century, the federal government often introduced new regulations in response to hazardous materials incidents. However, over the past 15 years few binding policies or legislation have been enacted. This demonstrates that government agencies and the U.S. Congress are not inclined to introduce new laws and rules that could hamper business. In 2003, the Federal Motor Carrier Safety Administration (FMCSA) and other agencies led efforts to develop a prototype hazardous materials tracking system (PHTS) that mapped the location of hazardous materials shipments and quantified the level of risk associated with each one. The second half of this chapter uses an in-depth gap analysis to identify deficiencies and demonstrate in what areas the prototype system does not comply with government specifications.

Chapter 3 addresses the lack of customized risk equations for Tier 1 HSSMs and develops a new set of risk equations that can be used to dynamically evaluate the level of risk associated with individual hazardous materials shipments. This chapter also discusses the results of a survey that was administered to public and private industry stakeholders. Its purpose was to understand the current state of hazardous materials regulations, the likelihood of hazardous materials release scenarios, what precautionary measures can be used, and what influence social variables may have on the aggregate

consequences of a hazardous materials release. The risk equation developed in this paper takes into account the survey responses as well as those risk structures already in place. The overriding goal is to preserve analytical tractability, implement a form that is usable by federal agencies, and provide stakeholders with accurate information about the risk profiles of different vehicles. Due to congressional inaction on hazardous materials transportation issues, securing support from carriers and other industry stakeholders is the most viable solution to bolstering hazardous materials security. Chapter 4 presents the system architecture for The Dynamic Hazardous Materials Risk Assessment Framework (DHMRA), a GIS-based environment in which hazardous materials shipments can be monitored in real time. A case study is used to demonstrate the proposed risk equation; it simulates a hazardous materials shipment traveling from Ashland, Kentucky to Philadelphia, Pennsylvania. The DHMRA maps risk data, affording security personnel and other stakeholders the opportunity to evaluate how and why risk profiles vary across time and space. DHRMA's geo-fencing capabilities also trigger automatic warnings. This framework, once fully implemented, can inform more targeted policies to enhance the security of hazardous materials. It will contribute to maintaining secure and efficient supply chains while protecting the communities that live nearest to the most heavily trafficked routes. Continuously monitoring hazardous materials provides a viable way to understand the risks presented by a shipment at a given moment and enables better, more coordinated responses in the event of a release.

Implementation of DHRMA will be challenging because it requires material and procedural changes that could disrupt agency operations or business practices — at least temporarily. Nevertheless, DHRMA stands ready for implementation, and to make the shipment of hazardous materials a more secure, safe, and certain process. Although DHMRA was designed primarily with terrorism in mind, it is also useful for examining the impacts of accidental hazardous materials releases. Future iterations of DHMRA could expand on its capabilities by incorporating modeling data on the release and dispersion of toxic gases, liquids, and other substances.

**KEYWORDS:** Hazardous Materials Transportation, Commercial Vehicles, Risk Management, Tier 1 HSSMs, GIS-based Architecture

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October 3, 2016

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## Chapter 1 Introduction

### 1.1 Transportation Security

The attacks of September 11, 2001 demonstrated that terrorism produces lethal consequences. Unsettling and disturbing, the events of 9/11 revealed that terrorist acts could be aimed effectively at domestic targets on a large scale — something that most people would have found unthinkable before that day. Although the attacks were not the first instance of commercial airliners being involved in terrorist attacks (e.g., Pan Am Flight 103 exploded over Lockerbie, Scotland in December 1988; Air India Flight 182 was downed by a bomb while flying over the Atlantic Ocean in June 1985), they are especially notable because terrorists seized control of four aircraft, transforming them into missile-like weapons to immolate high-value assets. The attacks showed vehicles (airplanes, ships, commercial vehicles) could readily be weaponized by determined terrorists to inflict significant damage. Understandably, in the immediate aftermath of these attacks, Congress, the president, and other government stakeholders immediately sought to introduce new laws, regulations, and oversight designed to prevent future terrorist acts. Much of the initial focus was on improving the safety of air transportation. In November of 2001, the Aviation and Transportation Security Act was signed into law, which created the Transportation Security Administration (TSA). TSA was given responsibility for overseeing aviation security, as well as the security of highways, railroads, mass transit, pipelines, and ports — although it was and continues to be most

closely identified with aviation. While aviation was the government's primary concern, there were some initial efforts to improve the security of commercial vehicles that transported hazardous materials. For example, the Federal Motor Carrier Administration scrutinized the operations of over 36,000 motor carriers deemed vulnerable to terrorist attacks. Early attempts to pass new legislation, such as a law to impose stricter regulations on individuals attempting to earn commercial vehicle licenses to transport hazardous materials, were unsuccessful. The preoccupation with aviation left the potential risks associated with other modes of transportation underappreciated and unaddressed, especially those posed by vehicles carrying hazardous materials.

Each year, over 2 billion tons of hazardous materials are shipped in the United States, with over half of that being moved on commercial vehicles. The total value of hazardous materials shipped on trucks exceeded \$800 billion in 2007 (FHWA, 2013). The manufacture and shipping of hazardous materials is expected to rise steadily over the next 30 years because they are essential to many of the products and services that underpin modern life. But hazardous materials are routinely left unsecured and are not tracked closely from the time they are loaded into containers and trailers until they arrive at their destination. Given that they are both unsecured and highly dangerous, they present an attractive target to terrorists because they can be readily seized and weaponized. Jones et al. (2010) discussed the potential of terrorists using chlorine gas as an unconventional but deadly weapon to cause significant numbers of injuries and fatalities. Because it is used in numerous processes, ranging from the manufacture of paper, plastics, and chemical products, to the municipal treatment of sewage and

drinking water supplies, large quantities are shipped every day throughout the U.S. Gussow (2007) reported on simulations which demonstrated that releasing chlorine gas in densely populated urban areas could produce fatalities in excess of 15,000 and over 100,000 injuries. In 2007, a train collision resulted in the release of 90 tons of chlorine gas near Graniteville, South Carolina. Nine people died and 5,400 of the town's 7,000 residents were evacuated (Jones et al., 2010; see also Van Sickle et al., 2009). Other incidents in 2007, in Tacoma, Washington and Las Vegas, vented much smaller quantities of chlorine gas, resulting in a small number of minor injuries. While these releases were accidental, they illustrate the danger posed by a single hazardous material.

## **1.2 Risk Management of Hazardous Materials Shipments**

Incidents involving trucks carrying hazardous materials are not an uncommon occurrence. From 2006 to 2015, the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) recorded 144,643 incidents (PHMSA defines incident as the unintentional release of hazardous materials), which were responsible for 1,519 injuries, 99 fatalities, and over \$600 million in economic damages. While PHMSA does not specify the cause of releases in its summary statistics, there are no known instances of terrorism being the cause of domestic incidents. Rather, accidental releases during transit, loading, unloading, and storage are the primary culprit. Nevertheless, these statistics underscore that the safety and security of hazardous materials are major concerns, and that even in the absence of deliberate efforts to intentionally release these substances, tracking and monitoring their location

and movement could produce valuable benefits. While the incidents that have occurred since 2006 have exacted considerable economic damage and inflicted numerous injuries, these numbers pale in comparison to what might unfold if attackers were to detonate a highly flammable material or vent extremely toxic gases in urban areas. As the recent events in Nice, France remind us, a determined terrorist can easily weaponized a single vehicle to injure or kill many defenseless individuals. Although this attack did not involve the use of hazardous materials, it is easy to imagine the consequences of a rogue terrorist commandeering a commercial vehicle with these substances onboard.

Closely monitoring and tracking the location and movement of hazardous materials transported by commercial vehicles cannot eliminate the possibility of future releases (intentional or accidental). However, this knowledge can reduce the likelihood or mitigate the effects of potential attacks directed at commercial vehicles with onboard hazardous materials. Knowledge of pickup and drop-off points, as well as planned routing, can assist stakeholders with identifying anomalous driver behaviors, potential and emerging threats, and ongoing incidents. In the case of hazardous materials incidents, this information can assist officials in coordinating emergency responses and mitigating their worst effects. Yet no systems have been developed and operationalized to monitor the movement of vehicles transporting hazardous materials in the U.S.

The purpose of this dissertation is to propose a comprehensive risk management system for monitoring Tier 1 Highway Security Sensitive Materials (HSSMs) which are shipped aboard commercial vehicles in the U.S. The need for such a system is clear.

Although the federal government and researchers have made previous attempts to develop systems to improve the risk management of hazardous materials, none have been entirely successful. The creation of new systems has principally been undertaken by the federal government, whereas academic researchers have tended to focus on micro-scale problems, such as developing equations to quantify the risk posed by individual shipments or the level of exposure for particular road segments or population centers (see Chapters 3 and 4).

This dissertation contributes to ongoing discussions among both researchers and public and private stakeholders by 1) mapping out the architecture of a hazardous materials tracking system that will provide instantaneous and continuously updated spatial data on the location, movement, and logistical facets of Tier 1 HSSM shipments; and 2) parameterizing a set of risk equations which can be used to quantify the amount of risk (i.e., the threats, vulnerabilities, and consequences; see Chapter 3) associated with individual shipments, and which are compatible with existing methodologies used by the federal government to analyze risk. These equations underpin the proposed risk management system. As such, this dissertation addresses the micro-scale problems academic researchers have long grappled with — how to parsimoniously calculate a shipment's risk profile and its spatial variability — as well as the broader problem of integrating all of the data collected on individual shipments into a single risk management framework and system that stakeholders can use to understand the dynamic nature of risk, so they can then devise appropriate plans to prevent, mitigate, or respond to a deliberate or accidental release of hazardous materials. While the



system's development was motivated to address issues related to terrorism, it serves as a valuable tool to coordinate responses to accidental hazardous materials releases (see below for more on academic and applied contributions). Certainly, by including only Tier 1 HSSMs the system's focus is narrow. However, Tier 1 HSSMs are the most dangerous materials shipped on U.S. highways, the gases and substances which, if released, are most likely to inflict massive damage and cause widespread injuries and fatalities. Improving our risk management of these materials is critical for securing the hazardous materials supply chain. The risk equations and system architecture can potentially serve as the foundation for an expansive risk management framework that applies to all hazardous materials.

### **1.3 Organization of the Dissertation**

This dissertation consists of three interrelated chapters, each of which is a standalone paper. While each paper can be read individually, they build upon one another. Taken as a group, they offer a cohesive narrative of the risk management system's conceptualization and development. The following paragraphs briefly describe the aims and findings of each chapter.

Chapter 2 begins with a historical overview of hazardous materials transportation industry regulations in the U.S. Since the late 19th century, the federal government has expanded its regulatory efforts. Often, new regulations have been introduced in response to hazardous materials incidents, which illuminated regulatory failings. The last major piece of legislation signed into law which dealt explicitly with hazardous materials transportation was the 1990 Hazardous Materials Transportation

Uniform Safety Act (later amended and revised in 1994). Although the 9/11 terrorist attacks prompted the Federal Motor Carrier Safety Administration (FMCSA) to conduct rapid inspections of motor carriers whose operations were deemed vulnerable to terrorist attacks — including many hazardous materials transporters — they did not lead to new, extensive regulations. Instead, minor legislation was passed in 2003 requiring carriers that transport hazardous materials to establish and implement security plans. The FMCSA also introduced a new program that instructed hazardous materials carriers to obtain safety permits when transporting certain high-risk materials (see 69 FR 39350). Despite these incremental changes, 9/11 changed little with respect to hazardous materials regulation, with the federal government opting for piecemeal reforms. This has left most security measures in the hands of individual carriers. In 2008, TSA issued voluntary Security Action Items for carriers that transport highway security sensitive materials; however, no binding legislation based on these items has been passed, and it is unclear whether any will be forthcoming. Nevertheless, in 2003, FMCSA and other agencies began to explore methods to monitor and track vehicles that were carrying hazardous materials. Eventually, these efforts led to the development of a prototype hazardous materials tracking system (PHTS) that imported locational data derived from truck telematics systems into a GIS-based software platform to map the location of hazardous materials shipments and to quantify the level of risk associated with each one.

The second half of Chapter 2 uses an in-depth gap analysis to identify the system's methodological and technical deficiencies. The purpose of the gap analysis is to

demonstrate in what areas the prototype system does not comply with government specifications. While development of the PHTS demonstrated the feasibility of a sophisticated monitoring and tracking system, it was not customized for Tier 1 HSSMs; omitted equations that could accurately evaluate the risk posed by individual shipments; had a geo-fencing solution which performed inconsistently; and could not facilitate communication between government agencies, carriers, and emergency responders. In examining both the hazardous materials transportation regulatory landscape and the PHTS, the paper contributes to ongoing discussions about how to improve the safety and security of hazardous materials. Despite its flaws, the PHTS offers a foundation on which to build future efforts. Given congressional reluctance to impose new laws or regulations, developing a robust monitoring and tracking program with the assistance of carriers and other industry stakeholders is potentially the most viable solution to bolster hazardous materials security. A suitable tracking program will also provide valuable data to carriers and facilitate more efficient supply chain management. Chapter 2 recommends developing a monitoring and tracking system for Tier 1 HSSMs and developing refined risk assessment and management tools — based on feedback from public and private stakeholders.

Chapter 3 addresses one of the PHTS's key failings — the lack of customized risk equations for Tier 1 HSSMs — by developing a new set of risk equations that can be used to dynamically evaluate the level of risk associated with individual hazardous materials shipments. After reviewing risk management systems currently used at federal and state transportation agencies, this chapter discusses the results of a comprehensive

survey that was administered to public and private industry stakeholders. The purpose of the survey was to understand the current state of hazardous materials regulations, the likelihood of various accidental and intentional hazardous materials release scenarios, what precautionary measures can be used to eliminate or mitigate the consequences of particular release scenarios, and what influence a number of social variables (e.g., population, economic impact) have on the aggregate consequences of a hazardous materials release. Respondents answered questions using a modified version of the Kent Scale (Meyer & Booker, 1991). Adopting the Kent Scale opened up the possibility of converting qualitative responses to quantitative scores, which established the necessary foundation to craft new risk equations. Survey participants viewed the majority of attack scenarios as more likely than not to occur at some point in the future. Under a majority of the scenarios, respondents felt there is between a 20 and 50 percent chance of attackers failing due to preventative security measures or technical incompetence. Twenty-three survey questions dealt with proposed TSA Security Action Items. Overwhelmingly, respondents claimed it was somewhat important, very important, or extremely important for stakeholders to implement these items. Respondents said that population density, critical infrastructure, economic activity, and public fear are the most important contributors to the aggregate impacts of a hazardous materials release. Based on these findings, a straightforward risk equation is developed that can be used to estimate the level of risk posed by individual shipments<sup>1</sup>. The

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<sup>1</sup> While the risk equation is a single equation (Risk = Threats x Vulnerabilities x Consequences), it combines values derived from discrete equations, which are used to calculate threats, vulnerabilities, and consequences, respectively.

equation leverages definitions of risk used by the Department of Homeland Security, TSA, and other federal agencies, all of which conceptualize risk as the product of threats, vulnerabilities, and consequences. The proposed equation may be calculated iteratively and at specified intervals to quantify the spatial and temporal variability of risk. Employing a spatially explicit approach to risk (further elaborated on in Chapter 4) ensures that carriers and government agencies have real-time knowledge of its variability. It underscores the fact that risk is most elevated in densely populated urban areas with a large number of critical assets and vibrant economic activity. The overriding goal in creating the risk equation was to preserve analytical tractability, implement a form that is usable by federal agencies, and provide stakeholders with accurate information about the risk profiles of different vehicles.

Taking the PHTS and risk equation as points of departure, Chapter 4 presents the system architecture for a GIS-based environment in which hazardous materials shipments can be monitored in real time. It also includes a case study to demonstrate the application of the risk equation. The Dynamic Hazardous Materials Risk Assessment Framework (DHMRA) combines a GIS-based desktop application with an underlying risk engine, which iteratively calculates the risk levels of various shipments, to assess vehicle risk dynamically. Although the risk scores generated by the risk equation provide valuable information, without a corresponding means to locate and visualize individual shipments' risk profile, the data would be unusable. The DHMRA maps risk data, affording security personnel and other stakeholders the opportunity to evaluate how and why risk profiles vary across time and space. The DHRMA desktop environment

contains three situational screens that let security personnel zero in on different attributes of hazardous materials shipments. It lets users quickly access shipment data, including its contents, planned departure and arrival times, and a detailed analysis of risk status. Users have the ability to flag shipments for additional investigation if they feel it is warranted, however, DHRMA's geo-fencing capabilities also trigger automatic warnings. Warnings are precipitated by a shipment deviating from its route plan, transgressing a geo-fence, or receiving elevated risk scores. The chapter's case study simulates a hazardous materials shipment traveling from Ashland, Kentucky to Philadelphia, Pennsylvania; providing detailed analysis of the risk posed by a shipment of chlorine gas. There is a positive correlation among threat, vulnerability, and consequence scores. These scores peak when the shipment moves into major urban areas, such as Washington, D.C., Baltimore, and Philadelphia. Taken together with Chapter 3, the material in Chapter 4 demonstrates the importance of having a risk management system which is attuned to the contingency of risk. A shipment's risk profile is a direct consequence of its location. For example, hazardous materials shipments traveling on rural highway networks pose significantly less risk than those situated near densely populated urban areas. If an intentional or accidental release were to occur in urban locations, the human, economic, and environmental costs would be staggering. The system's mapping environment, by placing all shipments on one screen, lets security analysts identify areas in which a large number of vehicles with hazardous materials onboard are traveling. This information could potentially be used to

inform routing decisions, and in the event of an incident, orchestrate an appropriate response.

This dissertation makes several important contributions to the academic literature on hazardous materials transportation. In its historical analysis, the dissertation illuminates a little-noticed, scarcely commented upon trend in hazardous materials regulation — that while regulations expanded throughout the 20th century, over the past 15 years few binding policies or legislation have been enacted. This is interesting for several reasons. First, it demonstrates that government agencies and the U.S. Congress are not inclined to introduce new laws and rules that could hamper business. This is consistent with the push toward deregulation that has prevailed within the U.S. economy over the last 30-40 years (e.g., Marten, 1981; Belzer, 1994; Berger & Mester, 2003; Johnston & Nath, 2004; Calomiris, 2006). Second, this suggests that despite increased concerns that terrorists will target commercial vehicles transporting extremely volatile and dangerous substances, government stakeholders are unwilling to establish mandatory procedures that shippers, carriers, and other stakeholders must abide by. This raises a crucial question: under what circumstances would the political incentives exist to tighten regulations on hazardous materials shipments? The TSA's 2008 voluntary Security Action Items have been endorsed by numerous stakeholders, including the majority of those surveyed as part of this research. Lacking some cataclysmic event, it is unlikely that TSA or government agencies will press the case to enforce these rules.

Moving beyond the historical analysis in Chapter 2, this dissertation's second major contribution is the development of new methods to assess and monitor the risk posed by commercial vehicles shipping hazardous materials. Knowing that it is unlikely new laws will require stakeholders to monitor and track shipments, the purpose of the risk management system is to improve public safety while incentivizing private industries to submit to a tracking and monitoring program. The risk equations and software described in Chapters 3 and 4 give public agencies the tools they need to quantify risk and plan for and manage responses to intentional or accidental releases of hazardous materials while offering industry stakeholders critical information that can be used to manage supply chains and optimize the routing of individual shipments. Because the risk equations are consistent with methodologies currently used by various government agencies, implementation can be seamless. In devising these equations, ensuring that they took on a form compatible with existing definitions and methods of calculation was a critical emphasis. Otherwise, the resulting system would be functionally useless because agencies would be disinclined to use it. Thus, the risk assessment methodologies draw from and complement academic literature while at the same time provide a practical application.

Generally, the overall success of a dissertation is measured in terms of how successfully it intervenes into ongoing discussions among research practitioners. Although the risk management concepts and methodologies proposed here certainly accomplish this, perhaps this dissertation's most important contribution lies in the potential contributions it could make to overhauling the day-to-day execution of risk



analysis and management. Because the ideas advanced in this document are based on the input of private and public stakeholders, it stands to reason that they are relatively uncontroversial. But even when stakeholders endorse an idea in the abstract, implementation remains a challenge precisely because it would entail material and procedural changes that could disrupt agency operations or business practices — at least temporarily. Nevertheless, DHRMA stands ready for implementation, and to make the shipment of hazardous materials a more secure, safe, and certain process.

## **Chapter 2 The Current State of Hazardous Materials Shipping in the United States**

### **2.1 Introduction**

The terrorist attacks of September 11, 2001 demonstrated how quickly an airplane could be weaponized and transformed into a machine capable of producing enormous damage to infrastructure and loss of human life. Policymakers mobilized in the days and months following 9/11 to establish new regulations intended to enhance the safety and security of air travel and public and governmental facilities. Although most early policies and rulemaking did not focus on surface transportation, there were some exceptions. For instance, Senator Orin Hatch introduced legislation in October of 2001 that would impose new regulations on issuing licenses to vehicle operators who transport hazardous materials. The bill would have prevented states from issuing licenses to these individuals “unless the Secretary of Transportation has first determined, upon receipt of notification...that the individual does not pose a security risk warranting denial of the license” (107th Congress, S. 1569). Ultimately, this bill did not pass. However, the bill revealed that members of Congress recognized the potential for highway motor carrier vehicles carrying hazardous materials to be weaponized and used to carry out terrorist attacks.

Over the next few years, new regulations and programs trickled out of the federal government. These regulations and policies were designed to protect the United States’ hazardous materials supply chain, with an emphasis on highway motor carriers. Along with the establishment of the Transportation Security Administration and Department of Homeland Security, new regulations were introduced to strengthen the

federal government's authority to monitor hazardous materials shipments. However, there have been no new sweeping regulations since 9/11 that apply strictly to hazardous materials transported on surface transportation networks. Despite the lack of new regulations, there has been sporadic yet severely lacking progress on this front. In 2003, the Federal Motor Carrier Safety Administration performed a study to evaluate the appropriateness of using smart truck technologies to enhance the monitoring of hazardous cargoes loaded on trucks. As a follow-up study in 2005, the federal government outsourced development and testing of a prototype truck-tracking system. This test appraised the feasibility of comprehensively monitoring hazardous materials shipments, in real time, from a centralized truck-tracking center.

This paper contributes to the literature on the security of hazardous materials transportation by situating today's regulatory policies within their proper historical context and demonstrating that fulfilling current regulatory mandates will demand increasingly sophisticated technologies to monitor the location and movement of hazardous goods. Using a gap analysis, this research demonstrates that a prototype system developed on behalf of the U.S. government to track hazardous materials shipments is inadequate and operationally deficient — it fails to meet the specifications required by the government. Identifying the gap between the current system performance and U.S. government expectations is used as a starting point to determine what changes would be necessary for a system to conduct real-time monitoring of all Tier 1 Highway Security Sensitive Materials (HSSMs). This gap analysis is essential for developing a new system architecture because it illuminates what changes should be

incorporated into the system's design and architecture to ensure it achieves optimal performance and meets regulatory standards (e.g., Akerman & Tyree, 2006; Blanchard, 2008). This task is critical, given that each year there are over two million shipments of Tier 1 HSSMs traveling across the country's highways. Some of the most dangerous, poisonous, and toxic gases, explosives, and chemicals have been designated as Tier 1 HSSMs. Table 2.1 summarizes what materials have been classified as Tier 1 HSSMs, with examples from each hazard class provided.

**Table 2.1 Tier 1 HSSMs**

<b>DOT Hazard Class</b>	<b>Description of Hazard</b>	<b>Example Materials</b>
<b>Division 1.1 Explosives</b>	Substances that have the potential to catalyze a mass explosion	Blasting caps Blasting explosives Trinitrobenzene
<b>Division 1.2 Explosives</b>	Substances that have a projection hazard but will not trigger a mass explosion	Some fireworks Grenades Weapons cartridges
<b>Division 1.3 Explosives</b>	Substances vulnerable to fire hazards, minor blast hazards, or minor projection hazards	Photo-flash bomb Display fireworks Some ammunition
<b>Division 2.2 Non-Flammable Gas</b>	Non-toxic, non-flammable gases	Corrosive aerosols Insecticide gases Refrigerated neon
<b>Division 2.3 Poisonous Gas*</b>	Gases that are poisonous when inhaled by humans; in the form of gas at 20° C or less and a pressure of 101.3 kPa	Chlorine Dinitrogen tetroxide Hydrogen sulfide
<b>Class 3: Flammable Liquids</b>	Any liquid that has a flash point that is not above 60.5° C	Gasoline Heating oil Hexanes
<b>Division 6.1 Poisonous Materials*</b>	Materials other than gas which are toxic to humans	Arsenic Carbon tetrachloride Chloroform
<b>Class 7 Radioactive Materials</b>	Materials that emit radiation	Uranium hexafluoride Radioactive materials
<b>Class 8 Corrosive Materials</b>	A liquid or solid that destroys human skin within a specified period of time; it also produces a severe corrosion rate in aluminum or steel	Copper chloride Fire extinguisher charges Hydrochloric acid
<b>Other Materials</b>	Any quantity of chemicals listed by the Chemical Weapons Convention — Schedules 1, 2 and 3	Phosgene Mustard gas Ricin

\* The TSA Highway & Motor Carrier Program sets variable threshold amounts for different materials in these divisions based on the Hazard Zone a material falls under. For both Divisions, the thresholds are as follows: Hazard Zone A and B,  $\geq 2.3$  kg in a single package; Hazard Zone C and D,  $\geq 3000$  L or 3000 kg in a single bulk package.

The remainder of the chapter is divided into four sections. It begins with a historical narrative of the federal government’s approach to hazardous materials regulation, dating to the late 19th century. This is necessary to properly contextualize regulatory trends since 9/11. The next section describes the prototype truck-tracking

system and the testing that was conducted to evaluate its performance, with the primary emphasis being on what this assessment proved about the feasibility of implementing a sophisticated monitoring system. While this system was generally successful and served a proof of concept, the ensuing gap analysis clarifies deficiencies and identifies obstacles to implementing it on a wider scale. The concluding section recaps the analysis and discusses the future of hazardous materials tracking for surface transportation networks. The discussion ends with an explanation on how a fully functioning monitoring system would be designed and operated.

## **2.2 Background on Transportation of Hazardous Materials Regulations**

Although a significant amount of research has historically situated the evolution of hazardous materials regulation and waste management in the United States (e.g., Colten, 1988; Jenkins et al., 2008; LaGrega et al., 2010), comparatively little work has examined the evolution in policies related to hazardous materials being transported on surface transportation networks (Field, 2004). Although there is no clear explanation for why this is the case, it is likely related to scholars tending to focus more on sited materials (i.e., those which occupy a single location and are not moved) and the implications they have for local populations, environments, and the uneven patterns of exposure that have resulted from hazardous waste disposal (e.g., Russell et al., 1992; Mohai & Saha, 2007; Elliott & Frickel, 2013; Taylor, 2014). Although this is understandable, it overlooks the enormous amounts of hazardous materials that have and will continue to move on United States highways — over 800,000 shipments per day. Horton et al. (2003) demonstrated that thousands of incidents involving vehicles

carrying hazardous materials resulted in injuries or fatalities. While the threat posed by fixed materials is undeniable and severe, the ubiquity of hazardous materials transport raises critical issues about how its regulatory landscape has evolved, what aspects of transport policies and rulemaking have been targeted, and whether new regulations have increased the vulnerability of some populations (e.g., Schweitzer, 2006). In general, new regulations have been introduced in response to crises that either involved large-scale materials releases or events that exposed key vulnerabilities in transportation security laws and practices.

Until 1866, there were no federal laws in the United States regulating the transportation of hazardous materials. Although explosives and other materials were moved via railways and other modes prior to this, oversight was established through contractual agreements between shippers and carriers (OTA, 1986). Following the rapid industrialization in the aftermath of the Civil War, increasing amounts of oil and other materials were transported by horses, river barges, and eventually by rail cars and ships. It became evident that the federal government would need to step in to provide greater oversight of hazardous substances that endangered human life and infrastructure (TRB, 2003). In July 1866, a new law was enacted that gave the federal government the authority to regulate and provide oversight of hazardous materials — specifically, shipments of explosives and combustible materials. In 1871, another statute was enacted which levied criminal penalties against anyone transporting hazardous materials on passenger vessels traveling on navigable waterways in violation of Treasury Department regulations (OTA, 1986). A key event for hazardous materials oversight

occurred in 1908, when the Explosives and Combustibles Act (later, the Explosives and Other Dangerous Articles Act) gave the Interstate Commerce Commission the authority to issue regulations pertaining to packing, marking, loading, and handling explosives and other hazardous materials that were bound for transit. Under this new law, the transportation of hazardous materials was prohibited unless approved by the Interstate Commerce Commission. From the 1920s to the 1960s, hazardous materials regulations that were first applied to railroads were then extended to other modes of transportation (OTA, 1986).

Hazardous materials governance remained more or less unchanged until the late 1960s, when the U.S. Department of Transportation (DOT) was formed. All oversight of hazardous materials then fell to the USDOT and a number of subsidiary departments within it, creating a sort of regulatory patchwork (some would argue that has remained in effect through now). Efforts to pass a comprehensive hazardous materials transportation bill stalled in the U.S. Congress until the early 1970s. Interestingly, a new push for regulation did not occur until an accident involving a cargo jet transporting hazardous materials occurred in 1973. This incident underscored that shippers routinely did not comply with existing regulations and lacked knowledge about newly installed federal rules pertaining to hazardous materials transport (e.g., the Hazardous Materials Transportation Control Act of 1970; OTA, 1986).

The cargo plane crash was key in motivating the passage of the Hazardous Materials Transportation Act (HMTA) of 1975, the purpose of which was to “improve regulatory and enforcement activities by providing the Secretary of Transportation with



broad authority to set regulations applicable to all modes of transport” (OTA, 1986, p. 148). Although the Secretary was given this power, the Research and Special Programs Administration (RSPA) gained the rulemaking authority for issues related to transporting hazardous materials (TRB, 2002). RSPA, which houses the Office of Hazardous Materials, also enforces compliance to ensure that shippers — as well as manufacturers and repairers of hazardous materials containers — abide by federal laws. The HMTA of 1975 remained the controlling law until 1990, when the Hazardous Materials Transportation Uniform Safety Act (HMTUSA) was signed into law. What precipitated this update was growing public awareness of hazardous materials shipments, which at the time numbered approximately 500,000 per day (Boyd, 1993; Cutter & Ji, 1997). The new law attempted to increase public safety by creating a more uniform regulatory landscape that would eliminate discrepancies between state and local enforcement. The 1990 Act addressed these issues by preempting state and local laws related to hazardous materials transportation which did not conform to federal laws and regulations (Boyd, 1993). Further, the HMTUSA mandated that shippers and carriers that handled hazardous materials were to register at least once every five years and pay an annual registration fee. This law also introduced new requirements related to highway routing, emergency response training, incident notification, and vehicle safety permits, among other issues (Cutter & Ji, 1997). Another update to the Act in 1994 strengthened the USDOT’s authority to mandate that shippers and carriers of hazardous materials submit a registration to the federal government. Companies whose vehicles were involved in accidents while transporting hazardous materials were also required to report all

incidents to the USDOT's Research and Special Programs Administration, which oversaw transport-related hazardous materials regulations (Field, 2004)<sup>2</sup>.

The terrorist attacks of September 11, 2001 (hereafter, 9/11) prompted elected and public officials across all levels of government to rethink and change their approach to transportation security. In the 1980s and 1990s, most regulatory attention was focused on mitigating the accidental or incidental release of hazardous substance due to container failures (e.g., Abkowitz et al., 1989). However, what 9/11 crystallized was that the federal government would need to adopt new planning procedures and rules to deal with deliberate releases of hazardous materials. Indeed, just after 9/11 there were a number of arrests made and people charged with fraudulently procuring licenses to transport hazardous waste materials, individuals suspected of having terrorist connections (Mauer, 2003). Additionally, in the weeks after 9/11 the Federal Motor Carrier Safety Administration (FMCSA) began a program under which agents made visits to motor carriers whose operations were particularly vulnerable to terrorist attacks (Field, 2004). During the first four months following 9/11, FMCSA completed 36,000 security sensitive visits. Many of these targeted hazardous materials carriers.

Despite the renewed attention FMCSA paid to hazardous materials carriers following 9/11, the priority was given to new regulations that improved the safety of air transportation, given its involvement in the attacks (Johnston, 2004a). Several pieces of landmark legislation were passed soon after the 2001 terrorist attacks, including the Aviation and Transportation Security Act of 2001, which established the Transportation

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<sup>2</sup> With the exception of some radioactive waste materials, individual states typically do not directly regulate hazardous materials transported by carriers on state highways.

Security Administration (TSA) and the Homeland Security Act of 2002, responsible for creating the Department of Homeland Security (DHS). The Homeland Security Act vested the USDOT with the authority “to prescribe regulations for ‘the safe transportation, including security of hazardous materials in intrastate, interstate, and foreign commerce” (TRB, 2005, p. 33–34).

Despite the focus on transportation security that emerged following 9/11, surface transportation security was somewhat overlooked at the federal level (although see TRB [2002] for an early discussion of transportation security challenges), and it became clear that sweeping legislation or programs focused on hazardous materials would unlikely be forthcoming. But there were several watershed moments related to surface transportation that warrant mention. The USDOT issued two advisory notices in 2002 and 2003, respectively, for carriers and shippers of hazardous materials, both related to preparing en-route security plans. In March 2003, the Research and Programs Administration issued a final rule on the Security Requirement for Offerors and Transporters of Hazardous Materials (68 FR 14510). This rule stipulated that carriers responsible for transporting hazardous materials must establish and implement security plans. Along with this, employee training was required to incorporate a security component (see also Johnston & Nath, 2004). Shortly afterwards, in 2005, the FMCSA initiated a new program that mandated carriers obtain hazmat safety permits for specified kinds of high-risk materials (69 FR 39350). Arguably, these new rules and policies motivated federal agencies to begin examining methods to improve vehicle security.

In late 2003, FMCSA undertook its Hazmat Safety and Security Field Operational Test. This initiative studied the benefits of using smart truck technologies and attempted to identify what benefits they would bring to the hazardous materials supply chain. The test found that using new technologies would save carriers money and reduce supply chain risks, but also that companies would be reluctant to submit data to a public sector reporting center, or use smart truck technologies, unless obligated to through federal regulations. Building on the 2003 field operations test, in 2005, TSA contracted out the development of a Prototype Hazmat Tracking System (PHTS). The goal of this study was to assess the feasibility of establishing a hazardous materials truck-tracking center (TTC) to monitor vehicles carrying these substances. From a regulatory standpoint, two further points contextualize efforts to improve surveillance of trucks moving hazardous materials. First, the 9/11 Commission Act of 2007 directed TSA to create a tracking program which targeted trucks carrying hazardous materials. Second, TSA issued a list of voluntary Security Action Items (SAIs) for carriers of highway security sensitive materials (HSSMs) in 2008.

Table 2.2 lists each SAI, which are grouped into four categories — general security, personnel security, unauthorized access, and en route security. Understandably, the majority of SAIs apply to en-route security, as an overarching goal of these is to prevent shipments of hazardous materials from being compromised during transit. But it is critical to underscore the voluntary nature of these measures. The failure to codify these items into federal law is consistent with a broader trend of devolution, under which the federal government's authority and willingness to impose

new regulations has declined, in favor of more indirect oversight that confers greater responsibility to either local governments or private entities for monitoring activities (cf. Thrower & Martinez, 1999). Short of a catastrophic incident that involves the deliberate or accidental release of hazardous materials, it is unclear whether robust, uniform legislation comparable to the HMTA will be forthcoming.

**Table 2.2 SAI Categories and Provisions**

<b>SAI Category</b>	<b>Provisions</b>
<b>General Security</b>	<p>Motor carriers should review their security assessments and plans in light of the new SAIs and address gaps accordingly.</p> <p>Employers should be familiar with the security practices that are recommended by industry groups and trade associations to improve transportation security.</p> <p>Employers should adopt inventory control processes, which will let them account for their containers, cylinders, and vehicles at all points along the supply chain.</p> <p>Employers should institute policies that protect critical security information. They should also work to secure communications between shippers, carriers, third-party logistic companies, and receivers.</p>
<b>Personnel Security</b>	<p>Drivers transporting hazardous materials should possess a valid commercial driver's license hazardous materials endorsement.</p> <p>When an employer hires new people or contractors who will have unescorted access to motor vehicles (in transport), the motor carrier facility, or information critical to the hazardous materials transportation, they should conduct a thorough background check on them.</p> <p>Employers should have employees complete TSA-sponsored domain awareness training, the TSA Hazmat Motor Carrier Security Self-Assessment Training Program, or their equivalent.</p>
<b>Unauthorized Access</b>	<p>Employers should install an access control system. This should entail the issuance of</p>

	<p>photo IDs or other visible forms of company identification to all drivers.</p> <p>Any employee, vendor, contractor, or visitor who will have unescorted access to restricted areas should be issued a photo ID. This system should control access to restricted areas.</p>
<p><b>En-Route Security</b></p>	<p>Motor carriers should adopt an implementation plan that will establish standard operating procedures for communications between drivers, company personnel, and emergency services agencies. Company vehicles should have security systems installed that will protect them when they are left unattended.</p> <p>There should be an appropriate security program established that will ensure that all cargo containers are secured when in use and unattended in order to prevent theft or sabotage of their contents.</p> <p>Employers should implement a seal/lock program to deter the theft or sabotage of cargo housed in containers or cylinders.</p> <p>Employers should institute policies that will govern operations during periods of increased threat conditions.</p> <p>Employers should establish security inspection protocols that will be performed alongside required safety inspections. These inspections should occur before the start of a trip and after any stop en-route when a shipment is left unattended.</p> <p>Employers should use standardized reporting procedures for documenting suspicious incidents, threats, concerns about transportation facilities, or problems with company vehicles.</p> <p>Shippers and receivers should implement shipment pre-planning to ensure that shipments are not handed over to motor carriers until they can be transported in a way that minimizes public exposure and potential delays.</p> <p>Before a shipment departs, employers should pre-plan primary and alternate routes. Routing should attempt to avoid densely populated urban areas or critical infrastructure</p>

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Employers should investigate security practices in light of hours of service available. They should adopt policies that will minimize shipment vulnerabilities associated with extended rest stops.

Except under emergencies, employers should adopt policies that will ensure that contracted shipments remain with the primary carrier and are not subcontracted, that driver/team substitutions are not made, and that transloading does not occur until a subcontractor complies with federal safety and security regulations and company security policies.

Employers should adopt technologies that require drivers to identify themselves with a password or biometric data to drive a tractor. Panic buttons should be installed on vehicles to let drivers transmit an emergency alert notification to dispatch.

Employers should adopt methods that will let them track a tractor and trailer along their intended route with satellite and/or land-based wireless GPS systems.

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Source: TSA

The history of hazardous materials regulations in the U.S. is complex. The late-nineteenth century through the mid-twentieth century was marked by the introduction of progressively more restrictive regulations on hazardous materials transportation. With the HMTA's passage in 1975, the responsibility for overseeing these materials was consolidated within USDOT agencies. Although the HMTA has been amended many times, a renewed push for closer scrutiny of hazardous materials transportation did not emerge until after the 9/11 attacks. Somewhat paradoxically, while 9/11 strengthened some provisions related to hazardous materials monitoring, unlike the 1973 plane crash that was a key catalyst of the HMTA, it did not lead to sweeping legislation to protect the transportation of hazardous materials. Instead, rules have been constructed

piecemeal, with many (such as the new SAIs) being voluntary despite applying to the most dangerous substances carriers move through the highway network. This speaks to the tensions between regulation and deregulation, which the federal government commonly faces when dealing with private industry stakeholders while attempting to improve safety (Johnston, 2004b). As described previously and in the next section, the federal government, particularly TSA, has taken an interest in creating new technological innovations to monitor hazardous materials. Technological fixes such as these — if effective — can potentially facilitate great strides in hazardous materials security while not imposing onerous burdens on carriers and shippers.

### **2.3 Prototype Hazmat Tracking System (PHTS) — Background, Description, and Accomplishments**

Under the direction of the U.S. Congress, TSA spearheaded the effort to develop a Prototype Hazmat Tracking System (PHTS) in 2005. TSA awarded this contract to a well-known aerospace and defense company (this company will be referred to Contractor A in the remainder of this paper in order to preserve its anonymity). Contractor A was tasked with: 1) developing and demonstrating the technological feasibility of a centralized truck-tracking center (TTC) that could continuously monitor the locations of hazardous materials shipments; 2) developing and demonstrating a non-proprietary universal interface, or a set of communication protocols that could transmit alerts and tracking information to the prototype TTC; and 3) analyzing the feasibility and benefits of using a risk-based approach to managing hazardous materials security risks on U.S. highways. Development of the PHTS began in 2005 and concluded in 2008. The



remainder of this section describes the system that was engineered and what the development process revealed about the feasibility of monitoring hazardous materials shipments in real time.

There were several key components of the PHTS. First, it adopted an XML<sup>3</sup>-based interface. This interface let fleet-tracking vendors feed data to the TTC. A web interface, or portal, was created, enabling shippers and carriers to interact with the TTC and submit or view corporate data. The TTC's main function was to aggregate data that it received and translate that data into a form that would produce actionable information for government agencies. To understand the risk associated with a particular shipment, the PHTS incorporated a risk engine (also referred to as a business rules engine). The risk engine dynamically calculated the risk profile of hazardous materials shipments from gate-out to gate-in. For operational testing, the PHTS used a pre-existing risk engine. The idea behind the risk engine is that it analyzes risk levels based on different factors, such as a shipment's contents and where a vehicle is located. As such, it generated a dynamic risk assessment for each vehicle. The preceding elements served as the conceptual and analytical foundation of the PHTS.

While this would have represented a step forward in risk-based hazardous materials management by itself, without visually mapping risk scores in a dynamic manner these data would have proven ineffective. The system required a means of visualization so that system operators who staff the TTC could quickly and easily identify

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<sup>3</sup> XML is shorthand for *Extensible Markup Language*. It is a text-based format that enables the electronic sharing of data on the internet as well as corporate networks. A full exposition of XML is beyond the scope of this paper.

high-risk shipments. After data were processed, the results were displayed on desktops and workstations in the TTC in the form of continuously updated maps and itemized databases. System operators, defined as security specialists, would be attuned to the fluctuations of a shipment’s risk levels as it passed through different portions of the highway network. The final piece of the PHTS was a robust communication infrastructure that supported rapid interactions between government agencies, hazardous material handlers, and first responders. Eighteen event types were recognized by the PHTS, which are listed in Table 2.3. The events selected represent some of the most critical for hazardous materials shipments, events that would signal the shipment had either been compromised or would require immediate attention because of an accident or other situation. The following paragraphs describe the architecture of the PHTS in more detail.

**Table 2.3 Events Recognized in the PHTS**

<b>Shipment has gone off course</b>	<b>Position report</b>
<b>Driver alarm</b>	Vehicle hijacking
<b>Unexpected cargo weight change</b>	Unexpected cargo temperature change
<b>Attempted security bypass</b>	Automatic vehicle throttle down
<b>Automatic vehicle stopping</b>	Unexpected trailer separation
<b>Unauthorized system disabling</b>	Overdue shipment
<b>Entered geo-fence</b>	Exited geo-fence
<b>Unauthorized</b>	Cargo data
<b>Position at the time of the message</b>	Emergency contact number

The PHTS used an enhanced version of Contractor A’s Transportation Event Analysis and Management System (TEAMS) to store and display event-based information received from transportation-based systems. TEAMS relied on a web service to receive and process event-based XML messages. Whenever the system received information about an event that had not already been processed through its database, a

new event was created. The output was in HTML format, which required that users only have a web browser to review the current event status. Further, the system used Esri-formatted map data to display events. Once events were received and processed, they could be overlaid on map templates, which users could zoom into and out of to pinpoint the location of various shipments.

Key characteristics of the TEAMS database included the risk engine, the ability to view historical tracks of vehicles, a notification system that informed users when new information/events became available, and geo-fencing capabilities. A geo-fence is a polygon that demarcates a zone that a vehicle should be unable to enter or exit. There were two types of geo-fences implemented in the system. First, an exclusive geo-fence was defined to prevent a vehicle from entering a specified area. That is, if a vehicle broke through the perimeter, the system generated an alert. On the other hand, an inclusive geo-fence effectively circumscribed a vehicle's movements, if a shipment ventured beyond this zone the system produced an alert. Creating and maintaining geo-fences is a key element for preventing hazardous materials shipments from adversely impacting densely populated areas, critical infrastructure, and other valuable assets. Their effective operation is imperative for a risk management system. All the pieces of TEAMS, combined, were used by TTC security specialists at a single workstation to view and manage shipments. Figure 2.1 illustrates the event scene users had access to when managing and mapping events.

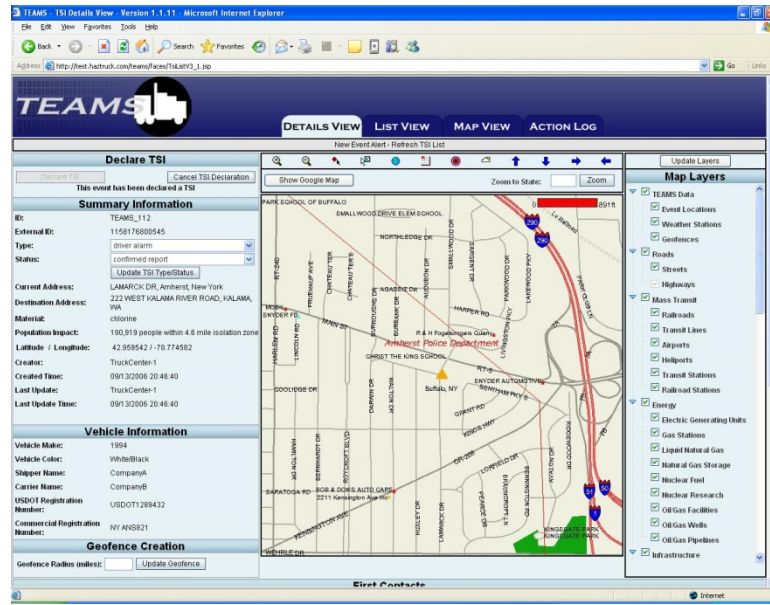


Figure 2.1 Screenshot of TEAMS Interface

Developing full featured geo-fencing capabilities was critical for enhancing TEAMS's ability to detect potentially dangerous hazardous materials shipments. The system gave users the ability to create geo-fences through the use of several methods. They could delineate the boundary of a geo-fence by hand drawing it on a map or they could upload existing shapefiles into TEAMS. Rather than creating multiple geo-fences based on the properties of each substance, users were able to create distance buffers around each truck based on guidance related to Emergency Response Guide information about the materials it carried. Due to reporting lag times, a second buffer was generated for each truck that accounted for its reporting interval. Combining multiple buffers around each truck with the fixed geo-fences drawn on the landscape improved performance by reducing computational demands. When the geo-fence data were meshed with risk calculations from the risk engine, users had access to a robust suite of applications to understand how and why a particular shipment's risk profile changes.

Because of limited data availability, however, the PHTS did not integrate a fully realistic set of risk estimates. However, this was sufficient to demonstrate that dynamic, spatially explicit risk calculations were feasible, which was the primary goal of the project.

Though the project goal was met, there was no intent to create a full-blown system that tracked each individual shipment on a broad scale.

Overall, the PHTS served as proof of concept for implementing the technologies that would be essential for a fully operational TTC. Further, the system showed that a centralized tracking facility had the resources to accept carrier tracking data and respond to emergency notifications from carriers when a geo-fence violation occurred. Although it would be necessary to make significant adjustments to operationalize a full-scale TTC, the PHTS, with the deployment of TEAMS, demonstrated that calculating the risk profiles of hazardous materials shipments in real-time and mapping those profiles was possible and could provide a much needed added layer of security for the hazardous materials supply chain. This is not to say the system was without its shortcomings. A functional tracking system would require more frequent position reports from trucks to improve the accuracy of mapping and risk assessments. However, making this change would yield a considerable return on investment and strengthen the risk-based approach to managing security risks that underscores the TTC concept.

## **2.4 Operational Testing Results and Gap Analysis**

### **2.4.1 Methodology**

Testing the reliability and accuracy of complex software presents many challenges. The methodology adopted to evaluate the prototype tracking system is

independent verification and validation (IVV), a set of procedures that can be used to identify gaps between the desired or expected performance of a system and how it performs under operational conditions (Lewis, 1992; Thompson, 2015). For this study, gap analysis identified areas in which the prototype tracking system failed to meet the specifications articulated by the federal security agencies. That is, analysis questions whether the prototype system, as built, is suitable for a large-scale monitoring program. While IVV has been used in a variety of contexts, in the context of software engineering, the goal of IVV is to determine whether a product is free of errors and meets the needs of end users (Bailey, 2015). It can assist designers and developers in pinpointing a system's design flaws, coding problems, and to determine whether it functions in a manner consistent with client expectations. IVV entails two processes — verification and validation. The purpose of verification is to demonstrate the consistency, completeness, and correctness of a software application: to show that the system has been constructed properly (see O'Keefe and O'Leary, 1993). Conversely, validation attempts to demonstrate whether the software's operation aligns with specification and meets the needs of users (Adrion et al., 1982). It is critical for an independent team to perform the IVV — although developers may participate in the process and facilitate testing, they cannot be responsible for verifying and validating software (Easterbrook & Callahan, 1998). Broadly, IVV is used to identify system flaws. Once the errors and drivers of substandard performance have been identified, software engineers can make revisions so it meets user expectations (Braude & Bernstein, 2016).

IVV has been used frequently by government agencies, such as the Department of Defense, the National Aeronautics and Space Administration (NASA), and the Department of Health and Human Services (Lewis, 1992). Likewise, it has been applied to the analysis of a broad range of software systems and software engineering problems (Wallace & Fujii, 1989). For example, Easterbrook and Callahan (1998) described the use of IVV to evaluate critical software required to operate the International Space Station. Rykiel (1996) examined the validation in the context of ecological modeling, discussing the circumstances under which validation can be used and evaluated strategies for adopting validation criteria. Oberkampf and Trucano (2002) provided an extensive discussion of the verification and validation of complex fluid dynamics models and outlined a set of experimental protocols for running validation experiments and quantifying experimental uncertainty. Robinson and Brooks (2009) used IVV to evaluate an industrial simulation model which had been developed to select waste storage sites for remediation; they determined the potential effects of remediation on hazardous materials supply chains. Indeed, IVV has often been applied to simulation modeling (Carson, 2002) in a broad array of areas, from the earth and environmental sciences (e.g., Oresekes et al., 1994; Niazi et al., 2015) to agent-based modeling of social systems (e.g., North et al., 2007). In a more topical example, Lathrop and Ezell (2016) analyzed nine terrorism risk assessment models using an IVV approach. As they observed, one of the challenges of validating models focused on terrorism is that only a small number of terrorist attacks have been observed. Consequently, traditional models of validation, which make conclusions based on correlations between model predictions and observed

events, are inadequate. In their place, Lathrop and Ezell (2016) recommended establishing alternative criteria (e.g., whether a model substantively informs policymaking decision) to evaluate the utility of models based primarily on subject-matter expertise and theoretical knowledge.

While the pilot study demonstrated the feasibility of designing and implementing the risk-based approach to tracking and mapping hazardous material shipments, many shortcomings would require correction before pursuing further system development. To identify the PHTS's strengths and weakness, an Endgame IVV analysis was performed that assessed the system under simulated real-world conditions (Lewis, 1992). Although it is ideal for IVV programs to stretch throughout the lifecycle of software and system development, often this is not possible. An Endgame IVV is a valuable tool that assesses the results of software testing after initial product design and development have been completed. As such, its purpose is to validate software performance and identify if that performance aligns with the required specifications validation (Lewis, 1992). The PHTS's accuracy, functionality, and reliability were evaluated based on 92 hazardous materials transportation simulations. This operational testing revealed how well the PHTS handled three event types: 1) activation of the panic alert; 2) the effectiveness of the exclusionary geo-fence; and 3) the effectiveness of the inclusionary geo-fence (see previous section for descriptions). Test results, along with qualitative observations of system performance, were used to develop a gap analysis (see below). Along with gauging the PHTS's performance, the IVV identified areas where its performance was not consistent with the specifications provided by DHS and TSA,



which are necessary to improve the risk management and tracking of Tier 1 HSSMs. The gap analysis also discusses specific failings that would prevent the PHTS from being adopted for a Tier 1 HSSM tracking system.

#### **2.4.2 Findings and Gap Analysis**

This section does not exhaustively describe all of the PHTS's limitations. Although it is technically possible to exhaustively test any system, generally this not feasible due to time and resource constraints (Easterbrook & Callahan, 1998). Accordingly, a narrower, more targeted testing protocol is useful to identify key gaps that would pose the most significant challenges for a client, in this case DHS and TSA. The following discussion highlights the most pressing issues uncovered by IVV and operational testing, problems which, if left unaddressed would effectively prevent a PHTS from being deployed (Table 2.4 includes a list of gaps that were identified during the analysis).

**Table 2.4 Key Gaps Identified in the PHTS**

<b>Gap Identified</b>	<b>Explanation</b>
<b>Lack of support for a Tier 1 HSSM regulatory program</b>	The PHTS was designed and tested prior to the TSA releasing Tier 1 HSSM SAIs in 2008. Its functionality was not built with this use in mind and would need revisions.
<b>Underpowered and outdated software</b>	The PHTS relied on older versions of Esri ArcGIS, which limited its functionality and application.
<b>No electronic manifest solution</b>	Developing an e-manifest solution based on XMFL e-forms technology would facilitate communication of data on shipments to the TTC.
<b>The risk engine applied a single rule to perform risk assessments</b>	Because the PHTS used an already-existing risk engine, it was limited in the accuracy of the dynamic risk scores it could provide.
<b>Inability to determine whether a truck adheres to a route</b>	The PHTS could not load electronic route plans from shippers and carriers, which significantly diminished the effectiveness of geo-fences and its potential to aid with risk management.
<b>Vehicle immobilization not possible</b>	The PHTS did not provide a solution for immobilizing a vehicle, which is a critical tool for preventing a compromised shipment from entering a restricted area.
<b>Poor geo-fence performance</b>	As noted in Table 2.5, the geo-fencing solution was unreliable, creating a number of false positives. There should be the integration of new applications to create geo-fences.
<b>Single Incident Management</b>	As configured, the PHTS only allowed a security specialist to manage a single incident, which would hamper stakeholders' ability to achieve a timely resolution.
<b>Limited communications options</b>	The PHTS did not support seamless communication between government agencies during incidents. It also relied too much on telephone communications.
<b>Lack of data mining capabilities</b>	Anticipating incidents requires that security specialists have the access to historical and current data they could examine to evaluate whether a situation poses a threat.

Three of the most critical problems identified by the IVV were functional defects, unsatisfactory performance, and poor system security. Even though geo-fencing was a

key component of the system, during system testing this function was unreliable. Events that should have prompted alerts often failed to do so, while other events that should have removed a geo-fence from the PHTS did prompt the necessary system updates. Slow performance also hampered the system, a problem that was attributed to the event analysis and management system that served as the PHTS's conceptual foundation. Along with cataloging information about individual hazardous materials shipments, the system was dynamically linked to the mapping application which visually displayed the location and movement of vehicles. The final problems that emerged during this testing were the PHTS's security vulnerabilities. Although most password-protected internet-based systems eventually time out after a certain period of inactivity, the PHTS did not. Further, it stored user identification on local machines rather than on the network, potentially leaving the system vulnerable to outside attacks.

Table 2.5 summarizes the problems encountered during PHTS testing as well their frequency. Most tellingly, the system had problems in over 50 percent of the staged events. Many problems stemmed the TTC being inundated by multiple events in close succession. In other cases, the operator responsible for monitoring the system could not identify, based on information provided by the system, which trucks were sending an alert. Other problematic findings included the system operator not receiving or responding to alerts during approximately 25 percent of the staged incidents as well as numerous difficulties with interpreting carrier macros and knowing what type of cargo that a shipment contained. An outgrowth of these issues was a lag in response time. The system had an established response timeline for responding to a security

incident. This timeline accounted for: 1) the amount of time to detect an event, 2) how long it takes the system monitor to establish communication with the TSA, and 3) the amount of time to contact the carrier and verify the nature of the alert. Based on the operational testing and additional simulation runs, the mean response time for panic button alerts was 8 minutes. However, this climbed to 16 minutes for geo-fence violations. Taken together, the mean response time was 12 minutes. Although these numbers seem impressive, law enforcement officials consulted as part of this analysis stated that 12 minutes is significantly longer than would be acceptable to confirm that an incident as occurred and declare a transportation security incident is in progress, especially in highly populated areas where response times must be quick to ensure that nearby residents and businesses are protected from the consequences of a hazardous materials release. It is unclear how they arrived at this number, although presumably they take a cue from emergency medical services and the importance of responding to call in under 12–15 minutes, as this leads to the best patient outcomes (e.g. Blackwell & Kaufman, 2002). While the comparison between terrorist incident reporting and emergency response is not exact, it provides a starting point to understand what appropriate reporting timeframes should look like. As such, this operational test confirmed that the PHTS was underpowered, which has a negative repercussions response times.

**Table 2.5 Quantitative Summary of Problems Identified in PHTS**

<b>Problem/Issue</b>	<b>Number of Geo-Fence Violation Alerts</b>	<b>Number of Panic Alerts</b>	<b>Total Combined Alerts</b>	<b>Percentage of Staged Events Impacted</b>
<b>TTC did not receive or respond to alerts</b>	21	5	26	28%
<b>TTC could not maintain current or multiple carrier contact information</b>	5	8	13	14
<b>TTC system operator could not identify which truck generated an alert for carriers</b>	20	32	52	57
<b>Interpretation of carrier macros to open up a trip, know what the cargo is, and respond to an alert</b>	19	3	22	24
<b>Carriers receive multiple contacts for the same event</b>	1	2	3	67
<b>TTC overwhelmed by multiple staged events*</b>	1	1	2	67

\* Based on three staged events; the remaining findings were based on 92 staged events

The operational test revealed other critical flaws of the PHTS’s design. In addition to the performance shortcomings noted, the system was not constructed to support a tracking solution focused on Tier 1 HSSMs. This is understandable, given that the TSA did not issue its guidance on these materials until June 2008, after field testing was complete. Future system designs must be geared toward monitoring Tier 1 HSSMs. Other problems with the PHTS included the repeated failures of some system components that were integral to the system. As constructed, the PHTS lacked the ability to implement an electronic route solution that would also permit route adherence monitoring. More simply put, the PHTS could not accept route plans from shippers and carriers. Without these data, system operators were unable to know whether a vehicle deviated from its planned route. This feature’s absence diminished

the system's risk management capabilities and the usefulness of geo-fences. The methods used to construct geo-fences were also cumbersome. The pilot study created buffers around individual trucks and made it difficult to determine when a vehicle neared a geographic threshold. While this seems like an attractive strategy, it will not stand up under everyday operations because it will generate too many false positive alerts. Indeed, the field testing revealed that the PHTS was vulnerable to producing false positives. Being inundated with false positives would distract system operators, preventing them from attending to activity going on elsewhere in the road network. While the geo-fence idea should not be abandoned, where they are sited and constructed should be the responsibility of state and federal officials. Equally troubling, the PHTS was missing a procedure to immobilize vehicles. In the event of an attack or hazardous materials release, it is imperative that there is an option to quickly immobilize a vehicle so that it cannot be weaponized and catastrophically impact surrounding locations.

Looking a bit deeper into the operation and management of the PHTS, a critical drawback was that security specialists could only manage a single incident. Recalling that there are approximately two million Tier 1 HSSM shipments each year, a TTC will be responsible for monitoring over 5,000 shipments at a given time. As such, it will be critical that multiple security specialists be able to monitor and manage multiple incidents. Along with speeding up response times, this would enable better collaboration among system monitors and improve communication between the TTC, public agencies, carriers, and shippers. This arrangement could be enhanced through

the use of custom, dynamic risk modeling algorithms that iteratively calculate the risk associated with individual shipments. A more streamlined user interface combined with more agile risk modeling, while necessary, must be accompanied by significant improvements to the PHTS's software. As noted previously, the system's performance was somewhat lacking, compounded by persistently slow or inefficient operations. Certainly, if deployed as-is, the mixture of false positives, poor geo-fence performance, and sluggish responses would render the PHTS ineffective.

## **2.5 Discussion and Conclusions**

Reviewing the history of hazardous materials regulation from the late 19th to the late 20th century, the federal government, through legislation and rulemaking, progressively expanded its oversight powers. While previously catastrophic events were enough to usher in broad reforms to hazardous materials regulations, this does not appear to be the case anymore. Although there were modest yet vague expansions in government power with respect to hazardous materials regulation following 9/11, the fact that the TSA's 2008 SAIs continue to be strictly voluntary suggests this is unlikely to change in the near future. That being the case, the federal government and other public agencies will need to identify alternative strategies to monitor hazardous materials shipped on U.S. highway networks. This paper contributes to ongoing discussions about the regulations and systems used to govern hazardous materials transportation by situating current regulatory practices within in a broader historical context. During the 20th century, the federal government incrementally tightened restrictions on the shipment of hazardous materials, but while the 9/11 attacks led to the introduction of

some new regulations, the TSA's newest SAIs are voluntary. There has been a move to develop new systems to monitor hazardous materials transported on highways. The FMCSA and TSA have conducted two studies since 2003 to examine the feasibility of smart truck technologies and telematics for tracking the location of hazardous materials shipments. Although it is unclear if shippers and carriers will sanction this type of monitoring, it provides a compromise which allows the government to increase oversight and ensure that companies are held accountable without imposing burdensome regulations that would interfere with the day-to-day operations of shippers and carriers. This paper discussed the results of the PHTS's operational field tests, conducted from 2005 to 2008. Therein lies its practical contribution — in the demonstration of the powerful opportunity risk-based Tier 1 HSSM management holds for industry stakeholders. Arguably, the operational test offered evidence of the PHTS's feasibility, even if the system had its share of problems. Most notably, system development and testing revealed that vehicles carrying hazardous materials can be dynamically tracked in real time. The PHTS combined information on the location and of the vehicle's contents to evaluate the risk associated with it. These data were then processed and displayed using maps generated by a GIS. However, as the gap analysis demonstrated, the system was unable to perform satisfactorily in a number of areas.

Future software engineering development needs to focus on creating an environment optimized for tracking Tier 1 HSSM movements. There were other deficiencies that would need to be addressed during a system redesign. The PHTS was underpowered, which led to substandard performance, hampering the ability of users to



track individual shipments. Upgrading the GIS software, developing new databases, and increasing computational power would be essential during the new system build. While the PHTS demonstrated that geo-fences are a valid tool for delineating where shipments can and cannot go, and therefore creating alerts when vehicles transgress their boundaries, there were a number of instances when they did not perform as intended. In many cases users were not alerted to a vehicle crossing a geo-fence. In other cases, they were unable to match an alert to a particular vehicle, or when multiple alerts were triggered, the system became overwhelmed. Perhaps most critically, the PHTS relied on a risk engine that was not created specifically for performing risk assessments of Tier 1 HSSMs shipments.

While this paper certainly moves the discussion on hazardous materials transportation forward, one limitation it presents is that the research is very narrowly focused on a subset of hazardous materials (Tier 1 HSSMs), which constitute a fraction of all hazardous materials shipped on U.S. highway networks. Periodization of current regulatory practices, however, can inform future debates on the best policymaking strategies to minimize the public health and safety threats posed by hazardous materials. Despite its targeted focus, the prototype software could be retooled to facilitate monitoring of other transportation modes of classes of hazardous materials. Future work should focus on rethinking how the PHTS conceptualizes and calculates risk. This would entail building a new risk engine that is more attuned to dangers posed by Tier 1 HSSMs. Populating a new risk engine with appropriate risk equations will demand extensive research on safety and security hazards posed by Tier 1 HSSMs. This

information can be gathered through a combination of expert knowledge and interviews with transportation officials in federal, state, and local government agencies.

Interviewing or surveying key industry stakeholders would be valuable activities to establish what the most pressing threats with Tier 1 HSSMs are. Input from these subject matter experts could be used to develop risk equations to more accurately quantify the level of risk associated with shipments.

Recent congressional inaction on issues related to hazardous materials transportation suggests that new regulations are unlikely without a catastrophic terrorist attack or accidental hazardous materials release. Nevertheless, even if participation in monitoring programs remains voluntary, shippers and carriers have a powerful incentive to buy into a more comprehensive risk management system. As such, it is imperative that public agencies, shippers, and carriers alike adopt a risk-based approach to managing Tier 1 HSSMs. Despite its shortcomings, the prototype software described in this paper offers a much needed foundation to move ahead with future work in this area.

## Chapter 3 Quantitative Risk Assessment

### 3.1 Introduction

Academic researchers and U.S. federal, state, and local government agencies have devised numerous methodologies to analyze the level of risk associated with hazardous materials shipments transported via highways, rail, and waterways (Erkut & Ingolfsson, 2005; Liu et al., 2013; Van Raemdonck et al., 2013; NRC, 2010; Masse et al., 2007). Risk analysis for hazardous materials transportation gained traction among academic practitioners during the 1980s (Erkut & Verter, 1998), however, many government agencies did not bring a concerted focus to the problem until after the September 11, 2001 terrorist attacks (e.g., Willis et al., 2006). 9/11 demonstrated that terrorists could adopt unconventional and deadly methods to execute acts of terror, with airplanes being transformed into weapons. Although the early response to 9/11 focused primarily on securing the air transportation system, concerned policymakers recognized that a more expansive response was in order, given that not just airplanes, but also trucks, waterborne vessels, and railroad cars could potentially be weaponized. Efforts by government agencies to improve their risk assessment capabilities followed over the next five years, with a number of new methods introduced to analyze risk. Nowhere was this more evident than at the Department of Homeland Security (DHS), where a number of offices developed risk assessment methodologies based on techniques that had previously been applied to natural hazards (NRC, 2010). Further, DHS also introduced a grant program that allocated resources to state-level agencies. Despite DHS — and other agencies — speeding up efforts to quantify and mitigate risk,

serious problems remain, with DHS grant allocations being influenced more by political factors than by objective risk assessments (Nordyke, 2014) while new risk analysis methodologies remain unproven, poorly documented, and rarely exposed to the scrutiny of peer review (NRC, 2010).

The main objective of this paper is to develop a semi-quantitative equation that can be used to measure the risk level of vehicles carrying Tier 1 Highway Security Sensitive Materials (HSSM) at specific points in the highway network. Risk methodologies and equations have been developed for a number of surface transportation domains, however, none have been created specifically for Tier 1 HSSMs — a critical oversight given the Transportation Security Administration's (TSA) focus on these materials. Building this equation required a stepwise process that involved background literature reviews, a survey of personnel employed by transportation agencies, and semi-structured interviews with subject-matter experts. The literature review examines academic publications as well as risk assessment methodologies currently used by federal government agencies.

To understand the day-to-day understanding of risk mobilized by staff local, state, and federal transportation agencies who are responsible for overseeing infrastructure security, a comprehensive survey was administered. The survey included questions on the 19 attack-and-release scenarios involving hazardous materials and their likelihood of occurring; the probability of terrorists failing due to technical hurdles or security measures under a subset of these scenarios; the potential impact of attacks on nearby populations, critical infrastructure, key resources, and the economy, among

others; and the effectiveness of the Transportation Security Administration's voluntary Security Action Items (SAIs) for circumventing potential attacks. Many of the survey questions leveraged the Sherman Kent Scale (hereafter, Kent Scale) to discern the likelihood of different events (Meyer & Booker, 1991). The Central Intelligence Agency and other federal agencies routinely use the Kent Scale to elicit expert opinion about the likelihood of different events (e.g., a terrorist attack) occurring. The scale converts linguistic descriptions of an event to numerical probabilities. Once given a numerical value, these data can be incorporated into quantitative and semi-quantitative forms of analysis. The survey results provide critical insights into experts' thinking about infrastructure security, where they perceive the most glaring security risks, and what terrorist attack scenarios transportation agencies believe are most likely. After survey data were collected, subject-matter experts from TSA, the Department of Homeland Security, and independent security consultants were consulted to offer feedback on the results and assist with the development of a comprehensive risk equation for Tier 1 HSSMs.

The survey and interview results were used to develop a semi-quantitative risk equation for evaluating the specific level of risk a Tier 1 HSSM shipment poses. The equation, following practices of DHS and other federal agencies, views risk as the product of threats, vulnerabilities, and consequences. The risk equation factors variables such as attack mode, type of hazardous material, trailer/container type, critical infrastructure and key resources, nearby population density, economic impacts, and proximate environmentally sensitive areas into its calculations. It highlights that risk

levels are dynamic and vary spatially — as such, risk values are calculated iteratively, with new risk estimates derived for a shipment when it enters a new portion of the highway network.

### **3.2 Literature Review**

While it is critical to understand academic thinking on risk analysis, there is a disconnect between risk assessment methodologies discussed in the peer-reviewed literature and the strategies used by government agencies. There are many reasons for this, ranging from inadequate personnel numbers at federal agencies, which prevents staff from accumulating and retaining institutional expertise, to the need for analytically parsimonious methods to quickly assess risk levels for a particular situation (NRC, 2010). This review focuses on risk analysis frameworks proposed in the academic literature as well as those that have been implemented by the Departments of Transportation and Homeland Security, Transportation Security Administration, and Federal Motor Carrier Administration, and other federal agencies. The National Research Council's (2010) review of risk analysis methodologies used within federal transportation and security agencies observed disconnect between agency practices and peer-reviewed literature. Reconciling these literatures is beyond the scope of this review. One area of agreement, however, is the importance of leveraging expert knowledge to conduct risk analyses due to the small number of events in which deliberate hazardous materials releases have occurred. Reviewing academic and governmental literature contextualizes the risk analysis framework articulated later in this paper. It also situates the proposed risk

framework by demonstrating it combines the analytical parsimony required by government agencies with the findings of academic research practitioners.

Expert judgment has often been used as a foundation of risk analysis and to identify risk management strategies, especially within the context of hazardous materials oversight and terrorism. Otway and Winterfeldt (1992) identified the expanding role of expert judgment in regulating and managing hazardous industrial activities. Leung et al. (2004) proposed a methodology for assessing the vulnerability of critical bridges and infrastructure to terrorist attacks. Because there was little quantitative data available on critical transportation infrastructure's vulnerabilities, they were largely dependent on expert judgments. Experts were asked to sort and filter risk scenarios based on their perceived likelihood and consequences (were the event to occur). Questions remained about the confidence of expert predictions, but lacking empirical data, Leung et al. argued that their work provided a foundation upon which to analyze terrorism scenarios. Apostolakis and Lemon (2005) combined a graph theoretic framework with a qualitative screening methodology to highlight the vulnerabilities of critical infrastructure. Decision trees were used to determine the impact of losing infrastructure services. Combining these methods offered decision makers a semi-quantitative prioritization methodology to determine which pieces of critical infrastructure warrant the most robust security measures. Chang et al. (2013) developed a novel methodology to assess the resiliency of community infrastructure in the face of tectonic and flood hazards. They interviewed experts to elicit their judgment

about the disruptions produced by a hazard and the subsequent recovery time needed to return an urban area to normal functioning (see also McDaniels et al., 2015).

U.S. government agencies evaluate risk as a function of threats, vulnerabilities, and consequences. However, various agencies define and measure these terms differently. The Federal Motor Carrier Safety Administration (FMCSA) developed qualitative self-assessment tools to let users estimate the risk profile of vehicles transporting hazardous materials. Threats, according to the FMCSA, are “sources of danger and can include both criminals and terrorists and the attacks that they might initiate to achieve their objectives;” vulnerabilities “are weaknesses that make a [carrier] more susceptible to attack or injury” (2009, p. 12)<sup>4</sup>. The FMCSA established a simple method to rank threats and vulnerabilities. The first step is to prioritize threats and rank them using verbal descriptions that are translated into numerical scores. For example, a threat may be viewed as highly likely, somewhat likely, possible, unlikely, or improbable. Next, vulnerabilities are ranked on a comparable scale (e.g., from very low to high). Threat and vulnerability scores are combined in a likelihood matrix to gauge how probable a terrorist attack is. Under this rubric, if a carrier deems a threat specific and credible and vulnerabilities are medium or high, the event receives the highest likelihood score. Conversely, if threats are improbable and vulnerabilities are very low, the likelihood of terrorist attack is small. There are several drawbacks to this approach. Most critically, the rankings are entirely subjective because they are performed by

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<sup>4</sup> The FMCSA does not define consequence explicitly, other than to say the outcomes of hazardous materials releases will vary based on the type of material involved. Despite this equivocation, consequences are integral to identifying and estimating risk.



individual carriers. As such, the system does not provide a reliable means of estimating how risk varies across transportation networks. Another problem (that applies to other risk assessment methodologies) is that the likelihood of an event is not synonymous with the probability. Because the number of deliberate hazardous materials releases that have occurred is very small, the lack of data prevents us from estimating the true probabilities. Currently, the FMCSA does not require carriers to submit formalized self-assessment documents. While this is problematic, equally troubling is that the methodology the agency proposes does not necessarily require the input of subject-matter experts, relying instead upon the employees of individual carriers. This has the potential to generate findings that are neither aligned with current understandings of risk nor validated by outside researchers or analysts.

Carriers in the railroad industry use the Rail Corridor Risk Management System (RCRMS) to select which routes security sensitive materials should be transported on. This methodology has been accepted and is relied upon by the Federal Railroad Administration (FRA) (VRT, 2012). All Class 1 railroads and some smaller carriers use the RCRMS to perform risk analysis and route selection. Although it treats risk as the product of threats, vulnerabilities, and consequences, the RCRMS defines threats and vulnerabilities differently than the FMCSA. The RCRMS defines threats as a product of: 1) a base level threat factor, 2) the amount of hazardous materials being transported, 3) the presence of high consequence targets, and 4) population density. Rather than framing vulnerabilities just in terms of the weaknesses that a carrier identifies, the RCRMS defines vulnerability as the likelihood of a person successfully executing an

attack if they actually begin an attack. Potential consequences are calculated based on the populations that would be impacted by a materials release, critical infrastructure and key resources affected, and environmentally sensitive areas exposed along a route. Carriers have the option to input a number of variables into the RCRMS. In addition to factors noted above, it also accepts data on the conditional probabilities of release (which vary based on USDOT tank car specifications), the proximity of key environmental assets, presence of nearby rail facilities, the location of police and fire stations, and historical incident rates. Based on these inputs, the RCRMS generates a single risk score for the entirety of a route. It accomplishes this by computing risk scores for individual rail segments and summing them across an entire route. Thus, while the final output is a single risk score, embedded within that score are spatially explicit considerations. Carriers use these data to identify the optimal routing. Because the system has built-in GIS capabilities, users can quickly grasp how spatial differences among different variables contribute to spatially uneven distributions of risk.

The 9/11 Act mandated that DHS identify and exhaustively document the risks associated with terrorist attacks on the U.S. hazardous materials trucking system (VRT, 2012). This motivated the development of the Trucking and Hazardous Materials Trucking Risk Assessment (THRTRA), which was performed jointly by TSA's Highway and Motor Carrier Programs. While it delved into risk analysis methodologies, the assessment's purpose was not to create an operational risk assessment system that could be used on a daily basis by federal agencies. Rather, it leveraged subject-matter expertise, open source research, and conversations with industry stakeholders to

implement a scenario-based approach that measured risk as a function of truck status, attack type, acquisition status. THTRA defined threats, vulnerabilities, and consequences similarly to the systems previously described (although see Table 3.x for a comparison). What distinguished THTRA from other assessment strategies was its use of the Sherman Kent scale (see below for a more detailed discussion) and qualitative binning to initially characterize and then quantify threat, vulnerability, and consequence levels. More specifically, the Sherman Kent scale translates verbal descriptions into quantifiable probabilities or likelihoods. Table 3.1 illustrates THTRA's use of the Sherman Kent scale and how verbal descriptions align with one another. THTRA's risk scores were relative, meaning they were reported for each non-asset specific attack scenario. Compared to the FMCSA and RCRMS methodologies, the assessments here relied more heavily on expert elicitations, which is more consistent with the tendencies identified in academic research. Drawing on subject-matter expertise is critical for identifying knowledge gaps, and has been used in disciplines ranging from natural hazards analysis (e.g., Meyer et al., 2013; Frickel & Vincent, 2011) and chemical risk communications (Cox et al., 2003), to risk analysis (Taylor-Gooby & Zinn, 2006) and identifying the risk of terrorism in a multimodal transportation context (e.g., Tsamboulas, 2010). Clearly, any effort to refine our knowledge of risk assessment in the domain of hazardous materials transport must tap into the knowledge of not just academic experts, but also individuals who have acquired practical expertise through their experiences working at transportation and security agencies.

**Table 3.1** Application of the Kent Scale by THRTA

<b>Threat and Vulnerability (Kent Scale)</b>	<b>Consequence</b>	<b>Risk</b>
<b>Certain</b>	Catastrophic	Critical
<b>Almost Certain</b>	Significant	Significant
<b>Probable</b>	Major	High
<b>Chances About Even</b>	Elevated	Medium
<b>Probably Not</b>	Moderate	Minor
<b>Almost Certainly Not</b>	Minor	Low
<b>Impossible</b>	Inconsequential	Very Low

The last risk system this review will examine is the Transportation Sector Security Risk Assessment (TSSRA), which was developed by the TSA in response to a 2009 DHS Appropriations requirement that asked TSA to examine and document transportation risks using a common analytic framework. Unlike the other systems discussed here, TSSRA was not mode specific. It established baseline characterizations of current risk levels across all transportation modes. TSSRA employed a scenario-based assessment framework that was not mode specific. Rather, it analyzed risk based on asset and attack type. As such, it adopted slightly more nuanced definitions of threats, vulnerabilities, and consequences. Most notably, TSSRA quantified vulnerability using two metrics — first, a law enforcement/counter-terrorism metric, and second, a countermeasure effectiveness metric (see NRC, 2010; VRT, 2012). Starting from an initial database of 800 scenarios, experts pared that number to 200. Like THTRA, TSSRA relied on significant input from subject-matter experts to analyze the risk of particular scenarios. TSSRA comes with several drawbacks, however. The most salient is its inability to analyze how risk changes as a function of location. Because its analysis uses representative assets instead of specific locations, it is unclear whether it is possible to

make its risk evaluations spatially explicit (i.e., calculate risk for particular vehicles when they are at different points on the highway network). TSSRA assists stakeholders with exhaustively imagining various attack scenarios and outcomes, but it sacrifices realism through its asset-based framework.

**Table 3.2** Summary of Definitions for Threats, Vulnerability, and Consequences by Risk Assessment System

<b>System</b>	<b>Threat</b>	<b>Vulnerability</b>	<b>Consequences</b>
<b>FMCSA</b>	- Sources of danger, including criminals, terrorists, and the attack they use to initiate or achieve their objective	- Weaknesses that make a carrier susceptible to attack or injury	- Not formally defined, but implicitly linked to the outcomes of a terrorist attack
<b>RCRMS</b>	- Product of a baseline threat level factor defined by experts and other variables, such as the amount of hazardous goods in a shipment, the proximity of high consequence targets, and population density	- Characterizes the likelihood of an attacker succeeding. That is, they achieve their desired effect once an attack begins	- Includes the population potentially impacted, any critical infrastructure and key resources exposed to an attack, and environmentally sensitive areas potentially affected
<b>THTRA</b>	- Relative likelihood of an attempt	- Relative probability of success given that an attack is attempted	- Human impacts, direct and indirect economic effects, and psychological impacts
<b>TSSRA</b>	- Viewed as a function of capability and intent - Capability is the conditional likelihood that an attacker has the resources and skills needed to undertake an attack scenario within a defined timeframe - Intent is the conditional likelihood of an attacker selecting a particular attack scenario once they have committed to launching one	- Consists of two elements - Law Enforcement/Counter-Terrorism factor, which is the conditional likelihood that national, state, and local law enforcement do not detect an attack - Countermeasure Effectiveness, which is the conditional likelihood of an attacker successfully circumventing an asset-specific defense system	- Includes human consequences, direct and indirect economic evaluations, and a psychological impact factor

Peer-reviewed literature and governmental documents are in agreement that (in the absence of a large historical database of attacks on vehicles that move transportation materials) relying on expert judgment to estimate the level of risk associated with particular shipment types is critical. Although using judgment introduces subjectivity into the assessment process, this is unavoidable. As the NRC observed, problems with subjectivity can be overcome if expert judgments are vetted through peer review. Existing risk assessment methodologies used by the federal government are consistent in positioning risk as the product of threats, vulnerabilities, and consequences, however, each has various strengths and weaknesses (see Table 3.2). Some methodologies — like those proposed by the FMCSA — do not incorporate the feedback of subject-matter experts, while others depend too greatly on academic expertise. Academic expertise is valuable, however, it should not be used exclusively. Doing so omits the perspectives of transportation agency personnel who engage with matters of risk assessment at an everyday practical level. The risk analysis equation described later in this paper will use the methodologies described in this section as a starting point, but will incorporate changes based on survey and interview findings.

### **3.3 Methodology and Methodological Justification**

To understand the security priorities of transportation officials around the United States, a web-based survey was administered to expert stakeholders from around the country. People employed at local, state, and federal agencies who are directly responsible — as part of their official job function — for securing some component of the United States' transportation networks were included in the sample

pool (see below for a discussion of the role expertise plays in prioritizing security priorities). Survey methods followed the protocols laid out in Dillman et al. (2014). To ensure all regions of the United States were represented, at least one official from each state was invited to participate. As Dillman et al. noted, a probability sample survey only succeeds to the extent that results can be extrapolated and generalized to a broader population. Targeting officials from multiple states and occupations satisfies this requirement by minimizing potential coverage and sampling errors.

The survey consisted of approximately 50 question and was administered using Qualtrics online platform. Appendix A contains the entire survey as well as tabulated responses and descriptive statistics. 295 individuals were invited to participate in the survey. Potential respondents were sent an initial email that explained the purpose of the survey and invited them to participate. A second round of follow-up emails were sent one week after the invitation to remind prospective respondents of the survey and to boost response rates. In total, 57 people completed the survey, for a response rate of 19.3%. Although this perhaps seems low, it is an acceptable response rate based on a review of other studies that adopted online surveys. Response rates for online surveys generally fall between 15% and 30% (Monroe & Adams, 2012). Survey questions asked about the likelihood of various terrorist attacks involving a Tier 1 HSSM release, risk factors that contribute most significantly to the aggregate impacts of a hazardous materials release, the probability of specific release scenarios occurring, whether the United States generally does an adequate job of securing the Tier 1 HSSM supply chain,



and the effectiveness of TSA's voluntary SAIs, which have been recommended for implementation — but which are not legally mandated.

Questions about the likelihood of particular events, scenario assessment, and the effectiveness of SAIs adopted a modified version of the Kent scale (e.g., Meyer & Booker, 1991). The purpose of the Kent Scale, which was originally developed for the CIA and has been used on a widespread basis for governmental studies, is to convert ranks or ratings to verbal descriptions, or vice versa. Figure 3.1 (Meyer & Booker, 1991) illustrates the Kent Scale's underlying logic. Survey respondents read about a particular scenario and are then presented with a number of written descriptions (usually 7–10). After interpreting the scenario, they will decide how likely it is to occur and chose the corresponding phrase that best reflects their assessment (e.g. “virtually certain,” “very likely,” “extremely unlikely”). Each phrase is then converted to a numerical probability, which facilitates semi-quantitative analysis. As such, use of the Kent Scale may underwrite a probabilistic approach to risk assessment. The adoption of the Kent Scale for academic studies has been uncommon, however, because a key motivation of this study is to develop a method of evaluating risk appropriate for government agencies, its use is warranted (see Jones & Hillis, 2003; Kreuzer et al., 2008; Gonzalez-Alvarez et al., 2010 for examples of the Kent scale being adopted to elicit expert judgments). Survey results and interviews with key stakeholders were used to develop a preliminary rating scale for quantifying the likelihood or consequences of particular release scenarios. Before discussing survey results, further elaboration on the nature of expertise and its importance for understanding hazardous materials releases is warranted.

**EXAMPLE 7.4: Sherman Kent rating scale**

Order Of Likelihood	Synonyms	Chances In 10	Percent (%)
Nearly Certain	Virtually (almost) We are convinced Highly probable Highly likely	9	99%
		8	80%
Probable	Likely We believe We estimate Chances are good It is probable	7	
		6	60%
Even Chance	Chances are slightly better than Chances are about even Chances are slightly less than	5	
		4	40%
Improbable	Probably not Unlikely We believe not	3	
		2	20%
Nearly Impossible	Almost impossible Only a slight chance Highly doubtful	1	10%

**Figure 3.1** Meyer and Booker's Presentation of the Kent Scale. An illustration of the Kent scale. Verbal statements about the likelihood of a particular event are converted to numerical probabilities. These probabilities can then be incorporated into quantitative or semi-quantitative risk assessments.

Expertise is a contested concept. Sometimes it is used pejoratively or dismissively to discount particular forms of knowledge that are inconsistent with one's ideological preferences. However, in this study, expert refers to a person who has a deep background in a particular subject area and is recognized by their peers as qualified to answer questions about it (Meyer & Booker, 1991). Expert judgments are data provided in response to a technical problem. They are not guesses — they are the product of an individual's training and relevant experience. Expert judgment can be used to interpret rare or complex phenomena on which information is lacking, to

forecast future events, and to integrate and analyze existing data, which can entail blending quantitative and qualitative data into a unifying interpretive framework (Meyer & Booker, 1991). Expertise is also valuable as an input for decision models. Once experts have rendered judgment on a question, it is possible to convert their responses to probabilistic values, combine those with external sources of information, and probabilistically estimate the likelihood of specific events (Hora, 2007).

Much research has investigated whether expert judgment has more value than other types of knowledge. For example, a number of studies from cognitive science have demonstrated that experts possess sophisticated mental models of the world based on years of training and experience that preferentially situates them to render judgment on the topics they are familiar with. Conversely, research on judgment and decision making has found that experts are sometimes prone to intentional or unintentional biases, which diminishes the quality of their conclusions (e.g., Shanteau, 1992; Washington et al., 2002; Hester, 2012). Although relying on expert judgment has potential drawbacks, gauging the likelihood and consequences of different Tier 1 HSSM release scenarios based on historical probabilities alone is not possible due to their rarity. There is a long tradition in the risk analysis literature of leveraging expertise when a situation is complicated by inherent uncertainties. As such, expert judgment is required to appraise the likelihood of a deliberate or accidental release occurring as well as the social, economic, political, and environmental consequences of such an event (cf. Meyer & Booker, 1991).

After completing survey analysis, semi-structured interviews were conducted with 12 subject-matter experts who specialized in hazardous materials transportation security. These professionals work for a variety of state and federal government agencies, including DHS and TSA, and as academic researchers. Interview sessions presented respondents with the survey findings. They were asked to validate these findings and evaluate their potential implications for risk analysis and management. Based on survey findings and published literatures, a preliminary risk equation was developed that can be used to estimate the threats, vulnerabilities, and consequences associated with particular shipments. Developing this equation leveraged risk assessment methodologies and frameworks currently used by the federal government, and was designed so that the results it generated were commensurate with risk analysis performed at other agencies, thus ensuring one-to-one comparisons across transportation domains and attack scenarios. The equation was developed iteratively, with continual input from subject-matter experts to ensure its reliability and validity.

### **3.4 Survey Results and Discussion**

Respondents felt it probable that attack scenarios could materialize at some point. With the exception of Scenarios 11, 12, 14, and 15, which between 60 and 85 percent of the respondents viewed as unlikely or extremely unlikely, the remaining scenarios generally scored between 30 and 40 percent. This suggests that security experts believe hazardous materials supply chains are vulnerable to potential attacks. Scenarios rated as the most unlikely to transpire would require the sophisticated and elaborate planning compared to those experts think are more probable. For example,

Scenarios 11, 12, 14, and 15 involve airborne devices or vehicles (drones, airplanes) or the use of improvised explosive devices to initiate an attack, with Scenario 15 encompassing a coordinated series of attacks. From this, we can infer that most security experts believe the most feasible attacks would be opportunistic. Although opportunistic attacks require planning, they would not demand that attackers commit the same level of resources to executing a terrorist action.

Scenarios that experts viewed as the most likely to occur: 1) explosive devices being detonated on or in close proximity to a vehicle, 2) hijackings, or 3) persons with insider knowledge taking control of a vehicle to purposefully release or detonate hazardous materials. While experts clearly believe that deliberate attacks are plausible, and in most cases at least more likely than not to happen at some point, they expressed the greatest confidence in hazardous materials being released accidentally or incidentally (i.e., not prompted by an intentional attack). Looking at the record of hazardous materials releases, the overwhelming majority were the product of vehicle accidents or accidental releases at processing, manufacturing, and holding facilities (Cutter & Ji, 1997). This knowledge should not be used to dismiss the possibility of terrorist attacks instigating the release of hazardous materials in the future. However, when ranking each scenario, experts likely drew from their knowledge of past events, leading them to score accidental releases higher than deliberate ones.

Following the questions on the likelihood of attack scenarios, the survey asked respondents to examine seven new attack scenarios to determine each one's probability of ending in failure. Each attack scenario presented the respondent with an attack

mode, the class of hazardous materials, and the type of shipping container that would be transported. Respondents were asked to assess the likelihood of each attack failing due to either technical difficulties or security measures. For Scenarios 1–5, between 30 and 50 percent of respondents claimed that attacks were at least probable to fail due to technical difficulties encounters or preventative security measures. However, respondents suggested that under Scenarios 6 and 7, the attacks would be much more likely to fail due to technical difficulties, whereas security measures would be much less effective. Intuitively, this makes sense. Scenarios 6 and 7 relate to a commercial vehicle being attacked with an explosive device placed on the side of a roadway. Arguably, policing every mile of roadway would be exceedingly difficult and consume immense financial and labor resources, and unless attackers attempted to sabotage a highly securitized route, it is exceedingly unlikely they would fail because of security provisions.

Interestingly, for the remaining scenarios — with the exception of Scenario 3 — respondents felt it was more probable attackers would fail due to security measures rather than succumbing to technical challenges. Under Scenario 3, respondents viewed technical mishaps and security measures as equally likely to ward off an attack. Analyzed collectively, the responses for Scenarios 1–5 indicate that the security measures currently in place are — in the participants’ minds — somewhat effective at preventing attackers from placing explosive devices on vehicles. Although it is important to recall that more respondents than not felt that the likelihood of security measures or technical problems thwarting an attack were greater than or equal to 50 percent, it is

equally important to remember that with the exception of Scenarios 6 and 7, respondents felt that technical difficulties and security measures were likely to produce failure. The Chances Even category accounted for a plurality of responses under many of the scenarios, which introduces interpretive ambiguities because it does not establish a clear picture of what respondents were thinking.

Next, respondents answered a series of questions about the overall security of the U.S. hazardous materials supply chain and the potential consequences for a number of socioeconomic variables were an attack to occur. Approximately 75 percent of the respondents described the Tier 1 HSSM supply chain as being either vulnerable or very vulnerable to attacks. However, because the survey did not ask about the appropriateness of regulatory actions, we cannot infer whether recognizing this vulnerability would translate into support for new laws or mandatory policies designed to increase security.

Respondents were then asked to imagine that a Tier 1 HSSM release took place and speculate about the contribution different variables would have on the aggregate impacts of an attack. A significant majority felt damage inflicted on nearby populations (through exposure and subsequent injuries or deaths), critical infrastructure, local and national economies, and public psychology would contribute highly to the composite impacts. This mirrors the findings of many studies. For example, considerable research has demonstrated that terrorist attacks traumatize children and adults alike, leading to post-traumatic stress disorder, anxiety, depression, and behavior abnormalities (see Fremont, 2004 and Shalev and Freedman, 2005 on the psychological consequences

experienced by victims of terrorism; Fullerton et al., 2003 reviews the psychological effects that radiate throughout broader communities and nations). Moreover, respondents believed that key resources, international political fallout, and the erosion of civil liberties on the domestic front would produce a medium–high effect on the overall consequences. Respondents expressed comparatively little concern for environmentally sensitive areas, seeing the injuries they would be afflicted with as not factoring hugely into the aggregate damages.

Because the number of variables was limited in the survey, respondents were asked to identify any additional factors that should be examined when deriving an attack's gross consequences. The most common answer was the event's duration. Even though an attack and ensuing materials release are point disturbances — i.e., they occur at a single point in time — the aftereffects could linger for days, months, or even years. The amount of time needed to contain and remediate a release is therefore an essential consideration. Depending on the chemical properties of the material released, the impacts could spread over a broad area. Some materials would be more toxic and damaging than others. One drawback of the survey is that it did not specify what type of material was released. Without this information, respondents had to make a generalized evaluation. While this does not invalidate the question's findings, it points out that risk assessments will need to account for the type of material that a vehicle is transporting. One respondent observed that it could be important to consider whether a successful attack would influence attackers and/or sympathizers, leading to future attacks. Although it is difficult to quantify this, and any analysis would be speculative,



risk assessments could benefit from studying whether a successful attack would lead to a clustering effect, whereby one attack spurs on others. Taken collectively, the answers about the net consequences of attacks and materials releases establish a starting point from which to develop ways of ranking and quantifying the risk levels associated with particular shipments. For example, vehicles passing through densely populated urban areas would pose more risk than vehicles moving through a landscape dominated by open land — even if it does contain environmentally sensitive assets. Clearly, respondents were most concerned with the effects an attack would have on human, social, and economic capital (cf. Sandler & Enders, 2008).

Respondents were also queried about their perceptions of what security challenges are most daunting for shippers, carriers, and consignees when moving hazardous materials. Approximately 90 percent of them viewed en route or personnel security as the most pressing issues. Business information security and inventory control processes were not viewed with the same degree of urgency. These results mirror what we would intuitively expect — preventing an attack and release of hazardous materials is largely an issue of protecting the shipment when it moves from origin to destination. Safeguarding a vehicles' physical integrity and the roadways they travel on is of paramount concern for averting terrorist actions. Likewise, if supply chain stakeholders are not vigilant about the personnel they hire, shipments are potentially endangered and the likelihood of an attack increases because individuals are entrusted with materials they could readily exploit for violent purposes.

A final set of questions probed respondents about their knowledge of the voluntary security action items (SAIs) released by the TSA in 2008. Approximately 65 percent of the respondents said they were not familiar with these items. There are several ways to interpret this number. On the one hand, the measures are voluntary, so none of the respondents would be tasked with enforcing them as part of their daily job routines. However, this astonishing lack of knowledge is also unsettling because it reveals a significant proportion of transportation security experts have no or very little understanding of recommended best practices for securing vehicles carrying Tier 1 HSSMs. It likely demonstrates that unless rules are formalized through legislation or other legally binding policies, a large majority of security professionals will have no incentive to become intimately acquainted with them. While the survey was not distributed to carriers and shippers, there is no reason to believe they will have greater knowledge of SAIs.

Despite the pessimism that could understandably result from this finding, the 23 follow-up questions, which asked respondents to evaluate the importance of SAIs (see Table 3.5 for a complete list), revealed that approximately 80–90 percent of those surveyed believed that each was very or extremely important for securing Tier 1 HSSM shipments and the hazardous materials supply chain more broadly. While this does not necessarily argue for the implementation of new regulations, it reinforces interpretations of earlier survey questions, principally that government agencies lack the infrastructure, policies, and procedures to effectively police hazardous materials

transportation. More important, it convincingly demonstrates that security experts largely endorse the purpose and intent of the SAls.

### **3.5 An Equation for Assessing the Risk of Tier 1 HSSMs**

Drawing from the information collected via the survey and interviews with subject-matter experts, this section advances a risk equation developed by Virtual Risk Technologies (VRT, 2013) that may be used to evaluate the level of risk associated with a Tier 1 HSSM shipment. Along with data garnered from interviews, the risk question builds from other equations that are already in use at federal governmental agencies. As noted previously, the goal of this project is to develop an approach to risk analysis that is both methodologically robust and can be used by DHS, TSA, and other agencies concerned with hazardous materials transportation. It is thus imperative for the equation and its constituent parts to take on a form that are compatible with existing risk analysis frameworks. This will facilitate implementation and ensure that the estimates — and values — of risk generated by the equation are commensurate with those produced by other government methodologies, thus enabling meaningful comparisons across risk domains.

Risk is the product of threats, vulnerabilities, and consequences (Eq.1). The definitions of each risk component are consistent with the DHS Lexicon. For a given Tier 1 HSSM shipment, risk is calculated iteratively as it moves through highway networks. These iterative calculations are based on a set of spanning scenarios, which are then summed to produce a total security risk score (Table 3.3). Using a subset of possible attack scenarios constrains the number of calculations, which improves analytical

tractability. The attack modes were selected from existing — albeit classified — DHS and TSA documentation. These attack modes have been identified as the most likely to affect a Tier 1 HSSM shipment. All of the scenarios chosen appear in other risk assessment methodologies used by federal agencies. Other attack modes were considered (e.g., aircraft attack; chemical, biological, or radiological attacks; IEDs conveyed by waterborne vessels), however, subject-matter experts argued the likelihood of these being executed were too low to merit inclusion. Numerical values for each of the equation’s variables are derived through separate calculations, which are described below.

(Eq. 1)  $R = T \times V \times C$

Where:

$R$  = level of risk

$T$  = threat

$C$  = consequence

**Table 3.3** Attack Modes Used to Populate Risk Equation

<b>Attack Mode</b>	<b>Description</b>
<b>1</b>	Explosive device placed on a CMV
<b>2</b>	Explosive placed on the highway infrastructure
<b>3</b>	Weapon launched at CMV from a distance
<b>4</b>	Explosive device placed in a vehicle near a CMB
<b>5</b>	Outsider hijacks CMV to immediately release or explode materials
<b>6</b>	Outsider hijacks CMV to release to explode materials at a nearby location
<b>7</b>	Insider hijacks CMV to immediately release or explode materials
<b>8</b>	Insider hijacks CMV to release to explode materials at a nearby location
<b>9</b>	Sabotage of a cargo tank motor vehicles carrying toxic inhalation hazard materials
<b>10</b>	Initiating a crash

Threat values are contingent on two elements — static and dynamic factors. Static factors are fixed variables for a given shipment, and they determine the baseline threat value. They include the attack mode, type of hazardous material a vehicle is carrying, and the trailer and container types. Recall that risk scores are calculated across all spanning scenarios — thus, since each attack mode is incorporated into risk analysis during each step of the calculation, they are considered as fixed variables. Baseline threat levels are derived from DHS lookup tables that reflect subject-matter experts' assessments of the different scenarios, which consist of various combinations of attack mode, hazardous materials, and containers. The other static factors are regarded as fixed because they remain unchanged during the course of a trip. Dynamic factors include population density and a shipment's proximity to critical infrastructure and key resources (CIKR). The latter encompass vital assets and systems which, if they were damaged or destroyed, would have severe repercussions for national security, economic security, and public health and safety. Equation 2 is used to calculate threat values for each attack scenario. Dynamic factors are place-based. The values assigned to  $t_{pop}$  and  $t_{CIKR}$  fluctuate based on the location of a shipment on the highway network and its relation to nearby areas.  $t_{CIKR}$  is positively correlated with the number of CIKR located in the exposure zone. If there are few CIKR in a particular area, the probability of an attack declines because the shipment will be less attractive to potential attackers. When a shipment passes through an area with a higher population density or greater number of CIKR, threat values increase because more people and assets would suffer exposure if an attack were to occur. The underlying assumption of this equation is that attacks are

more likely to occur in areas with large populations and an abundance of CIKR. Extensive research has demonstrated that densely populated urban areas face a high risk of terrorist attacks compared to less developed or rural areas, which has been reflected in part by national, state, and local governments prioritizing the defense of cities in their security planning (e.g., Brown et al., 2004; Coaffee, 2009; Raleigh, 2015; Martin, 2015). The method used to assess risk here is consistent with other methods the DHS and federal government have adopted for risk analysis, including RCRMS, which was described in the previous section, and the Office of Risk Management and Analysis’s Special Events Awareness Report (SEAR).

$$(Eq. 2) \quad T_i = T_{base,i} * \left( \frac{t_{pop,i} + t_{CIKR,i}}{2} \right)$$

Where:

$T_i$  = threat for attack mode  $i$

$T_{base}$  = baseline threat value

$t_{pop}$  = threat modifier based on population density of the exposed area

$t_{CIKR}$  = threat modifier based on CIKR in the exposed area

$i = i^{th}$  attack mode

The DHS Lexicon defines vulnerability as “a physical feature or operational attribute that renders an entity open to exploitation or susceptible to a given hazard” (DHS, 2010). The risk equation’s vulnerability term denotes the likelihood that, once begun, an attacker will achieve their stated goal. An unsuccessful attack is one that fails due to the attackers being unable to surmount technical challenges or because the security measures put into place will deter potential attacks. Equation 3 is used to calculate a shipment’s vulnerability. The values for  $V_{no\ failure\ (tech),i}$  and  $V_{no\ failure\ (security),i}$  vary according to the scenario, container type, and installed security measures.

$$(Eq. 3) \quad V_i = V_{no\ failure\ (tech),i} * V_{no\ failure\ (security),i}$$

Where:

$V_i$  = vulnerability to the  $i^{th}$  attack mode

$V_{no\ failure\ (tech),i}$  = the likelihood that attackers *do not fail* due to their own failures for the  $i^{th}$  attack mode

$V_{no\ failure\ (security),i}$  = the likelihood that attackers *do not fail* due to security measures for the  $i^{th}$  attack mode

$i$  =  $i^{th}$  attack mode

Estimates of failure due to attacker incompetence or security measures are made by subject-matter experts using the Kent scale. As noted, the Kent scale is used to translate linguistic descriptions of each variable into a quantitative value (Meyer & Booker, 1991). Table 3.4 contains descriptions of particular scenarios, which are translated into linguistic probabilities, which are then converted into numerical probabilities. Once they have attained their numerical form, the probabilities can be used to populate the vulnerability equation. Vulnerability is a function of attack mode, trailer and container type, and the security processes and procedures that are used to safeguard hazardous materials-truck-container combinations.

All of this information is summarized in a single table, which comprises the overall vulnerability framework — this table succinctly captures vulnerability scores for all of the scenarios being considered during a risk analysis (Table 3.4). Many government agencies have implemented a framework like this for vulnerability assessments.

Adopting it here preserves heuristic continuity across analytical methods, which is critical for these agencies to have a unified baseline from which to evaluate vulnerability. Similarly, the Kent Scale has been used frequently in governmental risk assessments (e.g., THTRA, the Office of Risk Management and Analysis's Risk

Assessment Process for Informed Decision-Making [RAPID], the Office of Infrastructure Protection’s National Comparative Risk Assessment [NCRA]) to quantify vulnerability based on subject-matter expertise.

**Table 3.4** Kent Scale for  $V_{no\ failure\ (tech)}$

<b>Description</b>	<b>Linguistic Probability</b>	<b>Numerical Probability</b>
<b>Attack is not challenging and simple to execute.</b>	Certain	1.0
<b>Attack is somewhat challenging but relatively simple to execute.</b>	Nearly Certain	0.93
<b>Attack is challenging and somewhat complex, requiring good logistics and coordination.</b>	Probable	0.75
<b>Attack is challenging and complex, requiring substantial logistics and coordination.</b>	Chances Even	0.50
<b>Attack is very challenging and complex, requiring substantial logistics and coordination.</b>	Probably Not	0.30
<b>Attack is very challenging and very complex, requiring substantial logistics, coordination, and resources.</b>	Highly Doubtful	0.07
<b>Attack is very challenging and extremely complex, requiring substantial logistics, sophisticated coordination, and significant resources.</b>	Practically Impossible	0.01
<b>Attack is not possible.</b>	Not Possible	0.0

The consequences of an attack are based on the number of people affected, nearby CIKR, potential impacts to environmentally sensitive areas, and economic repercussions (Equation 4). Population refers to the number of people who lie within the exposure zone for a particular hazardous material. Population data come from the U.S. Census, which are disaggregated to match up with individual roadway segments. Because the number of people in a location fluctuates based on the time of day (especially in urban settings), it is necessary to calculate separate population values for day and night. CIKR is partitioned into two terms ( $CIN_{CIKR1,i}$  and  $CIN_{CIKR2,i}$ ), based on the Level 1 and 2 CIKR lists maintained by DHS. The next factor, environmentally sensitive areas, refers to parks, rivers, streams, lakes, and reservoirs. This term’s value is based on



the number of environmentally sensitive areas located within 0.1 mi (0.16 km) of the vehicle carrying hazardous materials. Lastly, the consequence term accounts for the economic impact of a hazardous materials release. This valuation is based on the gross domestic product (GDP) of the nearest metropolitan area. GDP measures the total value of goods and services produced within an area's economy during a single year. The economic impacts of an attack are likely to be positively correlated with an area's GDP — as GDP increases, so do the expected losses from an attack.

$$(Eq. 4) \quad C_i = CIN_{pop,i} + CIN_{CIKR1,i} + CIN_{CIKR2,i} + CIN_{env,i} + CIN_{econ,i}$$

Where:

$CIN$  = consequence index number

$CIN_{pop}$  = consequence equivalence of the exposed population

$CIN_{CIKR1}$  = consequence equivalence of exposed Level 1 CIKR

$CIN_{CIKR2}$  = consequence equivalence of exposed Level 2 CIKR

$CIN_{env}$  = consequence equivalence of environmentally sensitive areas

$CIN_{econ}$  = consequence equivalence of economic impact within exposed areas

$i = i^{th}$  attack mode

Consequence equivalence scales are developed (Table 3.5) to derive the appropriate consequence index numbers (CIN). The CINs are environmental impacts and CIKR are always positive integers, whereas the CINs for affected populations and economic impacts may be any positive number. Two additional equations are used to estimate the consequence equivalence of the population and economic impacts (Equations 5 and 6). Several resources are used to estimate an attack's consequences, including the USDOT Emergency Response Guidebook; U.S. Census Bureau data (from which population numbers are collected); CIKR lists; U.S. Geological Survey, Environmental Protection Agency, and National Park Service databases of environmentally sensitive areas; and GDP data from the U.S. Bureau of Economic

Analysis. The methodology used to assess consequences enjoys widespread purchase across a number of federal government agencies. For example, U.S. Customs and Boarder Protection has implemented a similar methodology as part of its Security Management Assessment Risk Tool (SMART).

$$(Eq. 5) \quad CIN_{pop} = \log(population) - 2$$

$$(Eq. 6) \quad CIN_{econ} = \log(economic\ impact) - 8 \text{ [for economic impact} > \$1\ B; \text{ if } < \$1\ B, CIN = 0]$$

**Table 3.5 Sample Consequence Equivalence Table**

Population Exposed	# Level 1 CIKR Present in Exposure Zone	# Level 2 CIKR Present in Exposure Zone	Environmentally Sensitive Areas in Exposure Zone	Economic Impact	Consequence Index Number
1,000,000	2	4	-	\$1T	4
100,000	1	3	-	\$100B	3
10,000	-	2	-	\$10B	2
1,000	-	1	1	\$1B	1
100	-	-	-	<\$1B	0

Once the different components of risk have been evaluated, the security risk for a particular shipment can be evaluated using Equation 1 for each attack mode (by substituting the appropriate values for the threat, consequence, and vulnerability factors). A shipment’s dynamic security risk — that is, the overall risk when the shipment is at a specific location on the highway network — is then calculated by adding together the risk for each attack mode, as per Equation 7.

$$(Eq. 7) \quad R_{security} = \sum_{i=1}^{10} R_{security,i}$$

It is critical for recall that risk scores are both relative (i.e., not absolute) and non-dimensional, meaning that the numbers used to signify risk do not have units.

However, risk scores are calculated using a ratio scale, which enables direct comparisons of risk across multiple shipments.

### **3.6 Conclusion**

This paper makes several contributions to the growing literature on risk, transportation security, and hazardous materials transportation. A survey administered to transportation professionals who deal with hazardous materials security on a daily basis revealed that — for most of the attack scenarios presented — they felt there is a low to moderate likelihood of an attack being initiated. When queried about TSA’s Security Action Items, there was near universal consensus that adoption and implementation would prove fruitful and measurably enhance the security of hazardous materials shipments. With respect to the factors that would most significantly contribute to the aggregate consequences of a terrorist attack, survey participants cited impacts to local populations, critical infrastructure and key resources, adjacent economies, and public psychology as most important. Terrorist attacks produce a cascade effect, meaning their effects reverberate across multiple domains.

The survey results and interviews with subject-matter experts underscore the importance of adopting a holistic framework for risk analysis. Estimating the number of people who will potentially be affected by a hazardous materials release is an essential component of any risk analysis, however, this should not be viewed in isolation from other resources that constitute the social fabric which defines individuals’ everyday lives. As such, the risk equation developed in this paper weighs the potential consequences a hazardous materials release would have on the exposed population,

critical infrastructure assets, key resources, environmentally sensitive locations, and aggregate economic impacts. A key consideration in developing this risk equation was analytical tractability, thus, definitions of risk and equation structures that are currently used by federal agencies were adopted. While it is possible to envision other approaches to perform risk analysis that are more complex and integrate a larger number of variables, the methodology proposed in this paper will facilitate agency-led programs (e.g., by DHS and TSA) to improve real-time monitoring of vulnerable shipments.

Further, the risk equation proposed here may be calculated quickly, which makes it possible to repeatedly derive risk scores for a vehicle as it navigates highway networks. Accordingly, this equation could underwrite a comprehensive, spatially explicit risk monitoring protocol. Any model or equation must balance a commitment to realism and parsimony — while it is important to include as many variables as possible to generate an accurate evaluation of a shipment’s risk, incorporating too many factors would render them unusable. The risk equation and assessment framework described here, because it distills risk into a few key variables, can inform the development of risk monitoring systems to assist with routing (e.g., Razo & Gao, 2012) across a host of transportation domains (e.g., rail and waterborne commerce). Future work should attempt to define the conceptual architecture of a system to monitor Tier 1 HSSMs throughout the United States. Once operational, this kind of system would be critical for reducing the likelihood of terrorist events.

## **Chapter 4 The Dynamic Hazardous Materials Risk Assessment Framework—DHMRA**

### **4.1 Introduction**

According to the Federal Highway Administration (FHWA), approximately 2.2 billion tons of hazardous materials were shipped in the United States in 2007. Of this total, 1.2 billion tons were transported with trucks. In aggregate, the value of hazardous materials shipped on trucks that year exceeded \$800 billion (FHWA, 2013). Based on these figures, it is clear that the shipment of hazardous materials drives a significant amount of domestic economic activity. While there are many risks involved with the use and movement of hazardous materials, because they are key inputs into many industrial and manufacturing operations and go into products that enable U.S. consumers to enjoy a modern and comfortable standard of living, their use is unlikely to wane in the near future (Zhang et al., 2000). By extension, the tonnage and value of hazardous materials carried on trucks and other surface transportation modes is anticipated to grow.

Yet, if hazardous materials are released into the surrounding environment — either due to an accident or a malicious act — they can produce significant damage. Table 4.1 summarizes the number and types of incidents involving the shipment of hazardous materials on highways in 2015 (U.S. Department of Transportation — Pipeline and Hazardous Materials Safety Administration, 2016). Just over 15,000 incidents were recorded, which caused numerous injuries, 11 fatalities, and over \$52 million dollars in damages. What stands out most about these statistics is that while a majority of incidents occurred during the loading or unloading phase, the incidents that took place during transit accounted for the overwhelming majority of financial damages

and *all* fatalities. It is critical to note that 2015 was not an anomaly. From 2006–2016, in-transit events routinely exacted the greatest monetary damages, produced the severest injuries, and were the most likely to cause fatalities. Were a catastrophic release event to occur, either because of an accident or through intentional means (e.g., a terrorist attack), the magnitude and extent of the ensuing destruction, injury, and death would be immense — especially in densely populated urban locales. To improve emergency management efforts, it is critical for federal, state, and local government agencies to have dynamic information regarding the contents, position, and movement of commercial vehicles transporting hazardous materials (Milazzo et al., 2009).

**Table 4.1** Summary of Injuries, Death, and Financial Damages Attributable to Hazardous Materials Incidents in 2016

<b>Transportation Phase</b>	<b>Incidents</b>	<b>Hospitalized</b>	<b>Non-Hospitalized</b>	<b>Fatalities</b>	<b>Damages</b>
<b>In-Transit</b>	3,824	6	19	11	\$43,230,106
<b>In-Transit Storage</b>	330	2	1	0	\$1,920,906
<b>Loading</b>	3,143	4	26	0	\$1,152,879
<b>Unloading</b>	7,794	14	82	0	\$6,249,990

Although terrorist attacks have rarely been directed at hazardous materials shipments, the events of September 11, 2001 offer a vivid reference point which exemplifies the devastating consequences of a single attack. The number of attacks during the ensuing 15 years demonstrate, as well, that terrorism is a ubiquitous threat. Recent incidents in the United States and around the world illustrate that terrorists are opportunistically selecting targets based on their ease of access and the possibility of maximizing damage (e.g., Becker, 2014; Morris, 2015). Open highways and hazardous materials shipments present an attractive target for terrorists. Some measures have

been put in place to safeguard U.S. highways, however, infrastructure is characterized by numerous vulnerabilities that present potential exposure to terrorist attacks (Fink, 2007). Highways are easily accessed, unsecure, move a large number of goods and people, and do not receive the same level of oversight currently directed towards airports and port facilities. The openness of roadways makes it difficult to ensure security measures will successfully protect vehicles and hazardous materials from potential attackers. Remedying the security gaps related to hazardous materials that characterize U.S. highway networks is critical for eliminating or mitigating the effect of potential attacks. Although considerable work has previously examined hazardous materials routing on transportation networks (Kang et al., 2014a), the real-time risk posed by individual shipments has been understudied. Because of this, federal, state, and local governments have no comprehensive way to understand the levels of risk shipments of hazardous materials are exposed to. Protecting hazardous materials shipments against terrorist threats is obviously critical, but a dynamic risk management system could also facilitate swifter responses to accidental releases.

A comprehensive yet real-time risk management system must incorporate a sophisticated understanding of how risks, threats, and consequences are spatially distributed. Many perceive all locations as being equally likely to experience a terrorist attack, however, terrorism threats are distributed in a spatially uneven manner. Not all places are equally vulnerable to terrorist attacks (or hazardous materials shipments). Opportunistic target selection means that actors are most likely to select locations where there are few security measures or barriers in place (e.g., Drakos & Gofas, 2006;

see also Mustafa, 2005). For example, the risk profile of a commercial vehicle with hazardous materials onboard fluctuates during the course of its journey. Shipments traveling on an isolated rural road pose little risk because an attack would inflict relatively little damage. Conversely, hazardous materials shipments passing through a densely populated urban area would be potentially catastrophic. Given the complex array of variables that influence not only the choice of a target but the consequence of an attack involving hazardous materials, a fully parameterized risk management system must leverage analyses of historical incidents alongside expert knowledge to generate realistic vulnerability, threat, and consequence assessments (Haines & Longstaff, 2002).

This paper describes the conceptual architecture and implementation of a risk management system that provides government security specialists with the tools and information needed to track individual shipments of Tier 1 Highway Security Sensitive Materials. Current methods used to evaluate shipment risk are lacking because they focus on estimating the probability that a hazardous materials release will occur along a particular roadway segment.

The methods account for the expected consequences of an incident, but they focus on total population exposure (Erkut & Verter, 1998), which overlooks other social, economic, and environmental impacts of hazardous materials releases. These methods provide a useful way of summarizing risk, however, they do not provide stakeholders with the means to dynamically evaluate the level of risk posed by an individual shipment. Similarly, recent work on shipment routing has tended to focus on optimization problems or devising algorithms to minimize the impacts of a potential



incident, while failing to develop sophisticated analyses of the multivariate drivers of risk (e.g., Kang et al., 2014a,b; Toumazis et al., 2013; see below). Other methods treat the consequences of a hazardous materials release purely in terms of its effects on human health (Inanloo & Tansel, 2016). Such a narrow view is problematic because it disregards the specific contents of individual vehicles and the impacts materials will have on human health and the environment if released intentionally or accidentally. These data, combined with information about demographics, environmentally sensitive areas, and economic activity, can be used to generate context-sensitive assessments of the risk posed by hazardous material shipments.

The remainder of this paper is divided into four sections. The next section briefly reviews literature on risk and the methods that have most frequently been used to quantify the risks associated with moving hazardous materials on road networks. Next it describes an equation which locates risk as the product of threats, vulnerabilities, and consequences that can be used to instantaneously assess the risk profile of a hazardous materials shipment. Unlike more classical approaches to risk evaluations that base consequence assessments on population exposure, this methodology also accounts for the presence of critical infrastructure, key resources, environmentally sensitive areas, and economic impacts to holistically manage risk. After this, the conceptual architecture of a GIS environment is described which enables users to visualize and map the risk profiles of hazardous materials shipments. To illustrate the logic underpinning this system and the risk equation (see also Chapter 3), a case study is used to demonstrate how risk varies spatially. Knowing that the risk associated with a hazardous material

shipment changes dynamically as it crosses networks of roadways demands that we develop a method of risk assessment and management that accurately represents the spatial variability of that risk. Developing such a method is useful because it leads to more targeted security policies, and provides government agencies with the tools to understand how a hazardous materials release will impact specific locations. The equation and risk management system will give emergency managers the information needed to respond quickly and appropriately to an attack in order to mitigate its worst effects.

#### **4.2 Literature Review**

Due to the relative scarcity of accidents involving hazardous materials (Harwood et al., 1993 estimated a rate of 0.000001 accidents per kilometer of roadway), calculating the exact level of risk an individual shipment poses is challenging. Data are scarce, which means that researchers must leverage a combination of historical data and expert knowledge to generate risk estimates. Researchers generally approach risk calculations and hazardous materials routing problems from two points of view — local and global (Kang et al., 2014a). The goal of local route planning is to select optimal paths for individual shipments; global route planning attempts to coordinate multiple trips across one or multiple fleets in order to evenly distribute risk across the entire road network. Although individual shippers tend to be most concerned with routing individual trucks because they want to minimize their expenses and the potential for an individual release event (Dadkar et al., 2010a, b), government agencies, because they

have broader regulatory missions, are more focused on global routing and minimizing social risk (e.g., Erkut & Ingolfsson, 2000; Erkut et al., 2007).

Definitions of risk vary across academic disciplines, however, in the context of hazardous materials transportation, there is a general consensus among researchers that public risk is the product of population exposure and accident rates (Saccomanno & Shortreed 1993; Erkut & Verter 1998; Chang et al. 2005; Erkut & Ingolfsson 2005; Dadkar et al. 2008, 2010a). These metrics may be combined into a single consequence measure by adding together the product of accident rate and public exposure along all of the road segments — or links — where a shipment will move (Dadkar et al., 2010a). This path evaluation function (Chang et al., 2005; Erkut & Verter, 1998; Erkut & Ingolfsson, 2000) is additive and takes on the following form:

$$TR(r) = \sum_{i=1}^n p_i C_i$$

where  $p_i$  denotes the probability of an accident occurring along segment  $i$  of a road;  $C_i$  measures the consequence of a release accident taking place along segment  $i$ . Although the definition of *consequence* varies among authors, generally it refers to the number of people who are located along a road segment within a buffer zone that would be exposed to a release event. This traditional risk model does not capture the magnitude of potential impacts, the severity of injuries and fatalities, and short- and long-term economic and environmental damage. Erkut and Verter (1998) observed that for most hazardous materials shipments, the value of  $p_i$  falls between 0.1 and 0.8 per million miles. More recent work on routing and risk has adopted more expansive concepts of risk and consequence, noting that factors other than population should be taken into

account. Pradhananga et al. (2016) proposed a solution to hazardous materials routing that minimizes the sum of population-based and congestion-based risk costs, reasoning that incidents involving hazardous materials lead to significant congestion problems on directly impacted and nearby roadways. Cordeiro et al. (2016) introduced a modeling approach that explicitly incorporated the risks posed to the environment and nearby populations by hazardous materials shipments. Inanloo and Tansel (2016) also took a broad view to the problem, developing a tool that compared routing options based on the level of public exposure, economic benefits, and the health risks and delay costs associated with a release. Along with traditional network analysis, Inanloo and Tansel (2016) integrated modeling to estimate the geographical reach of a hazardous materials release based on atmospheric conditions.

Other recent work has expanded on the classical approach to risk modeling. Van Raemdonck et al. (2013) proposed a risk analysis framework that can be applied to multimodal transportation systems. This spatially explicit framework derives the probability of hazardous materials releases based on past events. From these calculations, global and local probability maps, which let users visualize locations on transportation networks that are especially vulnerable to release incidents, are generated. Panwhar et al. (2000) developed a GIS-based hazardous materials routing framework to minimize the likelihood and impact of accidents. The probabilistic risk assessment framework adopted within the system calculated the probability of a hazardous materials release taking place on a road segment while also accounting for impacts to critical resources that were located nearby. Considering that the facility's

vulnerability is critical for understanding the consequences of an incident — as such, Panwhar et al. (2000) demonstrated that routing and risk calculations must account for facilities such as schools, hospitals, and other critical infrastructure to accurately evaluate risk. Bubbico et al. (2004) established a simplified approach to transportation risk analysis that analyzed the probability of discrete release scenarios and estimated consequences based on ambient weather conditions and the characteristics of the built environment. This framework took into account the effect of population density on total risk while also leveraging a catalog of release scenarios to quickly estimate the social risk posed by individual shipments. More recent approaches to risk and routing analysis have used sophisticated techniques, using game theory (e.g., Dadkar et al., 2010a) and Value-at-Risk modeling (Toumazis & Kwon, 2013; Toumazis et al., 2013 Kang et al., 2014a, Faghih-Roohi et al., 2015). The latter is a risk measurement tool that was originally developed in the context of financial risk management, but has since been used to estimate the measure of risk associated with high-consequence, low-probability events.

Although increasingly complex forms of mathematical analysis and algorithms have been used to quantify the risk of hazardous materials shipments to develop optimal routing strategies, the measures used to assess the consequences of a release incident have been too narrowly focused, often privileging measures like population — which are easy to obtain — while sidestepping the role of nearby critical infrastructure, vulnerable resources, economic and environmental impacts, and the spatial and temporal magnitude of an event. Although there have been some attempts to

conceptualize risk and consequence more broadly, frameworks that have done so have generally integrated only one or two of these factors into their models (e.g., Panwhar et al., 2000; Van Raemdonck et al. 2013).

More holistic forms of risk management have increasingly captured the attention of researchers. One example is the all-hazards risk management framework (AHRM), which proposes a holistic evaluation of methods to mitigate natural- and humanly-created hazards (Chatterjee & Abkowitz 2009; Abkowitz & Chatterjee 2012). Unlike the other forms of risk analysis discussed above, this framework is not strictly mathematical, although it is quantitative. The AHRM converts risk into a monetary value to calculate the level of insecurity created by particular hazards. Despite its more holistic perspective, the AHRM does not deviate from more traditional models of risk calculation, and by viewing risk in purely monetary terms, researchers risk overlooking more qualitative dimensions of hazardous materials releases that cannot be distilled into a single metric, such as habitat loss or the disruptions that are caused when affected populations have to reconfigure their livelihoods. Furthermore, the AHRM omits any consideration of how risk varies spatially. As Liu et al. (2012) persuasively argues, the principal failing of traditional risk models is their propensity to evaluate risk for an entire route *before* a shipment even leaves its departure point, and to not recalculate risk profiles during the course of a journey (see also Fabiano et al., 2002). Certainly, it is more computationally parsimonious to use fixed probability and consequence values to measure risk; however, this leaves government agencies and other emergency responders with an incomplete understanding of what road segments

have elevated vulnerability to the effects of an intentional or accidental release (Oggero et al., 2006). Risk modeling has either highlighted accidental releases or left the type of release unspecified. But accurately evaluating the nature of the risk (and coordinating appropriate responses in the event of an incident) demands knowledge of the goods contained in a shipment (e.g., Griffin, 2009). A final problem with current risk modeling techniques is that they use definitions of risk, consequences, vulnerabilities, and threats which do not align with those employed by the local, state, and federal agencies tasked with overseeing the security of hazardous materials (see below).

Although there have been many strides made in risk assessment and the routing of hazardous material shipments, this brief review indicates that traditional risk evaluation methods lack a cogent framework to analyze the vulnerabilities and consequences that accompany different modes of terrorist attacks or release events. Developing a fully parameterized risk management and routing system entails moving beyond the development systems whose principal aim is to optimize shipment movements — and toward fine-grained individualistic analyses that can equip government agencies with the knowledge required to identify and contextualize the security vulnerabilities Tier 1 HSSM shipments are exposed to. The following section describes a methodology and risk equation that can be used to accomplish this task, both of which are compatible with methods currently in use at domestic homeland security agencies (e.g., Transportation Security Administration).

## 4.3 Methodology — Spatially Explicit Modeling of Tier 1 HSSM Shipment Risks

### 4.3.1 Calculating Risk

This section describes a methodology and conceptual architecture to evaluate the risk of Tier 1 HSSMs. The goal of the methodology is to offer a corrective to the deficiencies of current risk models while being consistent with the definitions of risk currently accepted by the federal government. Indeed, the practical objective of this intervention is to develop a holistic risk management system that can be used by government agencies. The previous chapter included an exhaustive overview of how different segments within the transportation industry measure risk. Although the starting point of this methodology is the federal government’s definition of risk, this builds upon previous academic work. Risk is calculated by multiplying threats, vulnerabilities and consequences (in accordance with the Department of Homeland Security’s Lexicon). Willis et al. (2005, p. 6) defined threat as “the probability that a specific target is attacked in a specific way during a specified period of time.” Similarly, vulnerability refers to the probability that “damages occur, given a specific attack type, at a specific time, on a given target” (p. 8). The following equation is used to quantify risk:

$$(Eq. 1) \quad R = T \times V \times C$$

Where:

$R$  = level of risk

$V$  = vulnerabilities

$T$  = threat

$C$  = consequence



This parameterization of risk shares commonalities with an equation proposed by Zhang et al. (2000), who adopted an expected consequence approach to risk, which used the following equation to estimate the level of risk of individual road segments:

$$R_l = S_l \times P_l \times N_l:$$

Where:

$R_l$  = total risk of hazmat movement along link  $l$

$S_l$  = number of shipments on link  $l$

$P_l$  = probability of a release accident for an individual shipment on link  $l$

$N_l$  = cumulative population of individuals affected by a release even on link  $l$

The methodology proposed here diverges from Zhang et al.'s (2000) model, however, by including a variable that estimates the risk encountered by a shipment due to the threat of an attack. Threats and vulnerabilities are each measured using probabilistic distributions based on a combination of historical data and expert knowledge instead of on less reliable point estimates. Three separate equations are used to derive risk scores for individual shipments. A full derivation of these can be found in Chapter 3. Following Bubbico et al. (2004), a series of look-up tables are used to populate threat, vulnerability, and consequence equations with specific values.

Briefly, the following equations are used to calculate these parameters:

$$(Eq. 3) \quad T_i = T_{base,i} * \left( \frac{t_{pop,i} + t_{CIKR,i}}{2} \right)$$

Where:

$T_i$  = threat for attack mode  $i$

$T_{base}$  = baseline threat value

$t_{pop}$  = threat modifier based on population density of the exposed area

$t_{CIKR}$  = threat modifier based on CIKR in the exposed area

$i = i^{th}$  attack mode

$$(Eq. 4) \quad V_i = V_{no\ failure\ (tech),i} * V_{no\ failure\ (security),i}$$

Where:

$V_i$  = vulnerability to the  $i^{th}$  attack mode

$V_{no\ failure\ (tech),i}$  = the likelihood that attackers *do not fail* due to their own failures for the  $i^{th}$  attack mode

$V_{no\ failure\ (security),i}$  = the likelihood that attackers *do not fail* due to security measures for the  $i^{th}$  attack mode

$i$  =  $i^{th}$  attack mode

$$(Eq. 5) \quad C_i = CIN_{pop,i} + CIN_{CIKR1,i} + CIN_{CIKR2,i} + CIN_{env,i} + CIN_{econ,i}$$

Where:

$CIN$  = consequence index number

$CIN_{pop}$  = consequence equivalence of the exposed population

$CIN_{CIKR1}$  = consequence equivalence of exposed Level 1 CIKR

$CIN_{CIKR2}$  = consequence equivalence of exposed Level 2 CIKR

$CIN_{env}$  = consequence equivalence of environmentally sensitive areas

$CIN_{econ}$  = consequence equivalence of economic impact within exposed areas

$i$  =  $i^{th}$  attack mode

Unlike other modes of risk assessment, this equation can be iteratively calculated to estimate the risk exposure of a hazardous materials shipment at any point along a road network. Dynamically updating risk values is critical for government agencies to have an up-to-date, real-time picture of what shipments merit scrutiny. After each variable of the risk equation has been calculated, the dynamic security is calculated. This score represents the overall risk of a shipment when it is at a particular location on the road network. It is derived by summing the risk for each of the attack modes which have been defined:

$$(Eq. 8) \quad R_{security} = \sum_{i=1}^{10} R_{security,i}$$

Risk scores are relative and non-dimensional. Because they are based on a ratio scale, the risk exposure of various shipments can be directly compared with one

another. Although these scores provide valuable information, taken alone they do not solve key problems that confront security agencies — to visualize where shipments are located and determine the spatial and temporal variability of risk's three components. The risk equation should be viewed as establishing a means of calculating the spatial variability of risk in numerical terms. A complementary system that converts these data into mapped information using geo-algorithms is necessary to display fluctuations in risk levels and to generate hypotheses about the underlying drivers of risk. Unlike the most conventional methods of calculating risk, the equation presented here captures not just population exposure, but also the economic, social, and environmental dimensions of risk, which results in a more comprehensive understanding of what locations are most vulnerable to hazardous materials releases. The next section briefly sketches out the conceptual architecture and platform of a Dynamic Hazardous Materials Risk Assessment Framework (DHMRA).

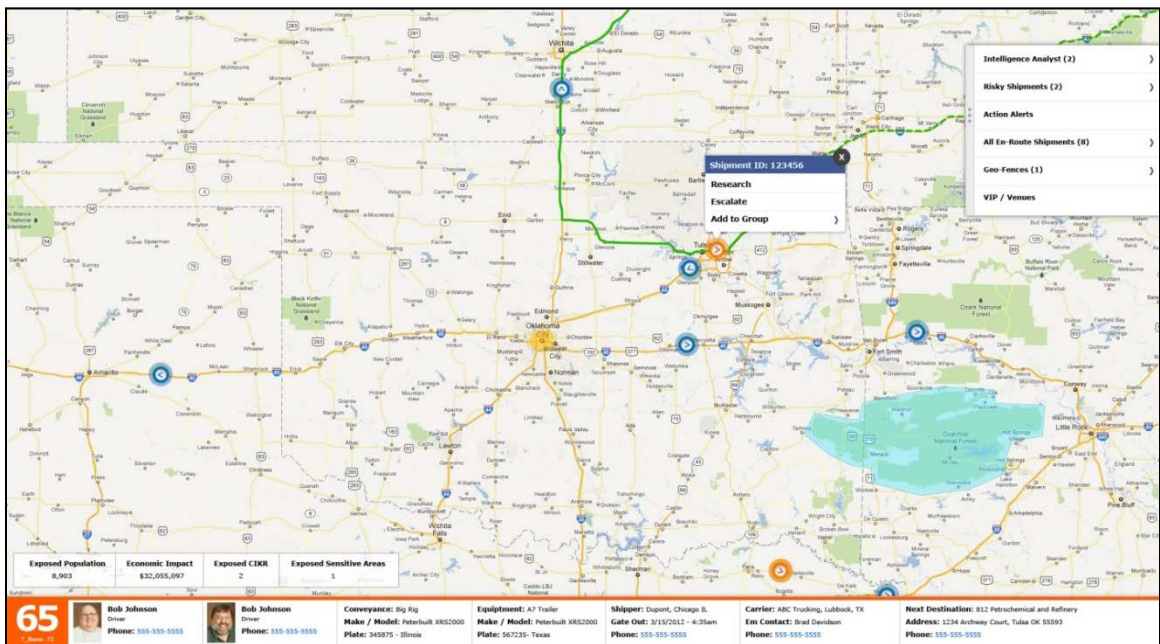
#### **4.3.2 Conceptual Architecture of the Dynamic Hazardous Materials Risk Assessment Framework**

The Dynamic Hazardous Materials Risk Assessment Framework (DHMRA) combines a desktop GIS-based application with an underlying risk engine that iteratively calculates the risk profiles of hazardous materials shipments. Government security specialists can use the GIS-based application to visualize how individual risk profiles change over time, identify roadway segments where shipments are concentrated, flag security anomalies (e.g., whether a shipment has deviated from its planned course), and coordinate responses to potential security incidents or hazardous materials releases.

Indeed, if risk scores were left in their raw numerical form, government agencies would be unable to quickly identify the most pressing vulnerabilities, being overwhelmed by tabular, unmapped data. As such, computing risk scores and visualizing risk complement one another, thus providing government agencies with detailed national, regional, and local summaries of shipment activities. This section briefly describes the software and desktop environment that are used to visualize the risk profiles of hazardous materials shipments. Discussions of software development and its underlying code are beyond the scope of this paper — rather, the aim is to illustrate the mapping platform and its capacity to translate risk scores and monitoring data into actionable intelligence.

The DHRMA's mapping environment is the Security Specialist Desktop (SSD), which provides users with three distinct screens — a situational awareness screen, a research screen, and an action screen. Each screen has different capabilities and presents risk calculations and individual shipment data at different levels of detail. In an operational environment, security analysts would be assigned a focal geographic area, which is captured on the situational awareness screen (Figure 4.1). This screen provides security analysts with a synoptic view of their assigned area. Summary consequence data are located in the lower left-hand portion of the screen, including the region's exposed population, potential economic impacts, the number of critical infrastructure elements and key resources, and environmentally sensitive assets. These data are integral for determining a shipment's risk profile, so displaying them on the situational awareness screen lets users immediately apprehend what factors are driving risk scores. Circles are used to represent individual shipments, the color of which varies based on

the calculated risk (e.g., shipments that warrant greater attention are colored orange and red). Users have the ability to click on individual shipments, which brings up key intelligence that would be used during an emergency situation, such as the driver's personal information, vehicle and trailer type, and the carrier and consignee contact data. Along with these data, in the upper right-hand corner, security specialists have access to an Intelligence Analyst List. Included on this list are materials which the TSA has prioritized based on intelligence it has received (e.g., if terrorists have targeted a material, it will appear here). Additionally, there is a high-risk shipments list, automatically generated by the SSD software based on risk profiles and intelligence, which contains all of the active hazardous materials shipments in the security analyst's designated area.



**Figure 4.1** Screen Capture of the SSD's Situational Awareness Screen

Figure 4.2 illustrates the research screen, which provides a security analyst with fine-grained details on individual shipments. If an analyst decides — based on

information gleaned from the situational awareness screen — that a shipment merits scrutiny, the research screen is used to track it. A panel on the left side lists shipment data, including the shipper information, the gate-out time, emergency and carrier contacts, an option to open up a new window that presents a detailed analysis of risk scores, and the planned destination. An analyst can flag a shipment to indicate it bears watching, and if the situation warrants, escalate its security/risk status. Once a shipment is placed on this screen, an analyst can watch it move in real-time. If the security risk presented by a shipment is high enough, an analyst can move it to the action screen, which enables a more thorough investigation (Figure 4.3).

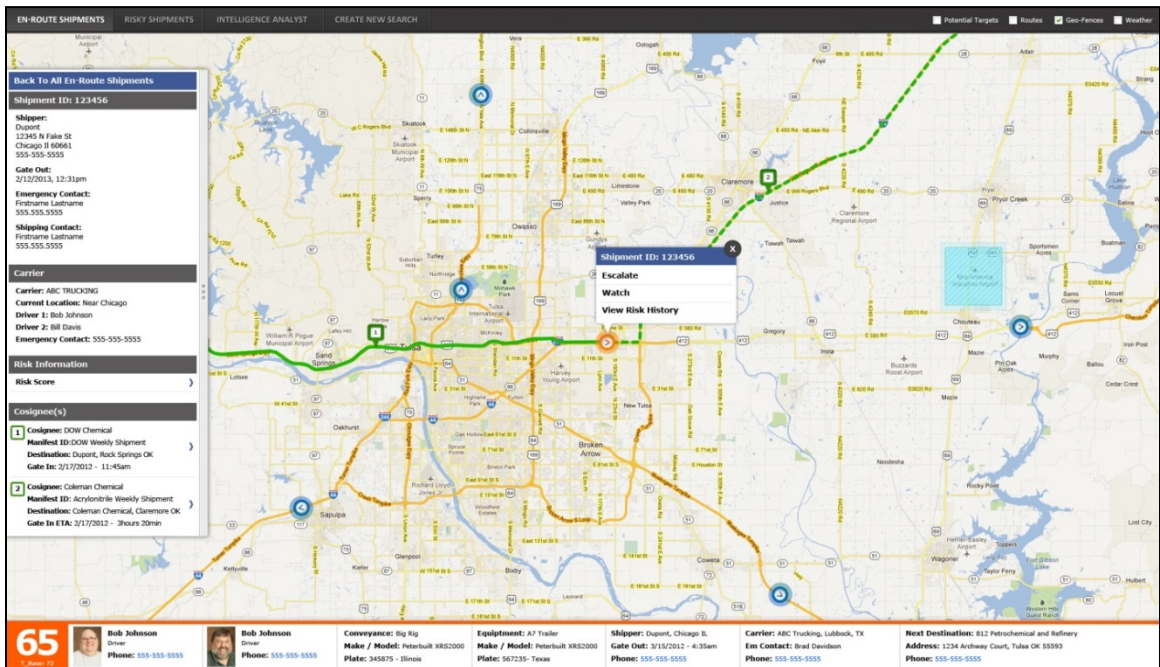


Figure 4.2 Screen Capture of the SSD's Research Screen

While analysts have the option to move a shipment to this screen of their own volition, the SSD software can automatically load a shipment here if it detects an anomaly. The action screen's purpose is to help a user determine whether a security incident is in progress. It supplies information the security analyst needs to make this

decision, including intelligence on shipment's current risk profile, nearby targets, the type of hazardous materials contained on the vehicle, the shipment manifest, driver information, and the nature of the anomaly detected (e.g., a shipment has departed from its planned route). Once a security analyst has determined that a security incident may be taking place, the action screen facilitates a rapid response.

The *action screen* contains a workflow panel that outlines step-by-step instructions on how to resolve a case. With the graphical layout, an analyst can quickly scan all relevant information. After working through the prescribed workflow, analysts have two options: 1) if further investigation reveals a shipment does not present a threat, they can close the case without taking actions, or 2) if they believe a shipment has been compromised, they can use the SSD's Fusion tool. The Fusion tool launches a virtual collaboration session that initiates dialogue among all relevant stakeholders. Critical stakeholders would typically include shipping partners; TSA officials; local, state, and federal agencies; and emergency response centers. Collaboration takes place over a secured network and is essential for coordinating a swift response to security incidents or accidental hazardous materials releases.

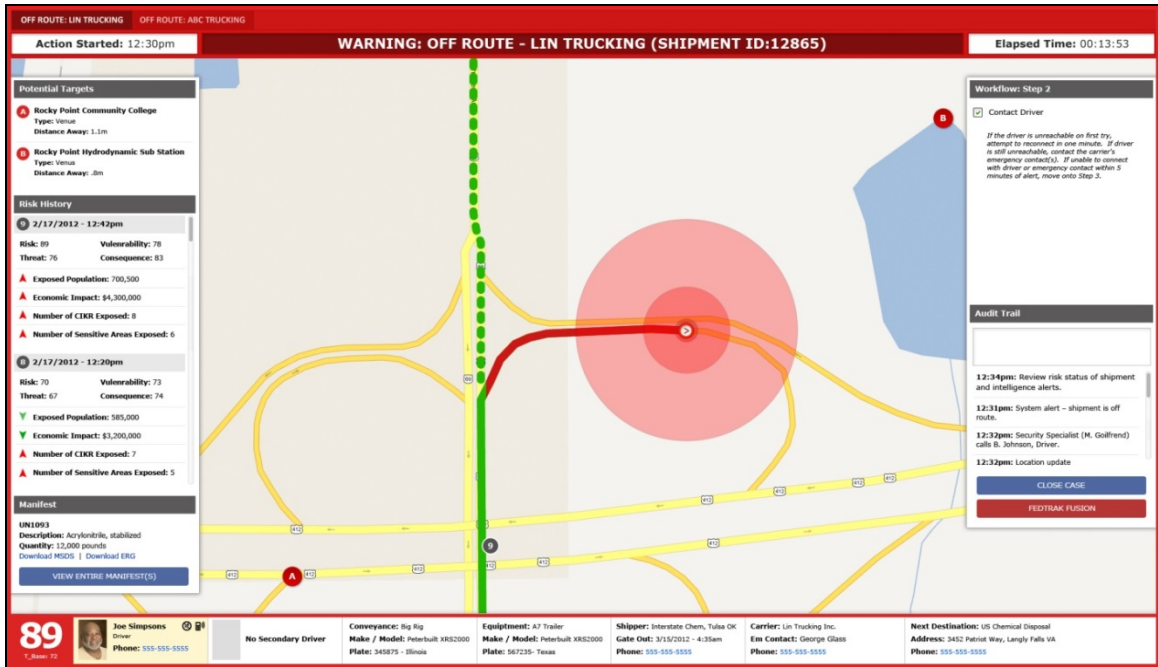


Figure 4.3 Screen Capture of SSD's Action Screen

All of the DHMRA's visualizations, workflows, and analysis are underpinned by the risk equation described in the previous section (and Chapter 3). The SSD's mapping environment provides security analysts with the insights they need to evaluate and manage the risk posed by shipments at the individual and collective levels. To illustrate the combined strength of the SSD and risk equation, the following section presents a brief case study. This case study reinforces the argument that threats, vulnerabilities, and consequences — and therefore risk — exhibit dramatic spatial variability.

#### 4.4 Case Study: Calculating and Visualizing the Risk of Simulated Hazardous Materials Shipments

The case study presented here considers the movement of six hazardous materials (in different containers and quantities) from Ashland, Kentucky to Philadelphia, Pennsylvania. Because each material presents different threats, vulnerabilities, and consequences, the level of risk posed by each varies (Table 4.2 lists



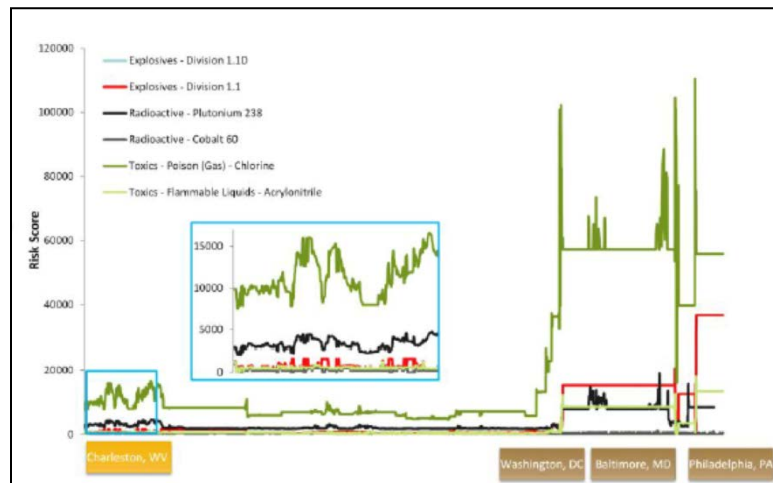
the characteristics of each shipment). The SSD’s underlying software was used to generate risk scores for each shipment for their entire trip. The framework’s visualization tools give users the opportunity to quickly analyze the entire risk landscape and determine, in real-time, which shipments pose the greatest danger. Proprietary look-up tables (cf. Bubbico et al., 2004) were used to generate threat and vulnerability values for each shipment.

**Table 4.2** Shipping Profiles for Simulated Case Study

<b>Material</b>	<b>Container</b>	<b>Weight (lbs.)</b>
<b>Explosive, Blasting Type A</b>	Explosive Packages	5,000
<b>Division 1.1 Explosives: Not Heavily Encased</b>	Explosives Packages	20,000
<b>Radioactive, Plutonium 238</b>	Radioactive Type B	1
<b>Radioactive, Cobalt 60</b>	Radioactive Type A	1
<b>Chlorine</b>	Pressurized Tanker	20,000
<b>Acrylonitrile, Stabilized</b>	Pressurized Tanker	20,000

As noted previously, risk scores tend to be amplified by the presence of large populations. Figure 4.4 captures this trend; the risk posed by all of the shipments increases dramatically when they enter densely populated urban areas such as Charleston, Washington, D.C., Baltimore, and Philadelphia. Trend lines reveal shipments pose little risk for much of their journey, with scores flatlining at low values throughout the more rural portions of West Virginia and Virginia. The release of chlorine — given its toxic inhalation properties and dispersal potential — would potentially cause the most significant damage. These findings are consistent with past events. Barrett and Adams (2011) showed that dispersion of chlorine gas can produce a high number of fatalities in urban areas. Jones et al. (2010) cited a number of recent incidents that involved the release of chlorine gas. For example, in 2005 a railroad tanker filled with chlorine gas

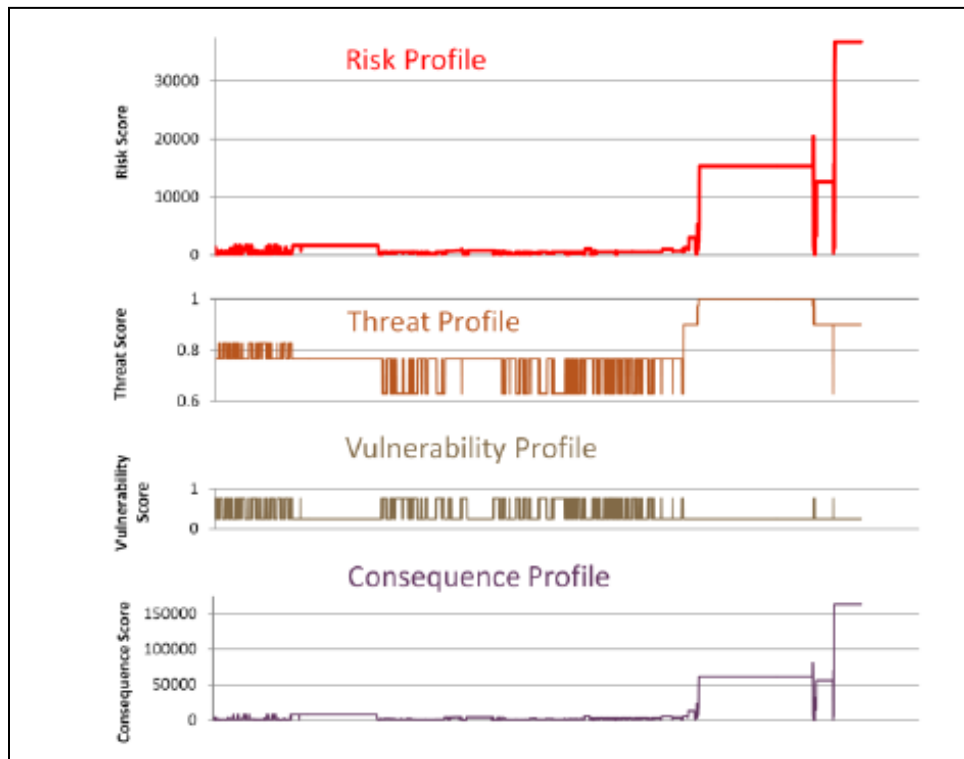
collided with another train near Graniteville, South Carolina. The accident diffused 90 tons of chlorine into the air, leading to nine fatalities and forcing 5,400 of the town's residents to evacuate. Underscoring the effects of chlorine is not meant to downplay the potentially severe impacts of the other materials, it is to illustrate that the impact of hazardous materials incidents is contingent upon their chemical properties. Although the release of chlorine may lead to the greatest number of injuries and fatalities, explosives will tend to inflict more lasting damage on the built environment. While injuries and fatalities would no doubt result from the detonation of explosive materials, the possible destruction of critical infrastructure and key resources, along with attendant economic damage, contribute most significantly to risk.



**Figure 4.4** Risk Score Trend Lines for Simulated Trip

Figure 4.5 decomposes the risk profile of a vehicle carrying chlorine gas by displaying threat, vulnerability, and consequence scores. Consistent with the results above, the shipment's risk exposure is greatest in urban areas. Note that threat and consequence scores peak in these locations because attackers are most likely to execute

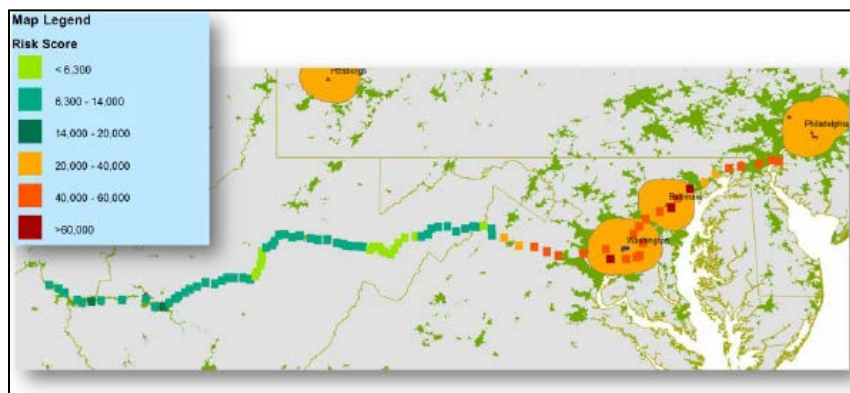
a vehicle attack in places where the amount of damage inflicted can be maximized. Vulnerability, on the other hand, bottoms out in cities. Recall that a shipment's vulnerability hinges on the relative likelihood of attackers successfully executing an attack. In rural locations, it is unlikely robust security measures will be in place to ward off an attack. Vulnerability scores tend to decline in urban settings there are more barriers to pulling off a successful attack. Generally, there is an inverse relationship between vulnerability and threat and consequence scores.



**Figure 4.5** Sample Threat, Vulnerability, and Consequence Score for a Shipment of Chlorine Gas

To clarify the geographies of risk produced by hazardous materials, the SSD generates heat maps which visualize how a shipment's risk varies spatially. Table 4.3 summarizes risk scores for rural, urban, and high-threat urban areas (HTUAs), while Figure 4.6 illustrates detailed risk scores for the aforementioned chlorine shipment. The

map clarifies the trends depicted by the trend lines. Areas in West Virginia are relatively insulated from the risk posed by hazardous materials. Risk scores are generally under 14,000 from there and into western Virginia. Risk skyrockets as the shipment approaches the densely populated Eastern Seaboard, stretching from Washington, D.C, to Philadelphia, in large part due to much higher consequence scores, which are driven by the number of people who live there as well as the concentration of economic activity. Unlike traditional methods of calculating transportation risk, the DHMRA offers a more detailed assessment of risk by demonstrating, in this case, that economic factors magnify risk. Relying on population alone to determine the consequences of a hazardous materials release provides agencies with an incomplete picture of risk.



**Figure 4.6** Spatial Distribution of Risk for a Chlorine Shipment

**Table 4.3** Sample Risk Scores for Chlorine Shipments in Rural, Urban, and High-Threat Urban Areas

<b>Variable</b>	<b>Rural Setting</b>	<b>Urban Area</b>	<b>HTUA</b>
<b>Consequence Radius (mi)</b>	5.53	5.53	5.53
<b>Threat</b>	0.765	0.765	1
<b>Vulnerability</b>	0.5	0.75	0.5
<b>Consequence: Decontamination</b>	9,612	9,612	9,612
<b>Consequence: Economic</b>	0	589	16,307
<b>Consequence: Environmental</b>	1	1	0
<b>Consequence: Population</b>	4,861	14,980	104,995
<b>Overall Consequence</b>	15,473	25,593	114,609
<b>Risk Score</b>	5,918	14,684	57,304

This case study demonstrates that HTUAs will be most impacted by hazardous materials in the event of a release. Although this is only one example, it illustrates how the SSD provides users with the visualization tools required to make quick and informed determinations about shipment risk. Modeling risk in this manner offers government agencies, planners, and emergency responders a precise idea of the most likely consequences following a release. This case study has focused on intentional acts which compromise hazardous materials shipments, however, the information generated by the DHMRA applies to unintentional releases, which arguably occur much more frequently. Given large numbers of accidents which involve hazardous materials each year (see Table 4.1), the information presented on the SSD can assist stakeholders with mitigating the worst effects of a release. This, in turn, can assist in reducing the number of injuries and fatalities as well as economic damages. Compared to traditional risk assessment models, DHMRA provides more intuitive representations of risk, which are

critical in emergency situations.

#### **4.5 Conclusion**

The DHMRA significantly improves our understanding of the risk hazardous materials shipments present as well as the spatially distributed nature of that risk. Although the overwhelming number of incidents which involve hazardous materials occur due to accidents, the possibility exists that terrorists could opportunistically target a hazardous material shipment to produce spectacular infrastructure damage, destroy critical resources, and injure or fatally wound large numbers of people. Because security risks are continuously changing, it is critical to build on traditional risk assessment methodologies (Erkut & Ingolfsson, 2005) by taking a more dynamic view of risk, one attuned to how risk profiles of vehicles vary as they move through areas with unique demographic, economic, and environmental characteristics. Along with operationalizing this dynamic view of risk, the DHRMA's risk equations more accurately conceptualize the far-ranging consequences of a hazardous materials release. Because the DHRMA uses straightforward equations to derive risk scores, they can be calculated quickly and efficiently. Potentially, the system could be used to optimize shipping routes, as knowledge generated from ongoing analysis will give transportation planners and private shippers the information needed to effectively modify route choice to reduce exposure to risk while minimizing travel times and costs.

This framework, once fully implemented, will improve our understanding of how risk varies along U.S. highway networks, which can inform more targeted policies to enhance the security of hazardous materials. In the process, it will contribute to

maintaining secure and efficient supply chains while protecting the communities that live nearest to the most heavily trafficked routes. Over the long-term, the DHMRA can promote a more adaptive form of risk management (e.g., Wise, 2006; Bjerga & Aven, 2015). Adaptive risk management encourages the use of iterative risk evaluations, anticipates hazardous materials release scenarios, and catalogs a set of alternative responses and flexible emergency responses. Responses to security incidents cannot be static or rely on a set of prescribed instructions. Once a release event occurs, stakeholders require tools that will enable them to coordinate with one another effectively and decide the most effective course of action — DHMRA’s desktop platform makes these forms of collaboration possible. Adaptive risk management will produce better outcomes when hazardous materials releases occur because it encourages flexible responses that can be modified as stakeholders acquire new information. Although risk can never be completely eradicated, the risk management framework presented in this paper at least improves manageability, ensuring that hazardous materials are safer and more secure than they otherwise would be.

## Chapter 5 Conclusions and Future Recommendations

Terrorism is an omnipresent problem. Although the 9/11 attacks were unprecedented in the scale and scope of destruction they inflicted, smaller terrorist attacks are unfortunately, routine. Most attacks are uncoordinated, but the act of a perpetrator working independently or with only very tenuous connections to broader terror networks. While terrorists use a variety of equipment and methods to execute their attacks — ranging from firearms and improvised explosive devices to suicide bombings — relatively few incidents have involved the weaponization of cars, trucks, waterborne vessels, and other vehicles that move on surface transportation networks. Although the recent terrorist attack in Nice, France, during which an individual drove a cargo truck at high speeds through a crowded promenade (killing 85 and injuring hundreds), offers a vivid reminder of the consequences which stem from a vehicle being used as a weapon— even without hazardous materials onboard. Given their relatively poor or nonexistent defenses and inconspicuousness, commercial vehicles transporting hazardous materials are an easy target. Terrorist actors could easily seize these vehicles, and before carriers or security agencies recognize that something is amiss, their contents could be detonated or released. Continuously monitoring hazardous materials provides a viable way to understand the risks presented by a shipment at a given moment and enables better, more coordinated responses in the event of a release. This is why the risk management framework outlined in this dissertation is so valuable — it can arm multiple stakeholders with the knowledge they need to reduce the likelihood of attacks against commercial vehicles with onboard hazardous materials.



As noted, this dissertation makes novel contributions to several literatures, including risk analysis and management, the transportation of hazardous materials, systems engineering, and shipment routing. Chapter 2 highlights the existing regulatory landscape for hazardous materials and the challenges of imposing new methods of surveillance on carriers reluctant to shoulder regulatory burdens. It describes, as well, the strengths and limitations of a prototype hazardous materials tracking system (PHTS) and potential strategies to improve monitoring of hazardous materials. Building from this point, Chapter 3 proposes the use of a newly created risk equation to characterize and quantify the risks posed by hazardous materials shipments. The straightforward equation is compatible with the risk assessment protocols used by the Department of Homeland Security (DHS) and Transportation Security Agency (TSA). Finally, Chapter 4 presented the conceptual outlines of the Dynamic Hazardous Materials Risk Assessment Framework (DHMRA), which offers users a comprehensive and spatially explicit understanding of how risk varies across transportation networks. Using this information, they can the minimize damage and human injuries and fatalities that could result from intentional or accidental hazardous materials releases. Obviously no system, irrespective of its sophistication, can anticipate and therefore ward off terrorist attacks. However, implementing DHMRA will prepare public agencies and private stakeholders alike to respond in an effective manner to potential threats and ongoing events.

Despite the advances DHMRA provides over existing risk management frameworks, much work remains to be done to ensure hazardous materials supply chains are well-defended against the threat of terrorist attacks and well-protected

against the risk of accidental releases. One of the limitations of this dissertation is its exclusive focus on a small subset of hazardous materials — Tier 1 Highway Security Sensitive Materials (HSSMs). A narrow focus was logical because Tier 1 HSSMs are by far the most dangerous materials in the domestic hazardous materials supply chains. If targeted by a deliberate attack, the release or detonation of these materials would produce catastrophic outcomes for the built environment, socioeconomic relationships, and human health. Tier 1 HSSMs thus warrant close scrutiny, and therefore make a natural starting point to design, build, and implement a tracking and monitoring system. Yet, large quantities of hazardous materials typically go unmonitored and are therefore still vulnerable. Future research should extend and apply the framework outlined in this dissertation to other classes of hazardous materials which are routinely transported on U.S. highway networks.

Although the risk equations developed in Chapters 3 and 4 have been empirically validated through the input of expert knowledge and some testing, DHRMA remains a largely conceptual framework. The GIS environment and mapping applications have been tested under simulated real-world conditions, however, full implementation has yet to occur. Future research will need to determine what modifications are needed to scale up its operation to ensure it is equipped to simultaneously process the thousands of hazardous materials shipments which are concomitantly on U.S. highways. Certainly, full implementation was beyond the scope of this project, however, a sound foundation has been established upon which future work can proceed. As full-scale testing moves forward, adjustments can be made to the risk equations, mapping interface, and GIS

environment to ensure satisfactory performance under a variety of conditions.

Future work also needs to look beyond the transportation of hazardous materials on highway networks. The domestic hazardous materials supply chain is thoroughly multimodal, with railways and waterways being critical for the movement of hazardous materials. DHMRA addresses one component of the multimodal hazardous materials supply chain, but it presents officials with a circumscribed picture of where individual shipments are by not reaching beyond roadway transportation. When a shipment is placed onto a tractor trailer, it gains visibility and the DHMRA is able to track it, however, once it transferred to another mode, government agencies lose sight of it. For example, the U.S. Army Corps of Engineers does not currently require carriers to submit regular reports on the location of vessels carrying hazardous materials (although it did previously; the rule stipulating that carriers do so was suspended in January 2011 and has not been reinstated). Developing mode-appropriate risk equations to quantify the risk of individual shipments would present an obstacle, but not an insurmountable one. The risk equations developed as part of this research are specific to highway transportation. Although TSA's foundational equation of  $Risk = Threat \times Vulnerability \times Consequence$  provides a starting point to generate equations for shipments transported on inland and coastal waterways, eliciting the input of subject-matter experts would be necessary to generate an appropriate system of equations tailored to the unique challenges presented by waterborne transportation. As noted in Chapter 3, the Federal Railroad Administration has implemented the Rail Corridor Risk Management System to aid with route selection and calculate a score that represents the level of risk posed by

rail cars transporting hazardous materials. Information from this system could potentially be integrated with risk management data generated by DHMRA (and from a new waterways risk management system) to develop a more comprehensive and integrated picture of risk across U.S. surface transportation networks. Integrating disparate systems, each with its own unique methodology for calculating risk, would no doubt prove challenging, but this is a worthwhile task that, over the long-term, will be necessary to understand the spatial and cross-modal variability of hazardous materials risk.

Although DHMRA was designed primarily with terrorism in mind, it is also, as noted throughout this document, useful for examining the impacts of accidental hazardous materials releases. Future iterations of DHMRA could expand on its capabilities in this area by incorporating modeling data on the release and dispersion of toxic gases, liquids, and other substances. Numerous research studies have modeled the dispersion and atmospheric residence time of toxic gases, and could provide a valuable source of data for anticipating the consequences of different release scenarios. While DHRMA facilities provide spatially explicit risk forecasting under a variety of release scenarios, these scenarios assume that an area of a fixed size will be impacted regardless of when or where they occur. Integrating sophisticated models geared toward understanding the behavior of particular substances under a range of atmospheric conditions would open the door for more accurate and fine-grained risk estimates.

Advances in knowledge typically come incrementally. The risk management framework laid out in this dissertation stands as a modest contribution to ongoing discussions about how public and private stakeholders can best protect the public against terrorist activities which single out commercial vehicles transporting hazardous materials. The potential ramifications of terrorists preying upon a hazardous materials shipment are immense. Imagine, for instance, a terrorist seizing tankers filled with chlorine gas in a crowded urban landscape and releasing it. Widespread casualties would certainly result, and the subsequent social and economic dislocations would prove daunting to cope with. Although DHMRA cannot entirely avert terrorist attacks, the knowledge it can generate about the location and status of hazardous materials shipments can help prevent nightmare scenarios from emerging. By instantly showing where particular shipments are traveling — and their risk profiles — carriers and government agencies can react swiftly when anomalous circumstances arise. A quick response may be the difference between forestalling an attack or watching as a calamitous series of events unfolds. DHMRA offers great promise, and once implemented will play an integral role in shaping a safer and more secure future for U.S. transportation networks. While the academic contributions of research are certainly important and worthwhile, perhaps the ultimate measure of its efficacy should be whether or not it materially transforms regulations, policies, and practices. Thus, if it succeeds at nothing else, DHMRA heralds a future in which hazardous materials are less vulnerable, and therefore less likely to be made into weapons that can victimize an unsuspecting public.

## **APPENDIX A Survey Results Tables**

## **Introduction**

This appendix provides the detailed survey results. The appendix presents questions asked in each of the topical areas covered by the survey. Breaks in topical areas are denoted by a change in chart color.

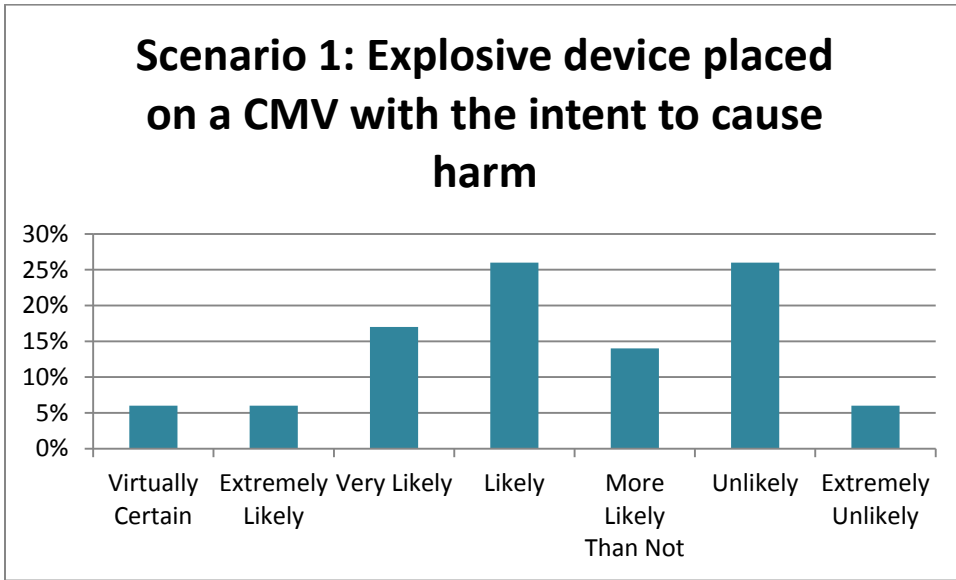
Section 1 examines a series of attack scenarios involving Commercial Motor Vehicles (CMV's) transporting Tier 1 HSSMs. These scenarios were presented to the survey participants. Survey participants then ranked the likelihood of each scenario occurring on a scale from Virtually Certain to Extremely Unlikely.

Section 2 presents an examination of threat rankings associated with trailer and container types. Survey participants were asked to assess the threat associated with each type of container or trailer that could be transportation a Tier 1 HSSM, and rank according to the threat they posed on a scale of 1 to 6, with 1 being the highest threat and 6 being the lowest threat.

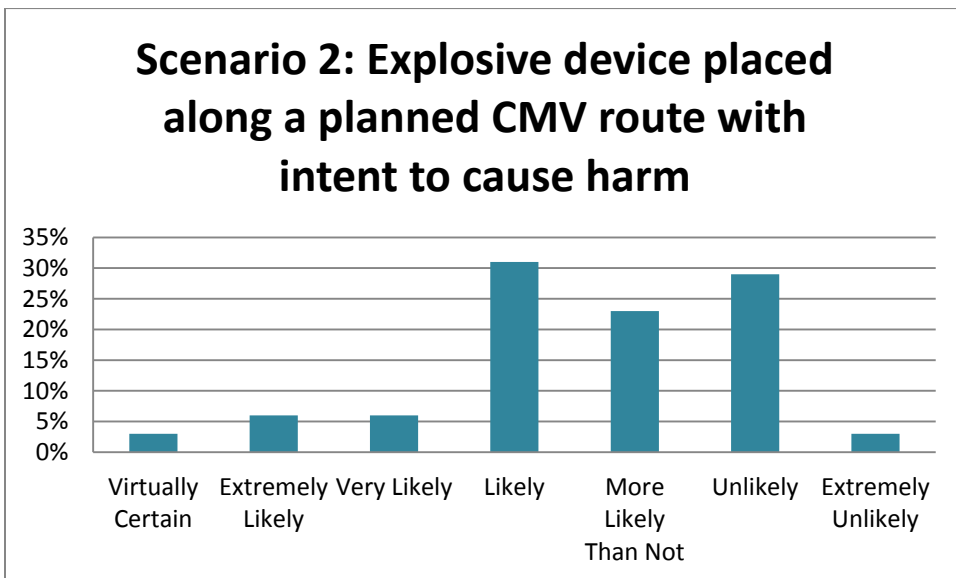
Section 3 presents seven attack scenarios which are designed to examine particular vehicle types. Survey participants were asked to analyze and select the likelihood that the attackers would fail due to: a) technical difficulties; and b) security measures. These responses were ranked from Certain to Not Possible.

Section 4 presents the survey participants with the Transportation Security Administration's Security Action Items (SAIs). Survey participants examined each of the 23 SAIs and ranked them according to importance in securing the United States Tier 1 HSSM supply chain. Ranking ranged from Extremely Important to Not At All Important. Section 5 presents survey results of the questions pertaining to factors contributing to the aggregate impacts of a terrorist attack. Questions were designed to ask each of the survey participants to rank a variety of potentially affected categories and the overall contribution they make to the aggregated impacts of a terrorist attack.

Section 1: Commercial Motor Vehicle Attack Scenarios



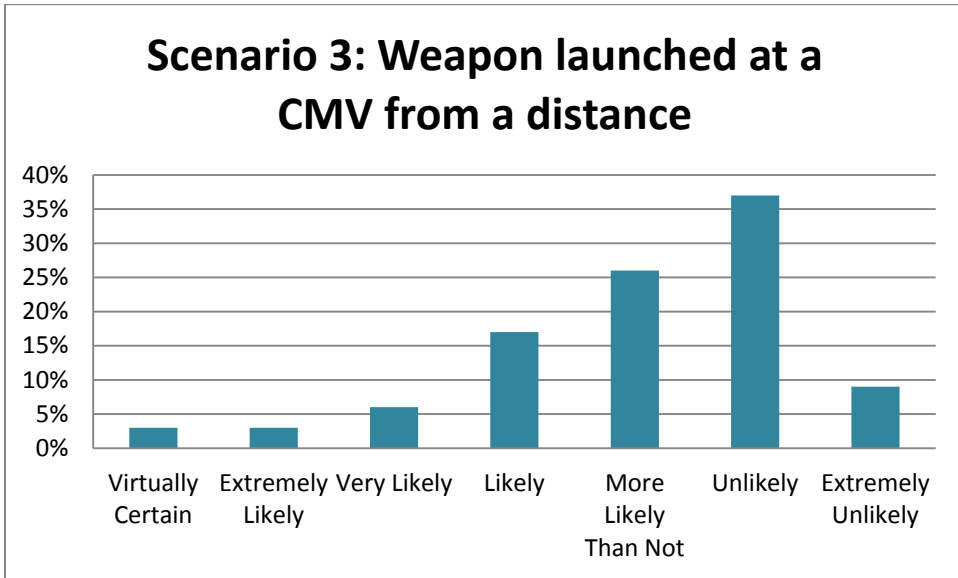
Scenario 1 asked the respondents to determine the likelihood of an explosive device being placed on a CMV with the intent to cause harm. 6% felt that this scenario was virtually certain, 6% extremely likely, 17% very likely, 26% likely, 14% more likely than not, 26% unlikely, and 6% extremely unlikely.



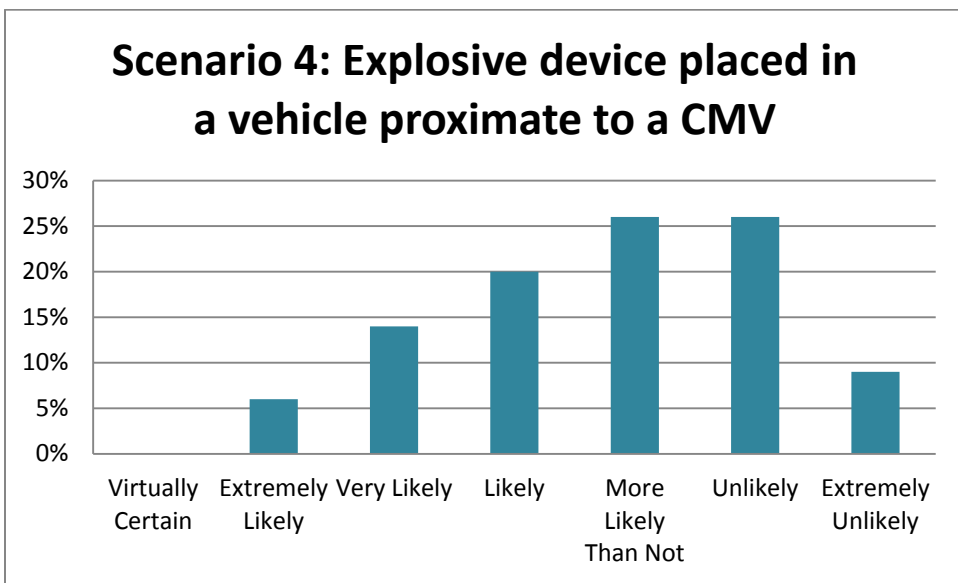
Scenario 2 asked the respondents to determine the likelihood of an explosive device being placed along a planned CMV route with the intent to cause harm. 3% felt



that this scenario was virtually certain, 6% extremely likely, 6% very likely, 31% likely, 23% more likely than not, 29% unlikely, and 3% extremely unlikely.

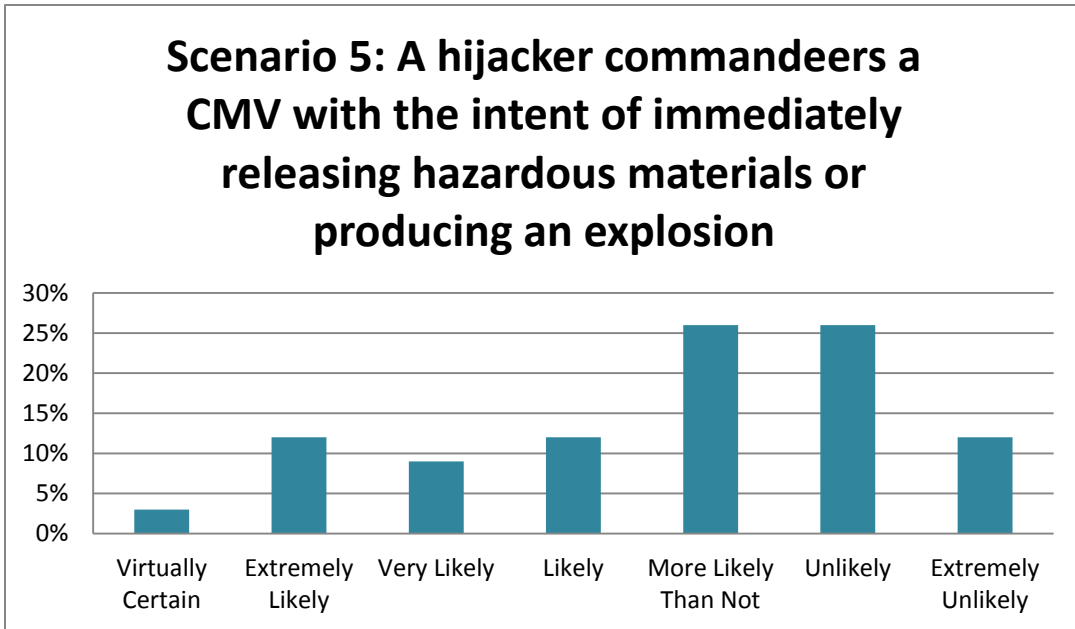


Scenario 3 asked the respondents to determine the likelihood of a weapon being launched at a CMV from a distance. Examples provided included a high powered rifle or a rocket propelled grenade. 3% felt that this scenario was virtually certain, 3% extremely likely, 6% very likely, 17% likely, 26% more likely than not, 37% unlikely, and 9% extremely unlikely.



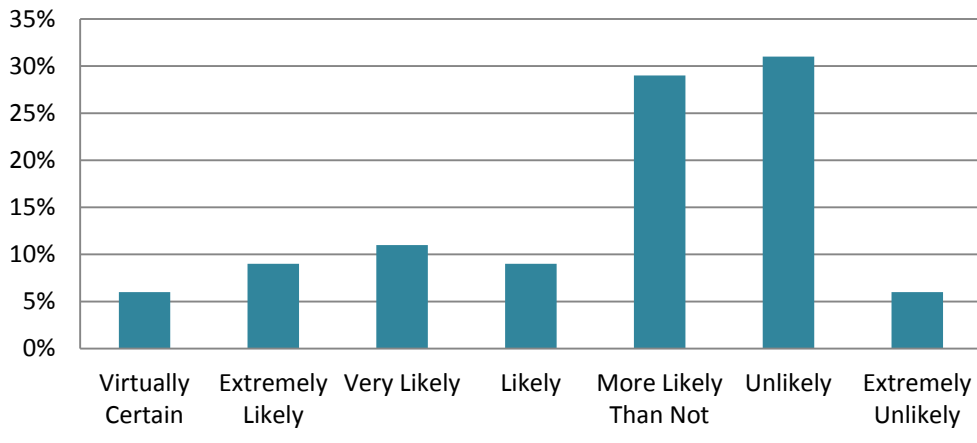
Scenario 4 asked the respondents to determine the likelihood of an explosive device being placed in a vehicle located proximate to a CMV (i.e. Vehicle Borne

Improvised Explosive Device-VBIED) with the intent to cause harm. Examples provided included a high powered rifle or a rocket propelled grenade. 0% felt that this scenario was virtually certain, 6% extremely likely, 14% very likely, 20% likely, 26% more likely than not, 26% unlikely, and 9% extremely unlikely.



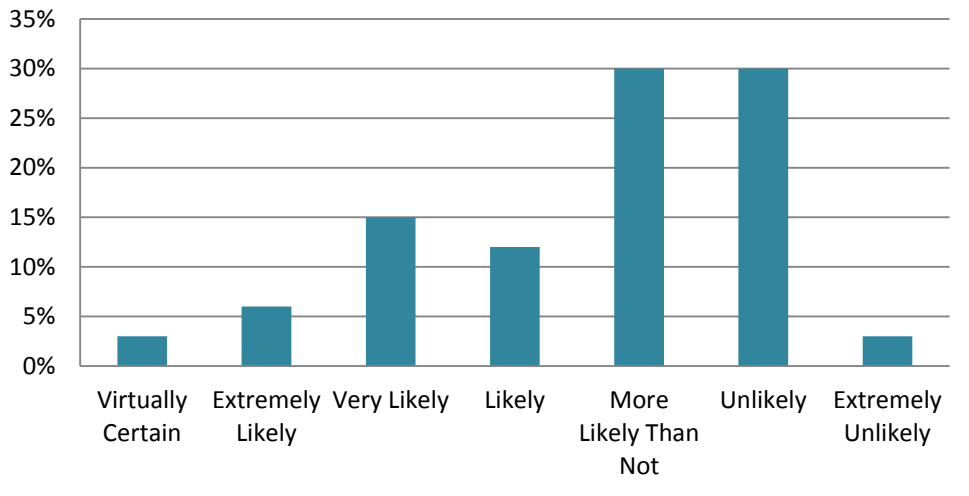
Scenario 5 asked the respondents to determine the likelihood of a hijacker commandeering a CMV with the intent of immediately releasing the hazardous materials or producing an explosion. 3% felt that this scenario was virtually certain, 12% extremely likely, 9% very likely, 12% likely, 26% more likely than not, 26% unlikely, and 12% extremely unlikely.

### Scenario 6: A hijacker commandeers a CMV and drives it to a nearby location with the intent of releasing hazardous materials or producing an explosion



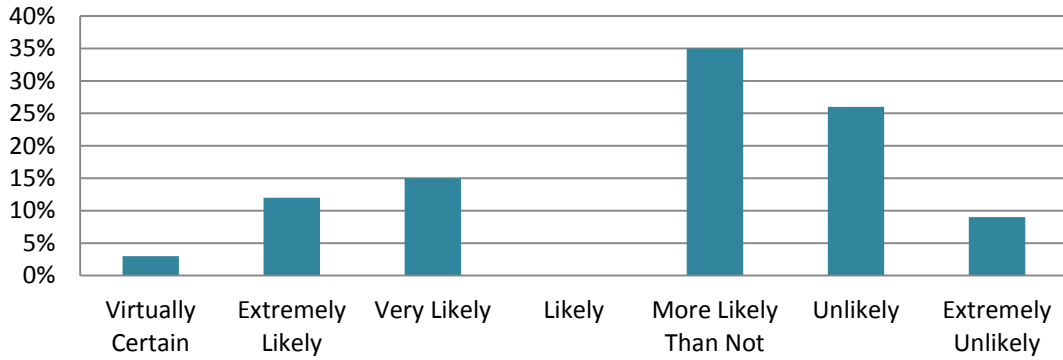
Scenario 6 asked the respondents to determine the likelihood of a hijacker commandeering a CMV and driving it to a nearby location with the intent of releasing the hazardous materials or producing an explosion. 6% felt that this scenario was virtually certain, 9% extremely likely, 11% very likely, 9% likely, 29% more likely than not, 31% unlikely, and 6% extremely unlikely.

### Scenario 7: An insider commandeers a CMV to immediately release hazardous materials or produce and explosion



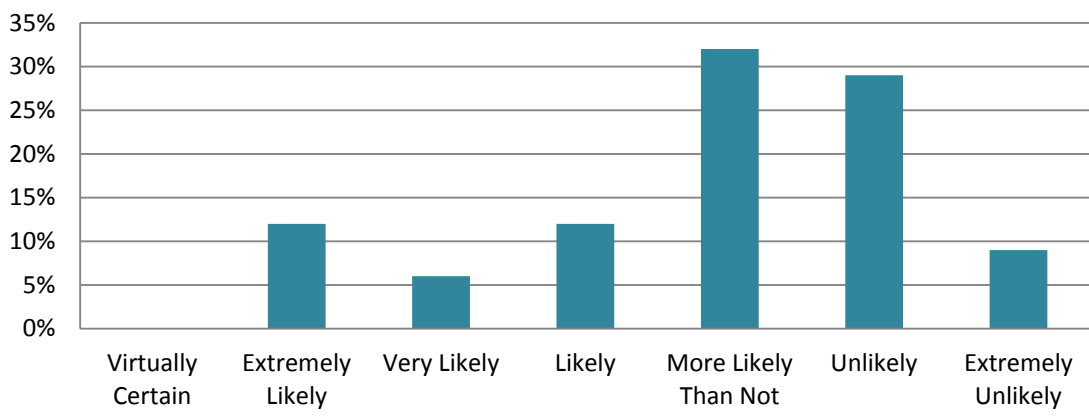
Scenario 7 asked the respondents to determine the likelihood of an insider, such as a trucking firm employee, commandeering a CMV to immediately release hazardous materials or produce an explosion. 6% felt that this scenario was virtually certain, 9% extremely likely, 11% very likely, 9% likely, 29% more likely than not, 31% unlikely, and 6% extremely unlikely.

### Scenario 8: An insider commandeers a CMV and drives it to a nearby location with the intent of releasing hazardous materials or producing an explosion



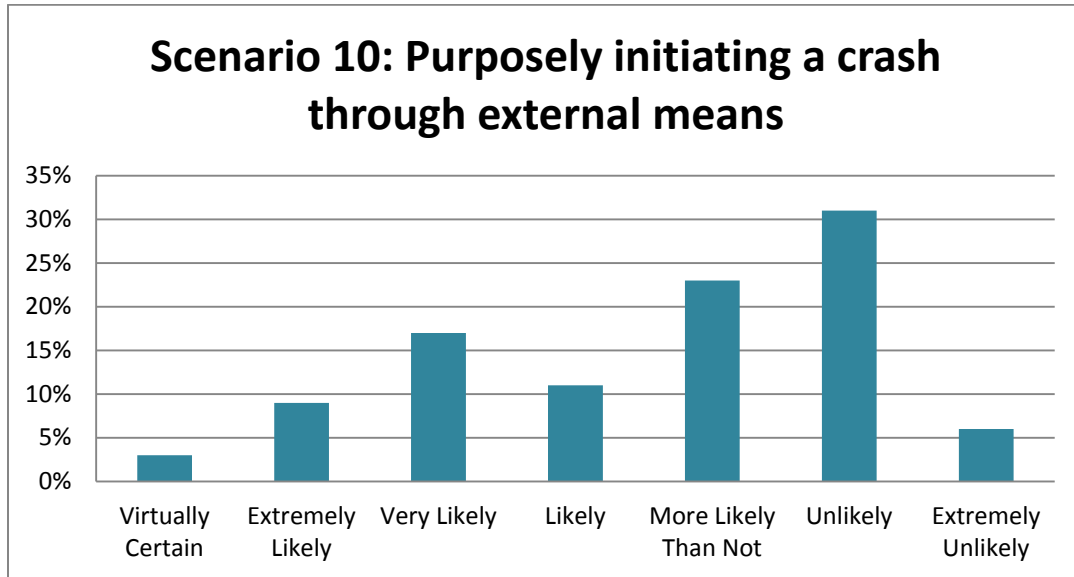
Scenario 8 asked the respondents to determine the likelihood of an insider, such as a trucking firm employee, commandeering a CMV and driving it to a nearby location with the intent of releasing the hazardous materials or producing an explosion. 3% felt that this scenario was virtually certain, 12% extremely likely, 15% very likely, 0% likely, 35% more likely than not, 26% unlikely, and 9% extremely unlikely.

### Scenario 9: Sabotage of Toxic Inhalation Hazard cargo tank CMV

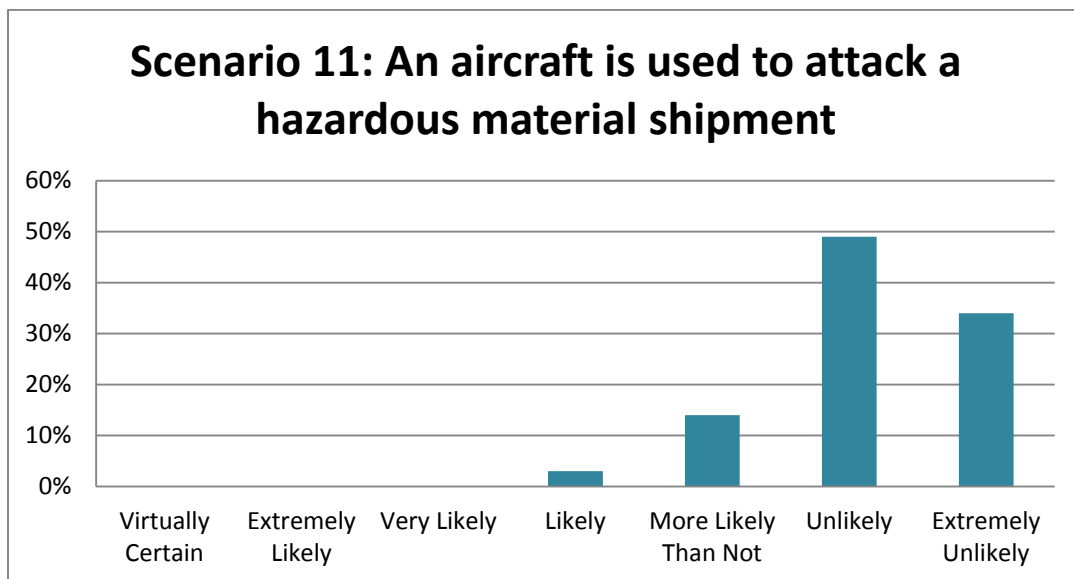


Scenario 9 asked the respondents to determine the likelihood of a sabotage of a toxic inhalation hazard cargo tank motor vehicle; for example, by opening or damaging a

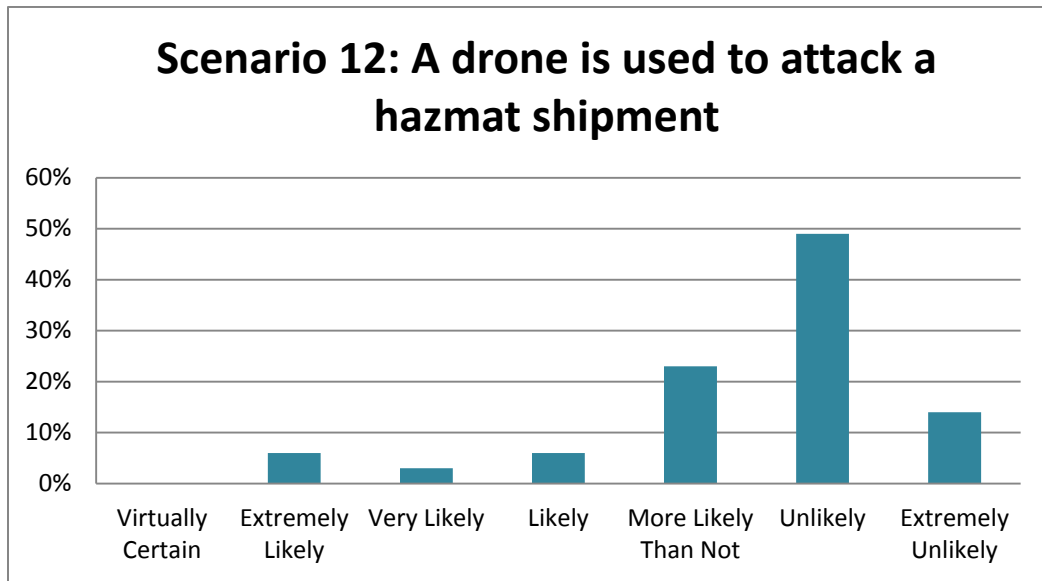
valve. 0% felt that this scenario was virtually certain, 12% extremely likely, 6% very likely, 12% likely, 32% more likely than not, 29% unlikely, and 9% extremely unlikely.



Scenario 10 asked the respondents to determine the likelihood of an attack that involved purposely initiating a crash through external means, for example placing something on the roadway or collision with another vehicle. 3% felt that this scenario was virtually certain, 9% extremely likely, 17% very likely, 11% likely, 23% more likely than not, 31% unlikely, and 6% extremely unlikely.

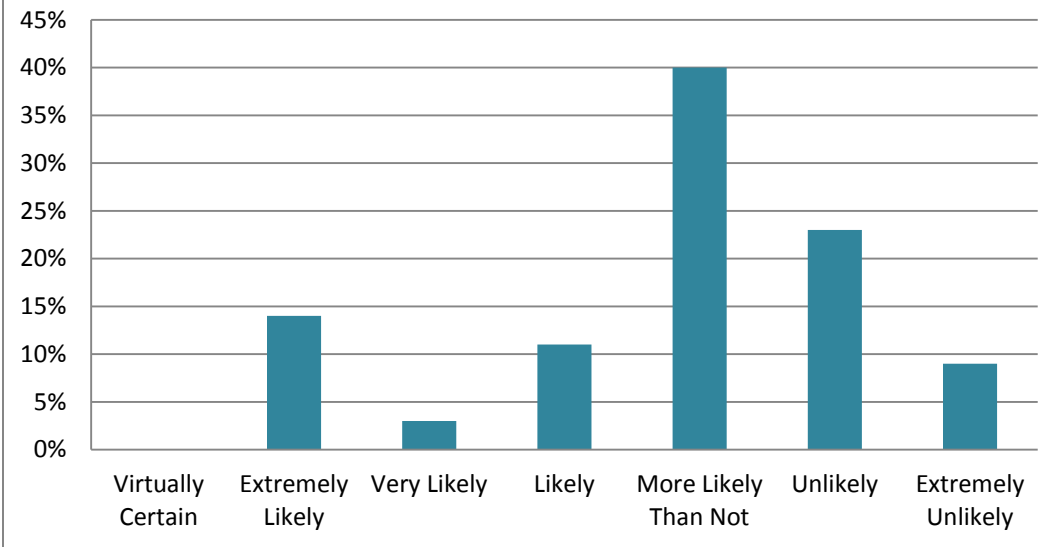


Scenario 11 asked the respondents to determine the likelihood of an aircraft being used to attack a hazardous material shipment. 0% felt that this scenario was virtually certain, 0% extremely likely, 0% very likely, 3% likely, 14% more likely than not, 49% unlikely and 34% extremely unlikely.



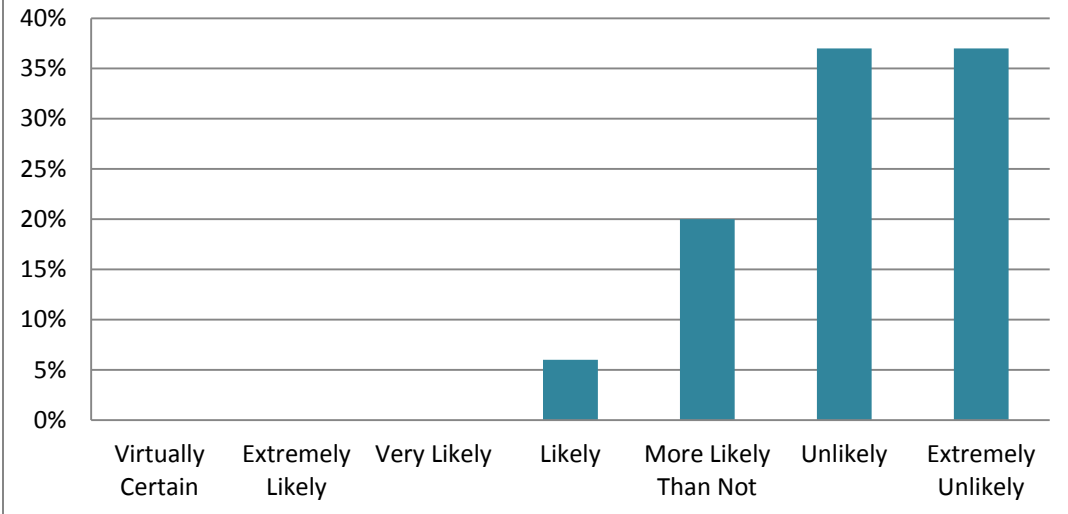
Scenario 12 asked the respondents to determine the likelihood of a drone being used to attack a hazardous material shipment. 0% felt that this scenario was virtually certain, 6% extremely likely, 3% very likely, 6% likely, 23% more likely than not, 49% unlikely, and 14% extremely unlikely.

### Scenario 13: Chemical, biological, radiological or nuclear attack



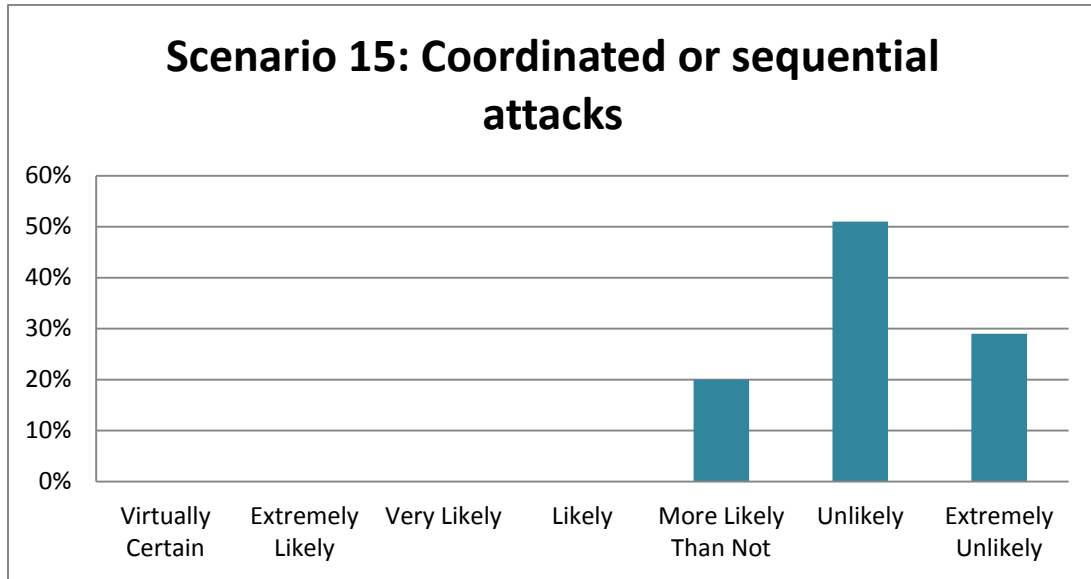
Scenario 13 asked the respondents to determine the likelihood of an attack that involved chemical, biological, radiological or nuclear materials. 0% felt that this scenario was virtually certain, 14% extremely likely, 3% very likely, 11% likely, 40% more likely than not, 23% unlikely and 9% extremely unlikely.

### Scenario 14: A waterborne vessel carrying an IED explodes close to a CMV



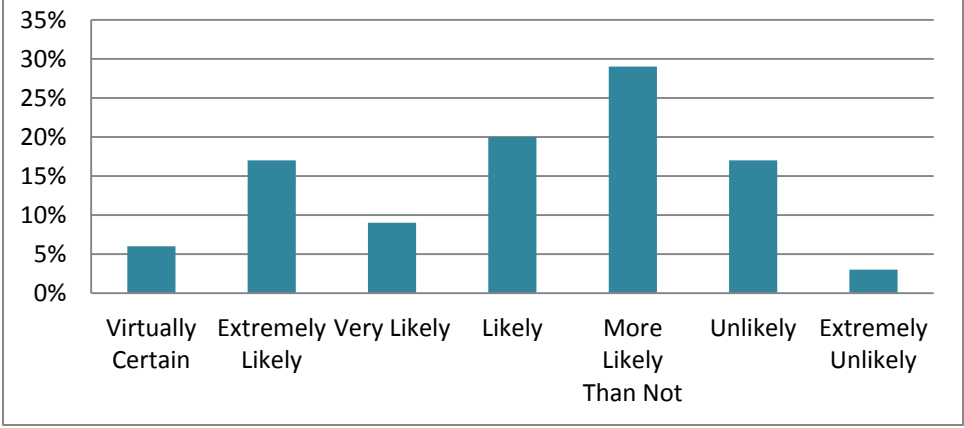


Scenario 14 asked the respondents to determine the likelihood of an attack that involved a waterborne vessel carrying an IED exploding close to a CMV. 0% felt that this scenario was virtually certain, 0% extremely likely, 0% very likely, 6% likely, 20% more likely than not, 37% unlikely and 37% extremely unlikely.



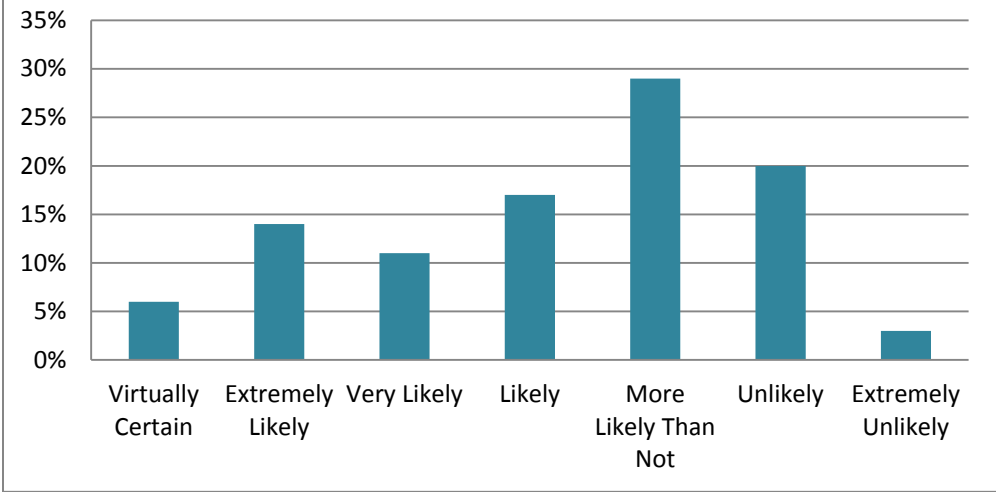
Scenario 15 asked the respondents to determine the likelihood of an attack that involved coordinate or sequential attacks. For example sabotage of a truck’s braking system and subsequent use of a rocket propelled grenade once the vehicle crashes. 0% felt that this scenario was virtually certain, 0% extremely likely, 0% very likely, 0% likely, 20% more likely than not, 51% unlikely, and 26% extremely unlikely.

### Scenario 16: Burglary or theft of hazmat



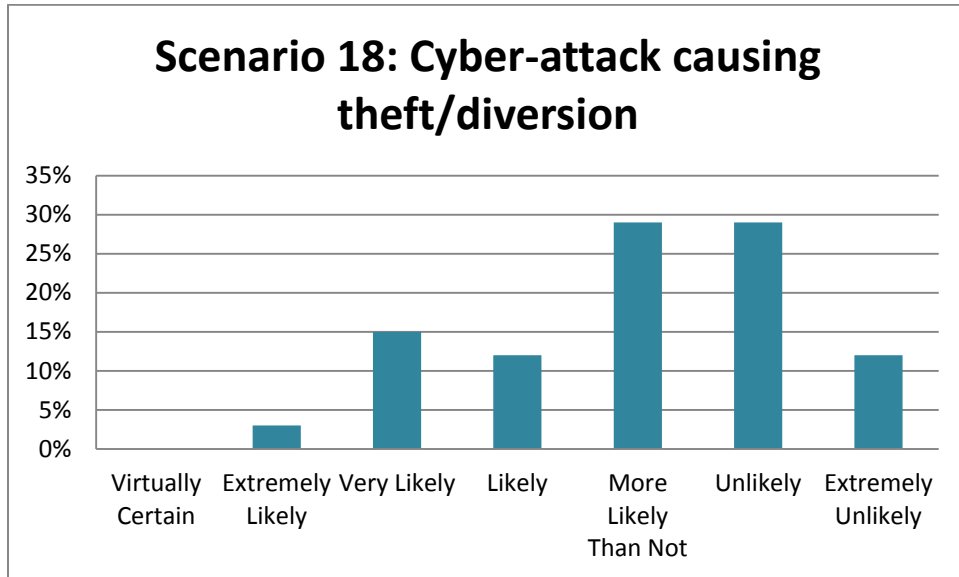
Scenario 16 asked the respondents to determine the likelihood of an attack that involved burglary or theft of hazardous materials with the intent to cause harm. 6% felt that this scenario was virtually certain, 17% extremely likely, 9% very likely, 20% likely, 29% more likely than not, 17% unlikely, and 3% extremely unlikely.

### Scenario 17: Damage to hazmat that does not produce a release or explosion

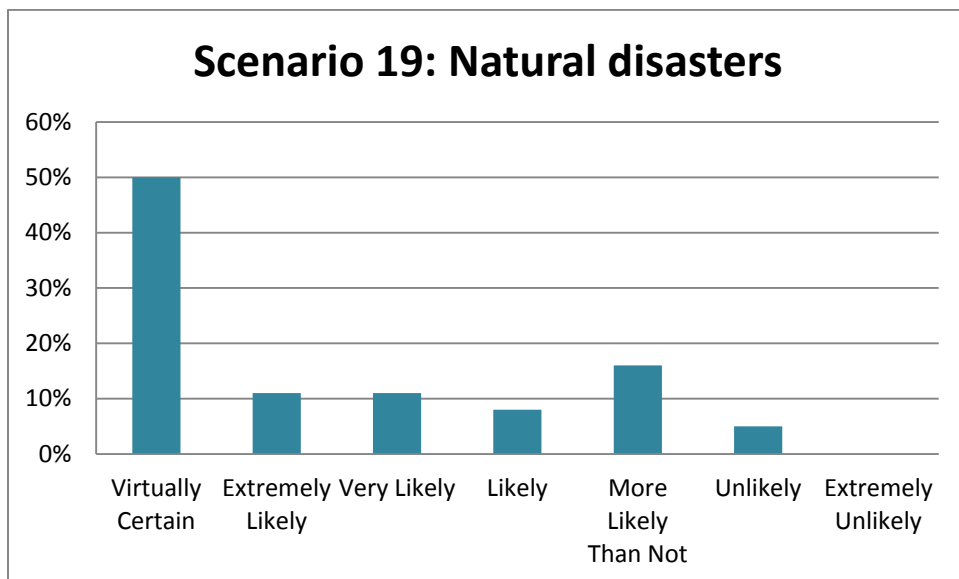


Scenario 17 asked the respondents to determine the likelihood of an attack that involved damage to a hazardous material (through vandalism or some other means) that does not produce a release or explosion. 6% felt that this scenario was virtually

certain, 14% extremely likely, 11% very likely, 17% likely, 29% more likely than not, 20% unlikely and 3% extremely unlikely.



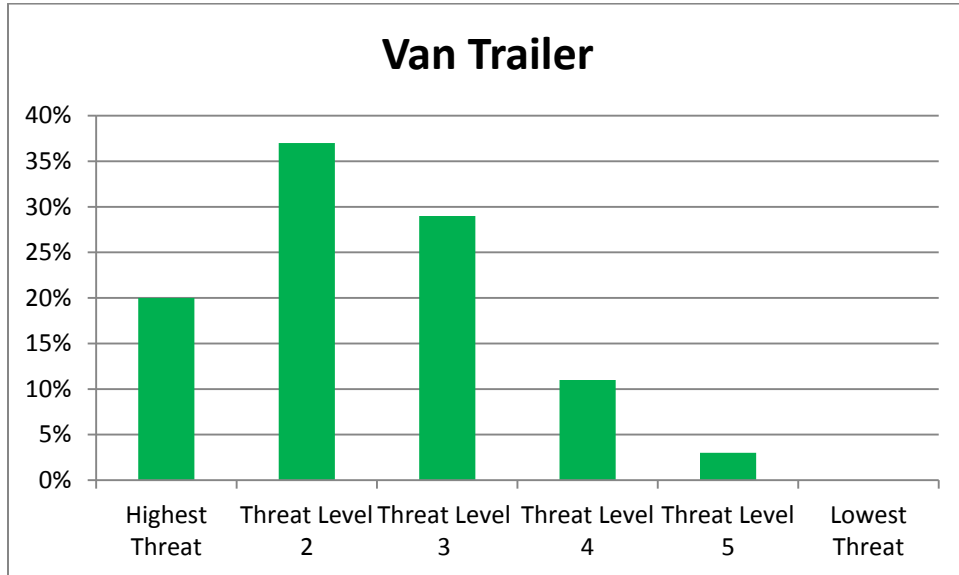
Scenario 18 asked the respondents to determine the likelihood of an attack that involved a cyber-attack causing theft or diversion, such as electronically changing a manifest so that hazardous materials are delivered to an improper destination. 0% felt that this scenario was virtually certain, 3% extremely likely, 15% very likely, 12% likely, 29% more likely than not, 29% unlikely, and 12% extremely unlikely.



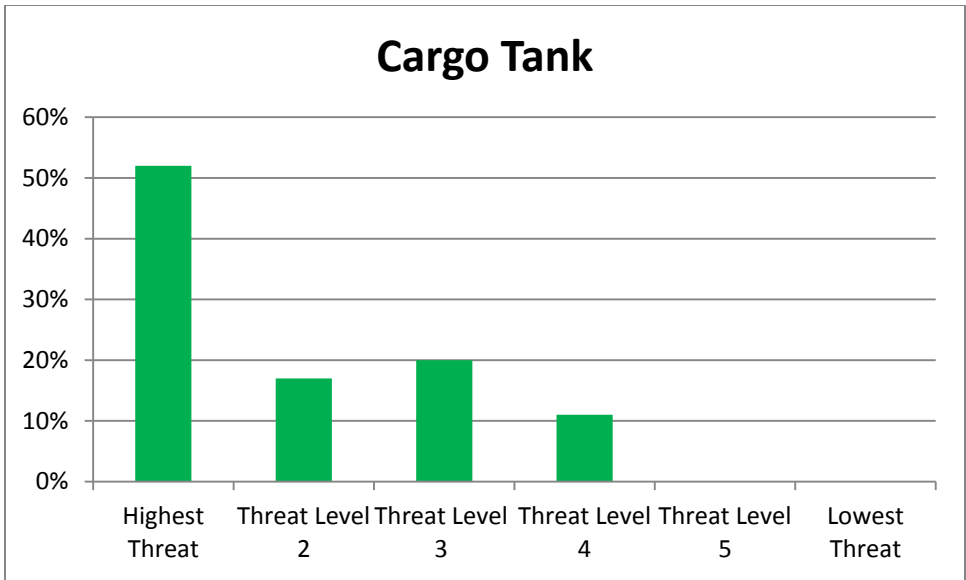
Scenario 19 asked the respondents to determine the likelihood of natural disasters such as a hurricane, tornado or earthquake resulting in a release or explosion. 50% felt that this scenario was virtually certain, 11% extremely likely, 11% very likely, 8% likely, 16% more likely than not, 5% unlikely, and 0% extremely unlikely.

## Section 2: Examination of threat rankings associated with trailer and container type

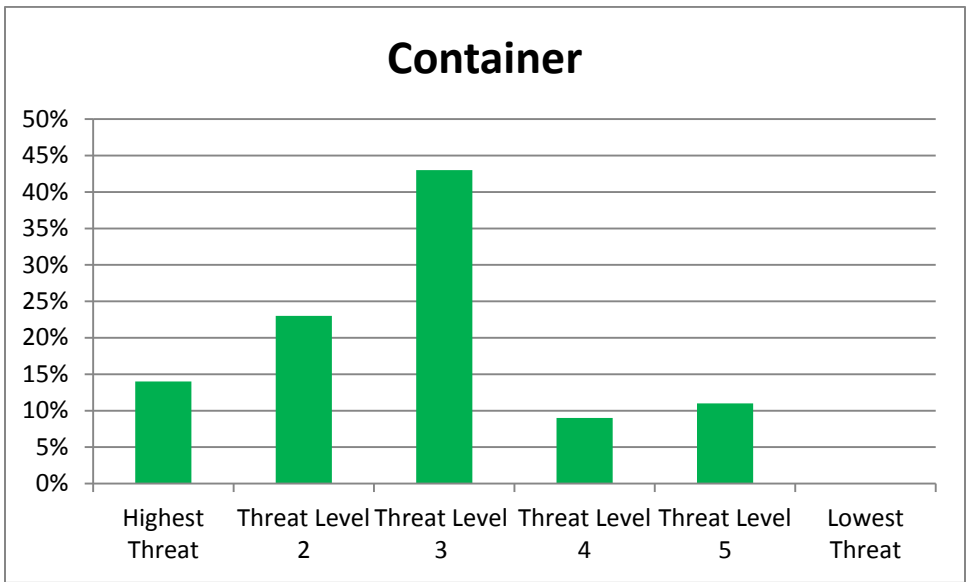
Survey participants were asked to assess the threat associated with each type of container or trailer that could transport a Tier 1 HSSM, and rank according to the threat they posed on a scale of 1 to 6, with 1 being the highest threat and 6 being the lowest threat.



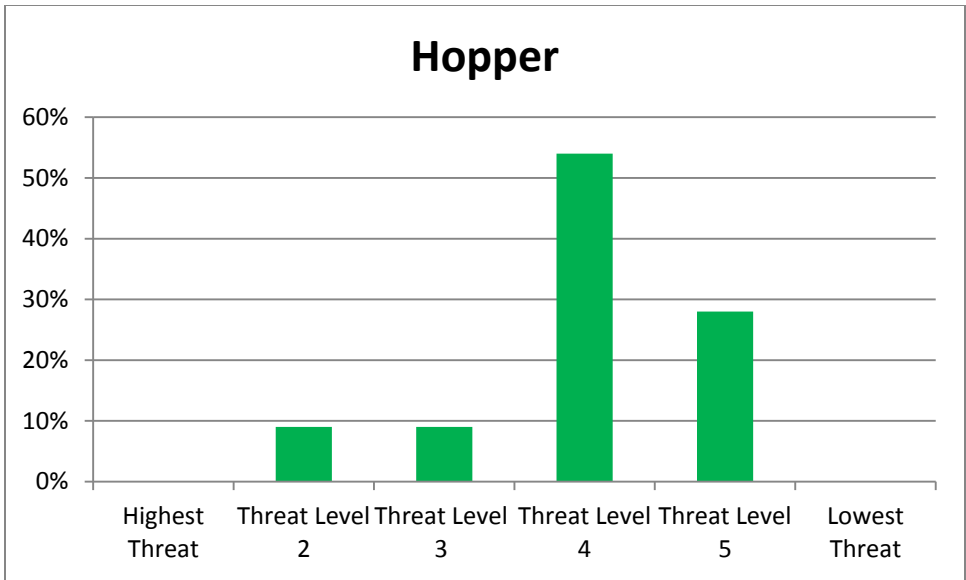
20% of respondents felt that van trailers presented the highest threat when transporting Tier 1 HSSM's. 37% felt that the van trailer was the second highest threat, 29% the third highest threat, 11% the fourth highest, 3% the fifth highest threat and 0% felt that a van trailer posed the lowest threat.



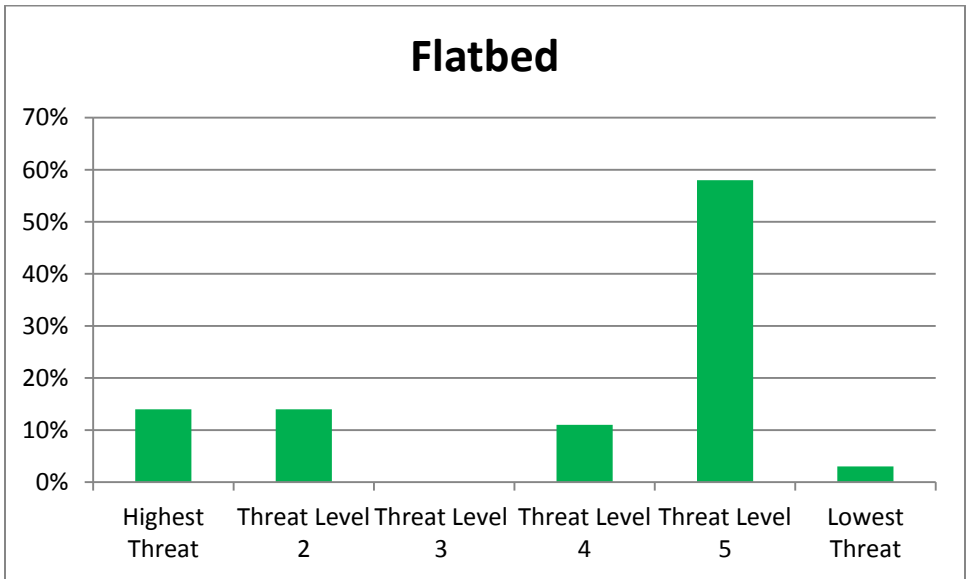
52% of respondents felt that cargo tanks presented the highest threat when transporting Tier 1 HSSM's. 17% felt that the van trailer was the second highest threat, 20% the third highest threat, 11% the fourth highest, 0% the fifth highest threat, and 0% felt that a cargo tank posed the lowest threat.



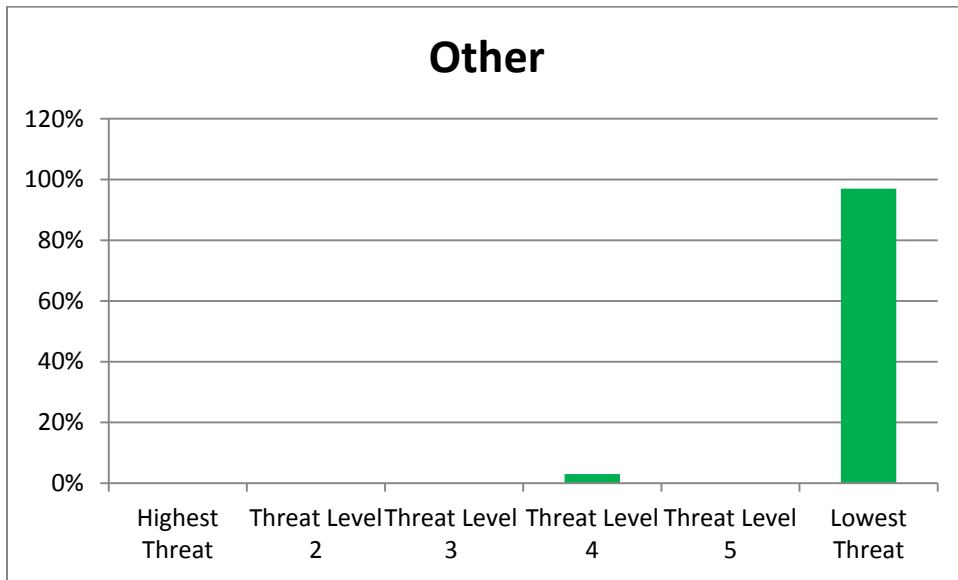
14% of respondents felt that containers presented the highest threat when transporting Tier 1 HSSM's. 23% felt that the van trailer was the second highest threat, 43% the third highest threat, 9% the fourth highest, 11% the fifth highest threat, and 0% felt that a van trailer posed the lowest threat.



0% of respondents felt that hoppers presented the highest threat when transporting Tier 1 HSSM's. 9% felt that the van trailer was the second highest threat, 9% the third highest threat, 54% the fourth highest, 28% the fifth highest threat, and 0% felt that a hopper posed the lowest threat.



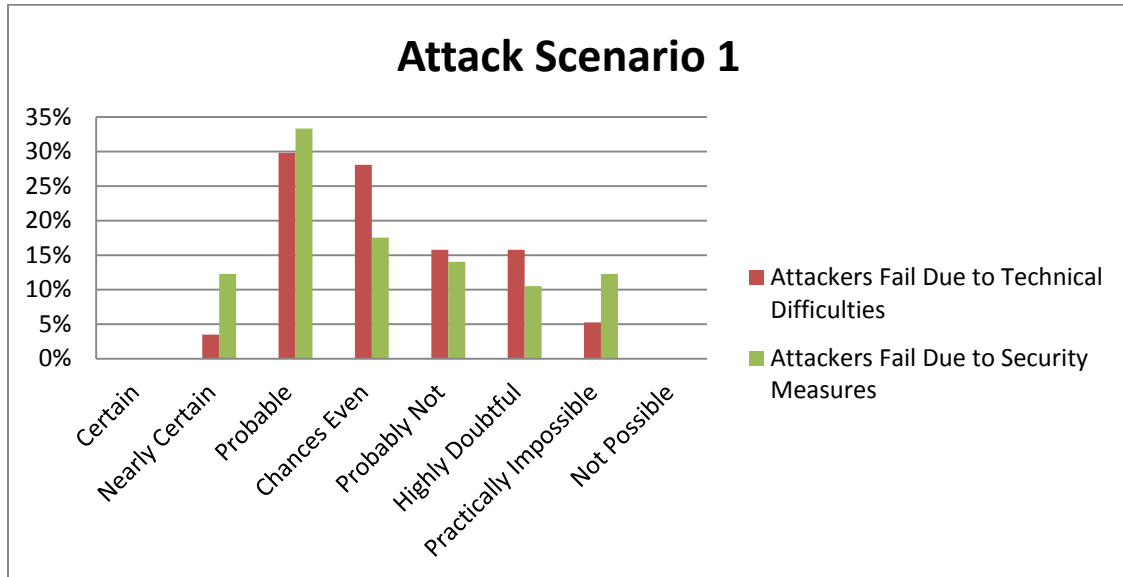
14% of respondents felt that flatbeds presented the highest threat when transporting Tier 1 HSSM's. 14% felt that the van trailer was the second highest threat, 0% the third highest threat, 11% the fourth highest, 58% the fifth highest threat and 3% felt that a flatbed posed the lowest threat.



0% of respondents felt that the other category presented the highest threat when transporting Tier 1 HSSM's. 0% felt that the van trailer was the second highest threat, 0% the third highest threat, 0% the fourth highest, 3% the fifth highest threat and 97% felt that other types not listed posed the lowest threat.

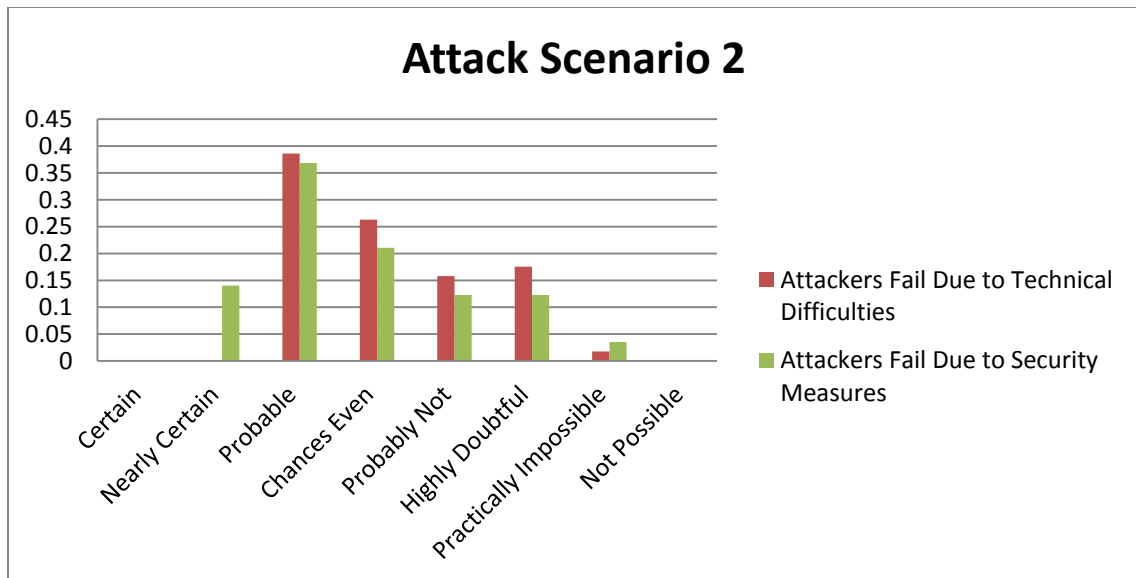


**Section 3: Probability of attackers failing on specific scenarios due to technical difficulties or security measures**



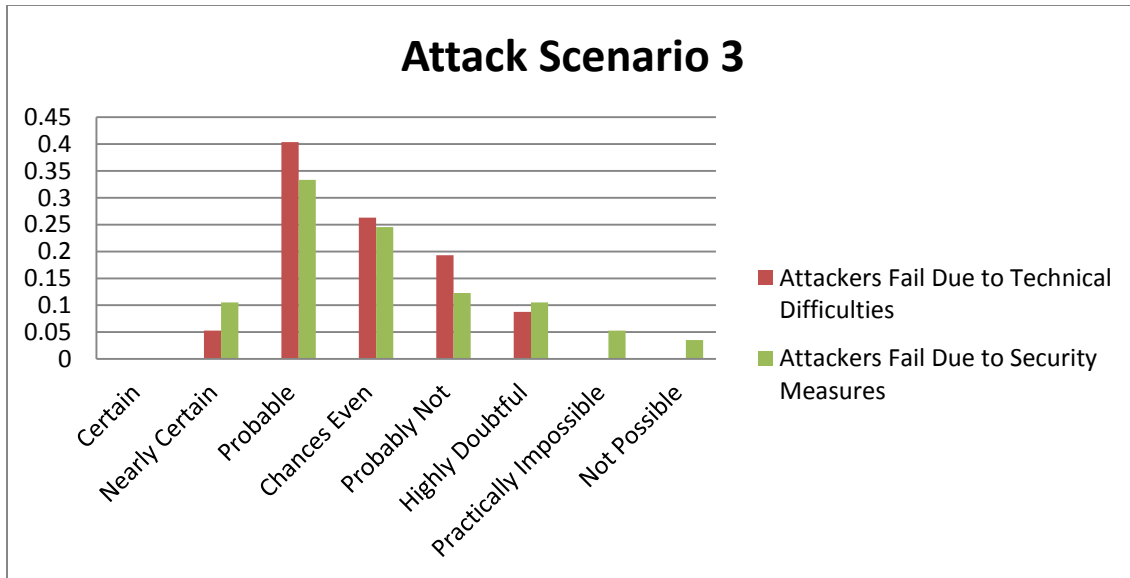
Attack Scenario 1 outlined a scenario wherein an explosive device was placed on a CMV. The hazmat type was Class 1 explosives, which were placed on a van trailer. 4% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 30% felt that failure due to technical difficulties was probable, 28% felt that chances were even, 16% felt that the attack would probably not fail due to technical difficulties, 16% felt that it was highly doubtful the attack would fail due to technical difficulties, and 5% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 12% felt that it was nearly certain the attack would fail. 33% felt it was probable the attack would fail due to security measures, 18% felt chances were even, 14% felt that the attack would probably not fail due to security measures, 11% felt that it was highly doubtful the attack would fail due to security measures, and 12% felt it was practically impossible for the attack to fail due to security measures.



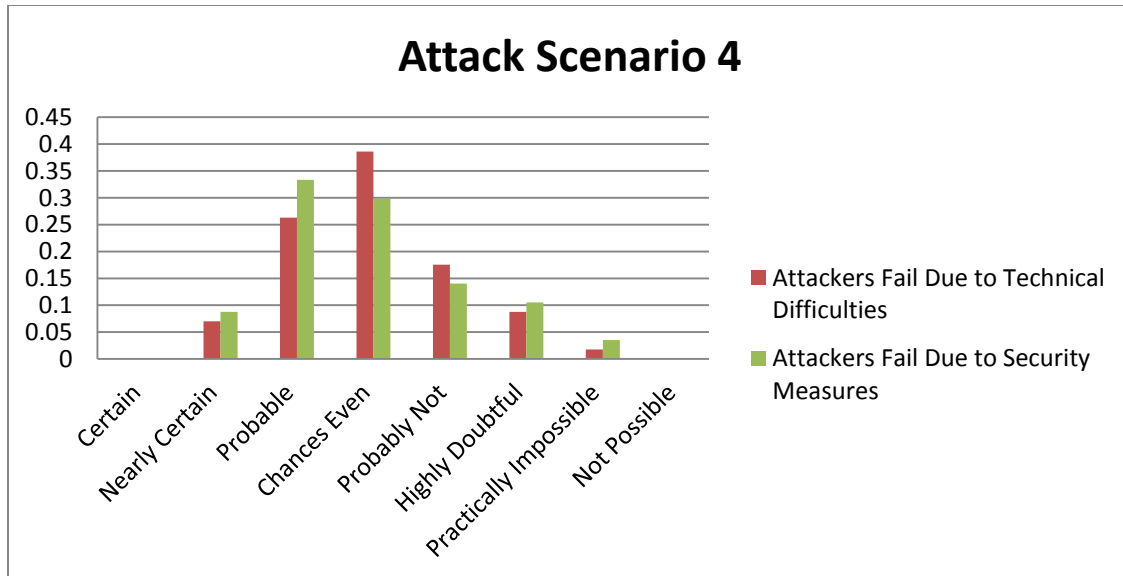
Attack Scenario 2 outlined a scenario wherein an explosive device was placed on a CMV. The hazmat type was Class 1 explosives, which were placed in a container. 0% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 39% felt that failure due to technical difficulties was probable, 26% felt that chances were even, 16% felt that the attack would probably not fail due to technical difficulties, 18% felt that it was highly doubtful the attack would fail due to technical difficulties, and 2% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 14% felt that it was nearly certain the attack would fail. 37% felt it was probable the attack would fail due to security measures, 21% felt chances were even, 12% felt that the attack would probably not fail due to security measures, 12% felt that it was highly doubtful the attack would fail due to security measures, and 4% felt it was practically impossible for the attack to fail due to security measures.



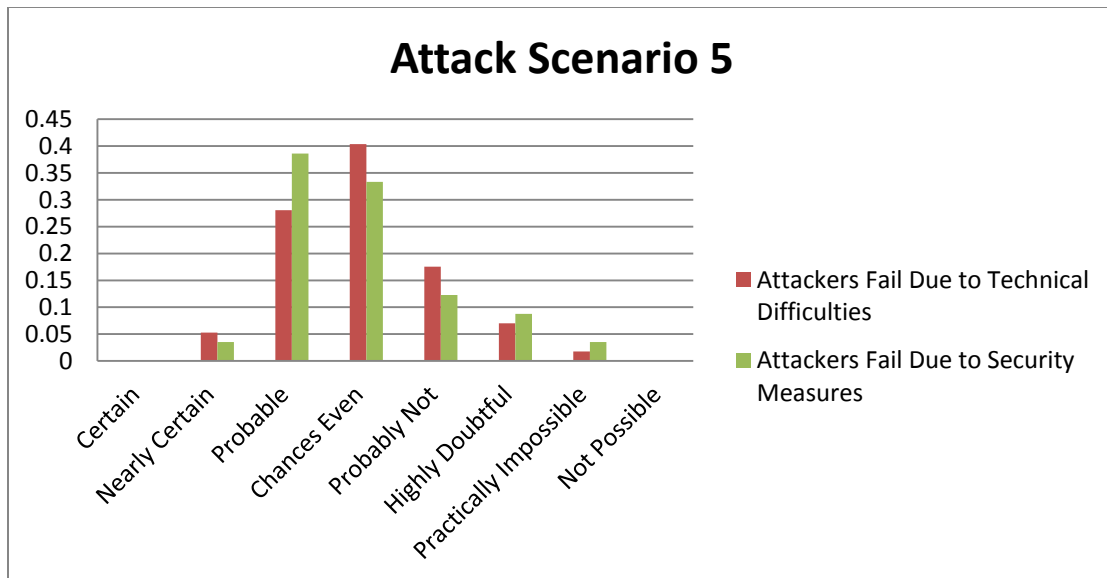
Attack Scenario 3 outlined a scenario wherein an explosive device was placed on a CMV. The hazmat type was Class 2 Gases that are non-flammable and toxic, which were placed in a van trailer. 5% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 40% felt that failure due to technical difficulties was probable, 26% felt that chances were even, 19% felt that the attack would probably not fail due to technical difficulties, 9% felt that it was highly doubtful the attack would fail due to technical difficulties, and 0% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 11% felt that it was nearly certain the attack would fail. 33% felt it was probable the attack would fail due to security measures, 25% felt chances were even, 12% felt that the attack would probably not fail due to security measures, 11% felt that it was highly doubtful the attack would fail due to security measures, 4% felt it was practically impossible for the attack to fail due to security measures, and 4% felt that it was not possible for the attack to fail due to security measures.



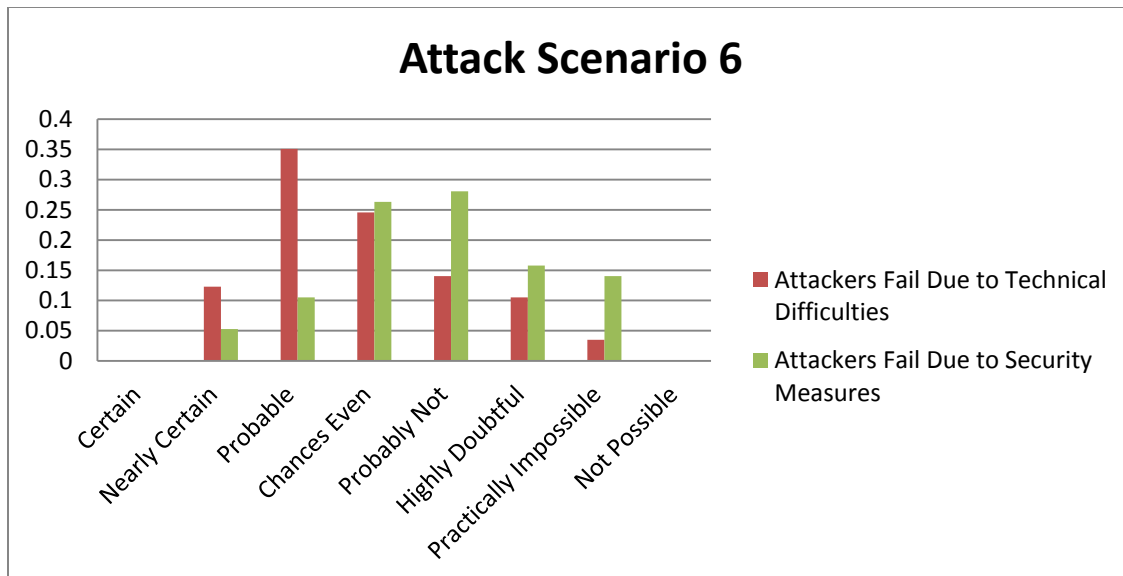
Attack Scenario 4 outlined a scenario wherein an explosive device was placed on a CMV. The hazmat type was Class 2 Gases that are non-flammable and toxic, which were placed in a cargo tank. 7% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 26% felt that failure due to technical difficulties was probable, 39% felt that chances were even, 18% felt that the attack would probably not fail due to technical difficulties, 9% felt that it was highly doubtful the attack would fail due to technical difficulties, and 2% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 9% felt that it was nearly certain the attack would fail. 33% felt it was probable the attack would fail due to security measures, 30% felt chances were even, 14% felt that the attack would probably not fail due to security measures, 11% felt that it was highly doubtful the attack would fail due to security measures, and 4% felt it was practically impossible for the attack to fail due to security measures.



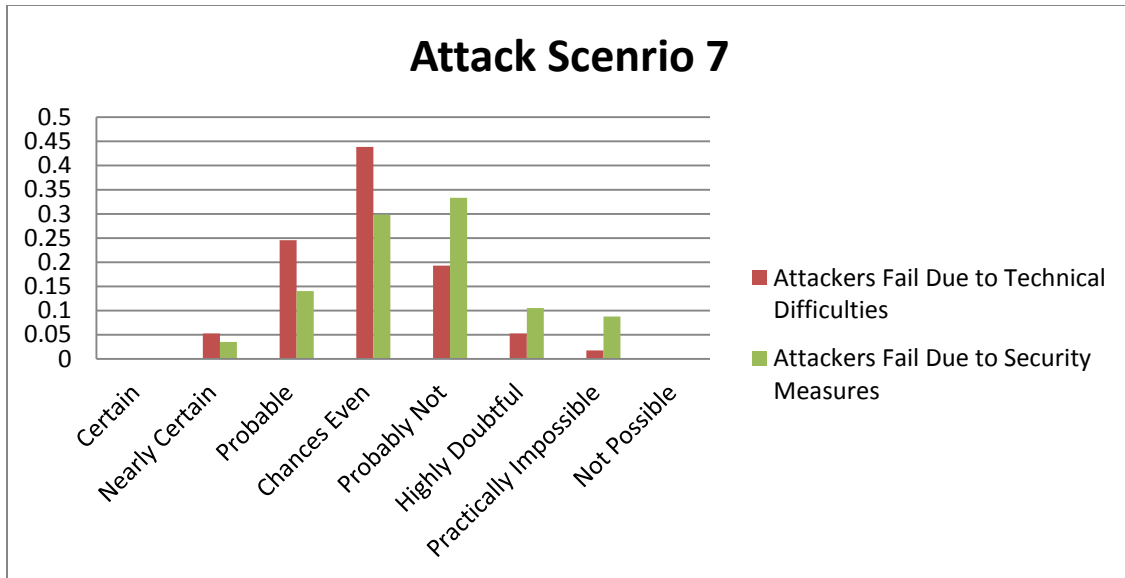
Attack Scenario 5 outlined a scenario wherein an explosive device was placed on a CMV. The hazmat type was Class 2 Gases that are non-flammable and toxic, which were placed in a container. 5% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 28% felt that failure due to technical difficulties was probable, 40% felt that chances were even, 18% felt that the attack would probably not fail due to technical difficulties, 7% felt that it was highly doubtful the attack would fail due to technical difficulties, and 2% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 12% felt that it was nearly certain the attack would fail. 35% felt it was probable the attack would fail due to security measures, 25% felt chances were even, 14% felt that the attack would probably not fail due to security measures, 11% felt that it was highly doubtful the attack would fail due to security measures, and 4% felt it was practically impossible for the attack to fail due to security measures.



Attack Scenario 6 outlined a scenario wherein an explosive device was placed along the planned route of a CMV transporting hazardous materials. The hazmat type was Class 1 explosives, which were placed in a van trailer. 12% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 35% felt that failure due to technical difficulties was probable, 25% felt that chances were even, 14% felt that the attack would probably not fail due to technical difficulties, 11% felt that it was highly doubtful the attack would fail due to technical difficulties, and 4% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 5% felt that it was nearly certain the attack would fail. 11% felt it was probable the attack would fail due to security measures, 26% felt chances were even, 28% felt that the attack would probably not fail due to security measures, 16% felt that it was highly doubtful the attack would fail due to security measures, and 14% felt it was practically impossible for the attack to fail due to security measures.

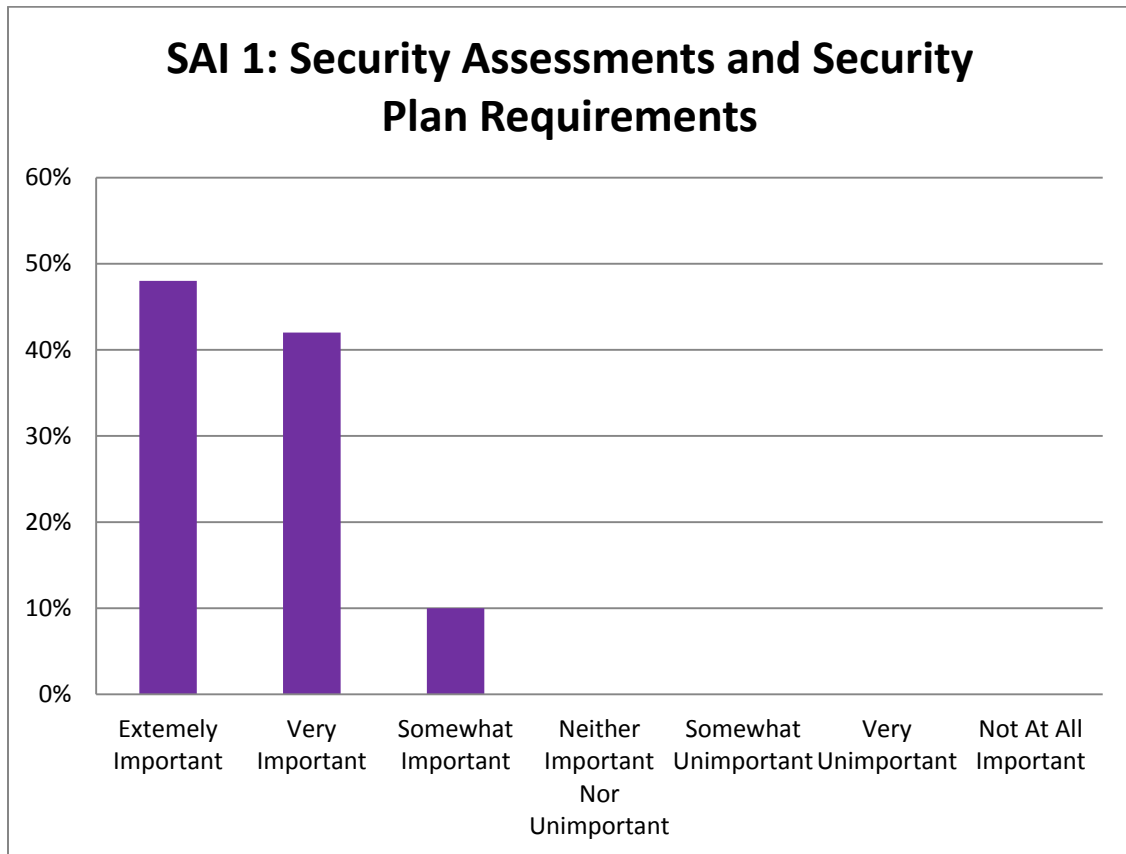


Attack Scenario 7 outlined a scenario wherein an explosive device was placed along the planned route of a CMV transporting hazardous materials. The hazmat type was Class 1 explosives, which were placed in a container. 5% of respondents felt that it was nearly certain that attackers would fail due to technical difficulties. 25% felt that failure due to technical difficulties was probable, 44% felt that chances were even, 19% felt that the attack would probably not fail due to technical difficulties, 5% felt that it was highly doubtful the attack would fail due to technical difficulties, and 2% felt that it was practically impossible for the attack to fail due to technical difficulties.

In relation to attackers failing due to security measures, 4% felt that it was nearly certain the attack would fail. 14% felt it was probable the attack would fail due to security measures, 30% felt chances were even, 33% felt that the attack would probably not fail due to security measures, 11% felt that it was highly doubtful the attack would fail due to security measures, and 9% felt it was practically impossible for the attack to fail due to security measures.

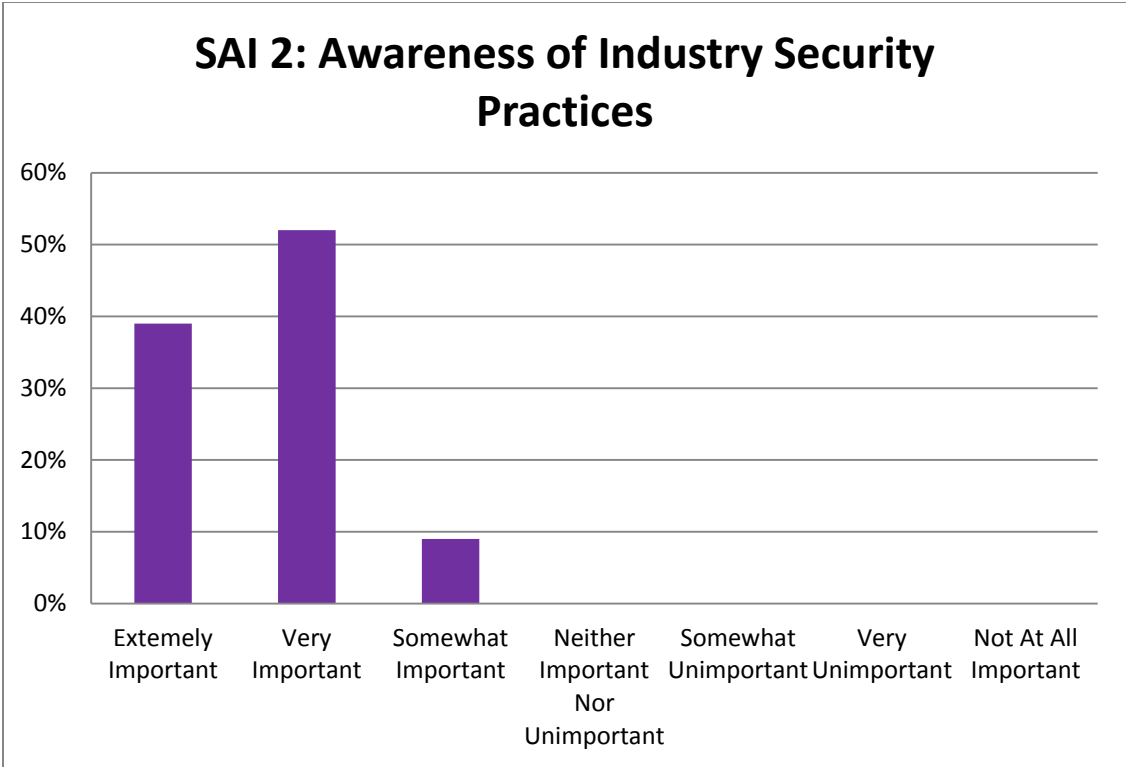
#### Section 4: The Transportation Security Administration’s Security Action Items

Survey participants were presented with the Transportation Security Administrations Security Action Items (SAIs). Survey participants examined each of the 23 SAIs and ranked them according to importance in securing the United States Tier 1 HSSM supply chain. Ranking ranged from Extremely Important to Not At All Important. Only 33% of the respondents were familiar with the SAIs. However the description provided enabled them to answer the questions surrounding the relevance of each SAI.

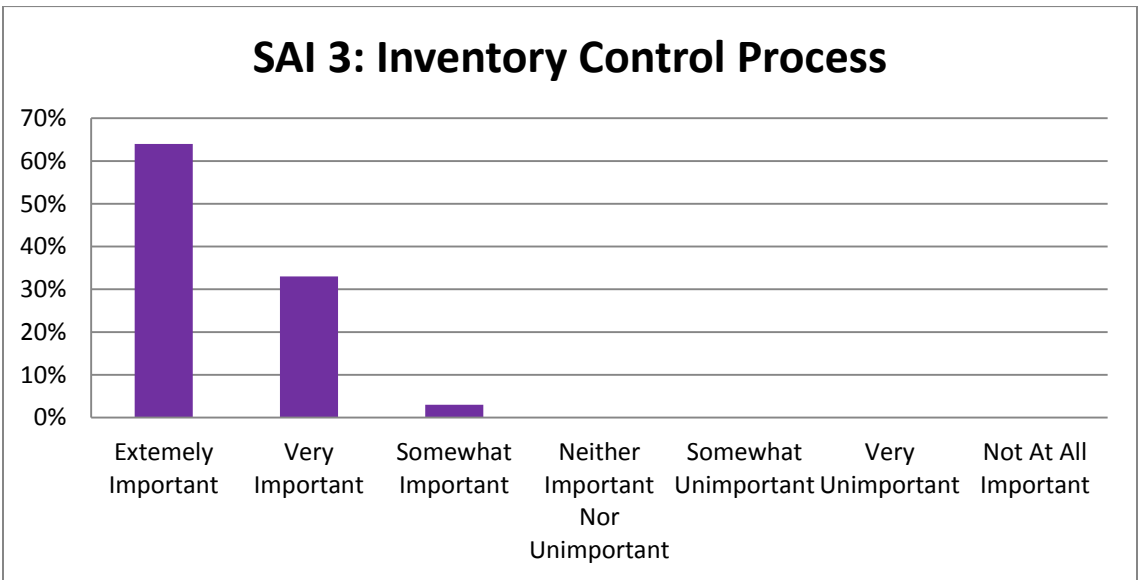


SAI 1 is titled Security Assessments and Security Plan Requirements. It suggests that employers should review their security assessment and determine the security action items which are appropriate to correct their assessed risks. 48% of survey respondents ranked this as extremely important, 42% as very important and 10% as somewhat important.

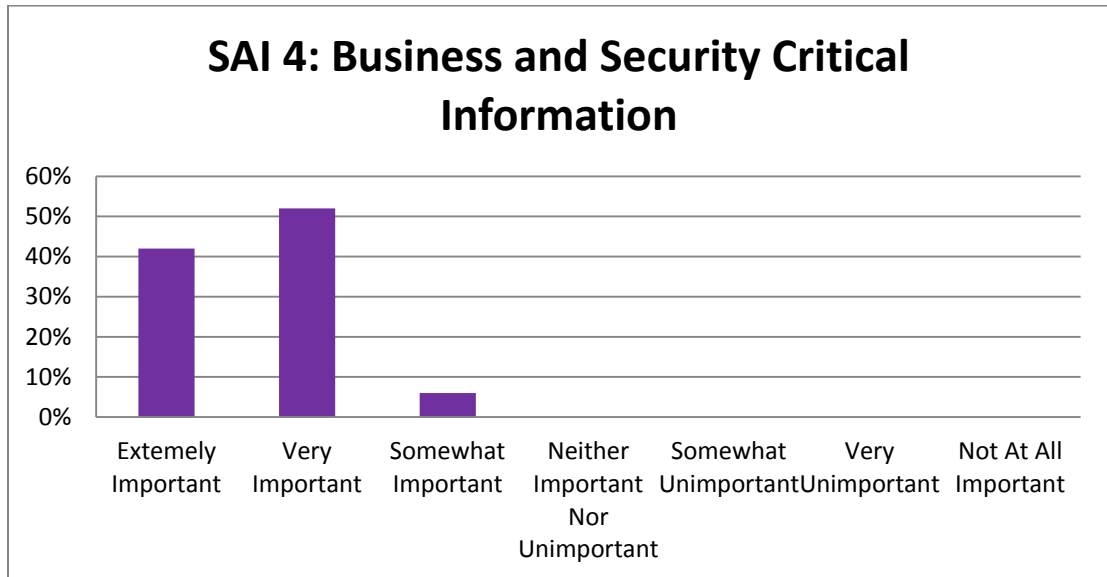




SAI 2 is titled Awareness of Industry Security Practices. It suggests that employers should be familiar with security practices recommended by industry groups and trade associations to further enhance transportation security. 39% of survey respondents ranked this as extremely important, 52% as very important and 9% as somewhat important.

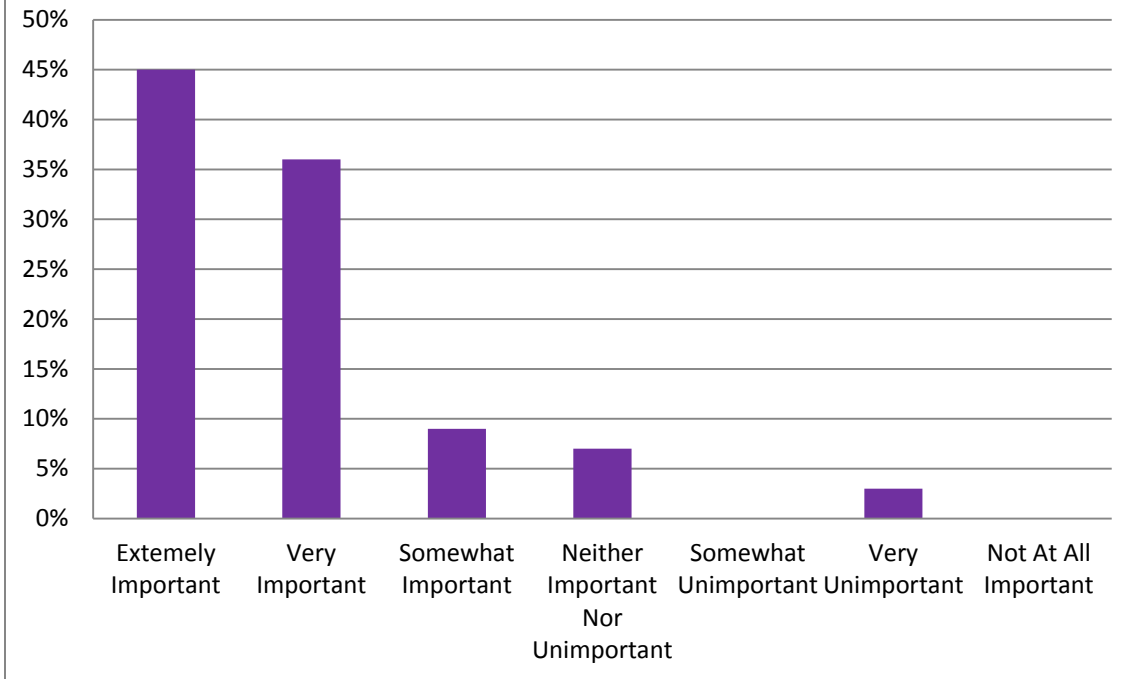


SAI 3 is titled Inventory Control Process. It suggests that employers should implement procedures to maintain accountability for their containers, cylinders and vehicles at all times while in transport throughout the supply chain. 64% of survey respondents ranked this as extremely important, 33% as very important and 3% as somewhat important.

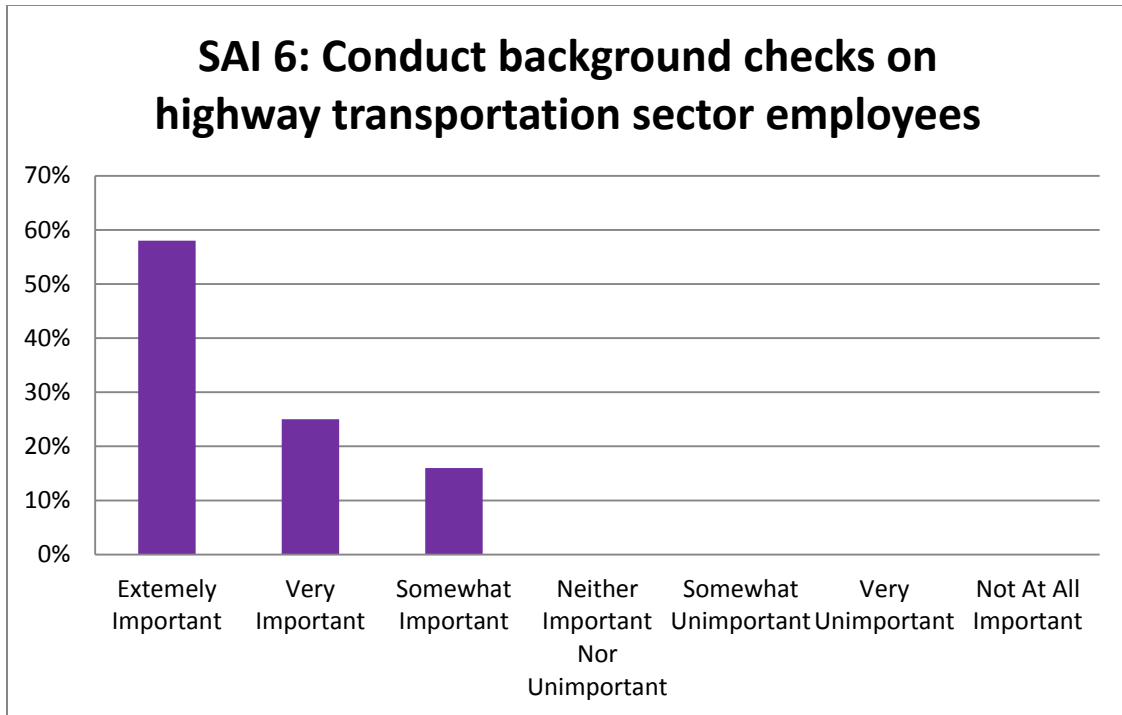


SAI 4 is titled Business and Security Critical Information. It suggests that employers should implement policies to protect security critical information. 42% of survey respondents ranked this as extremely important, 52% as very important and 6% as somewhat important.

### SAI 5: Possession of a Valid CMV Drivers License and Hazmat Endorsement

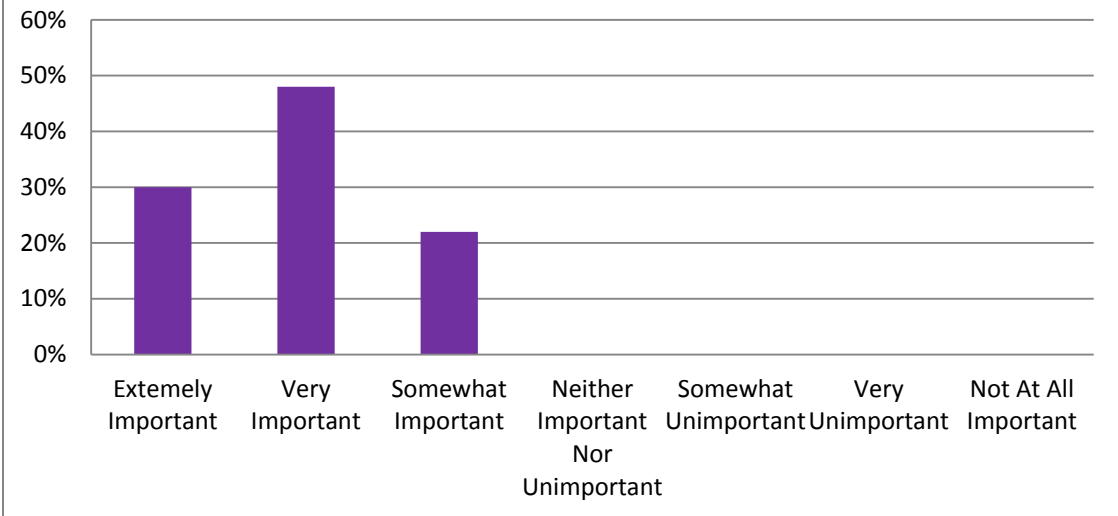


SAI 5 is titled Possession of a Valid CMV Driver’s License and hazardous materials endorsement. It indicates that all drivers should have a valid license and carry the hazmat endorsement. 45% of survey respondents ranked this as extremely important, 36% as very important, 9% as somewhat important, 7% as neither important nor unimportant, and 3% as very unimportant.



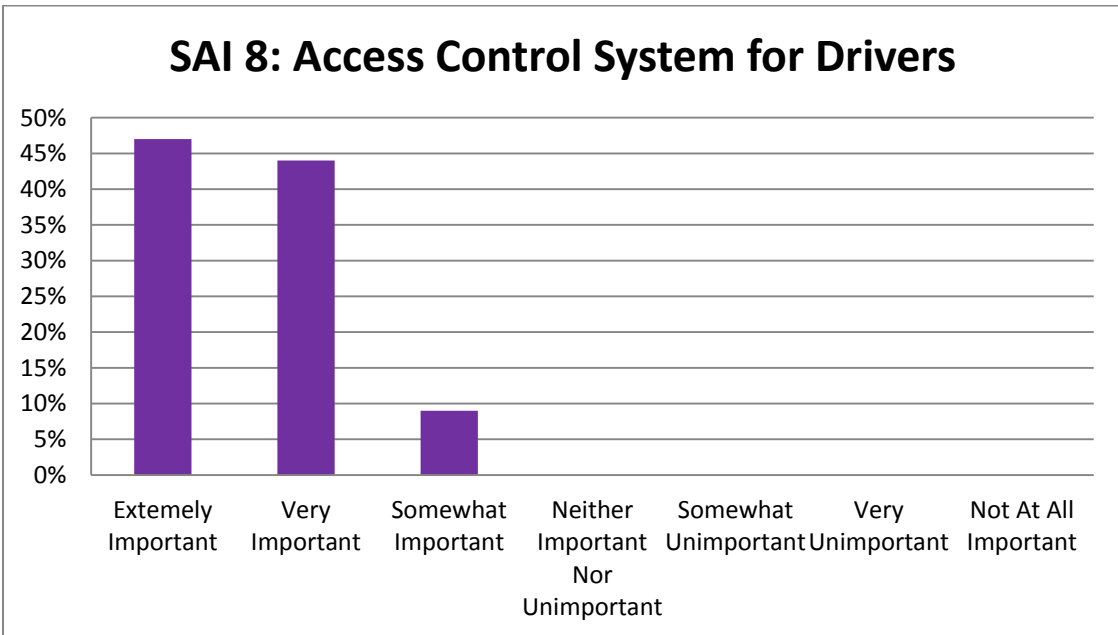
SAI 6 is titled Conduct background checks on highway transportation sector employees other than motor vehicle drivers with a valid CDL with Hazmat endorsement. It suggests that during the hiring process employers should conduct background checks on employees and contractors with unescorted access to motor vehicles, the motor carrier facility, or information critical to hazmat transportation. 58% of survey respondents ranked this as extremely important, 25% as very important and 16% as somewhat important.

### SAI 7: Security Awareness Training for Employees

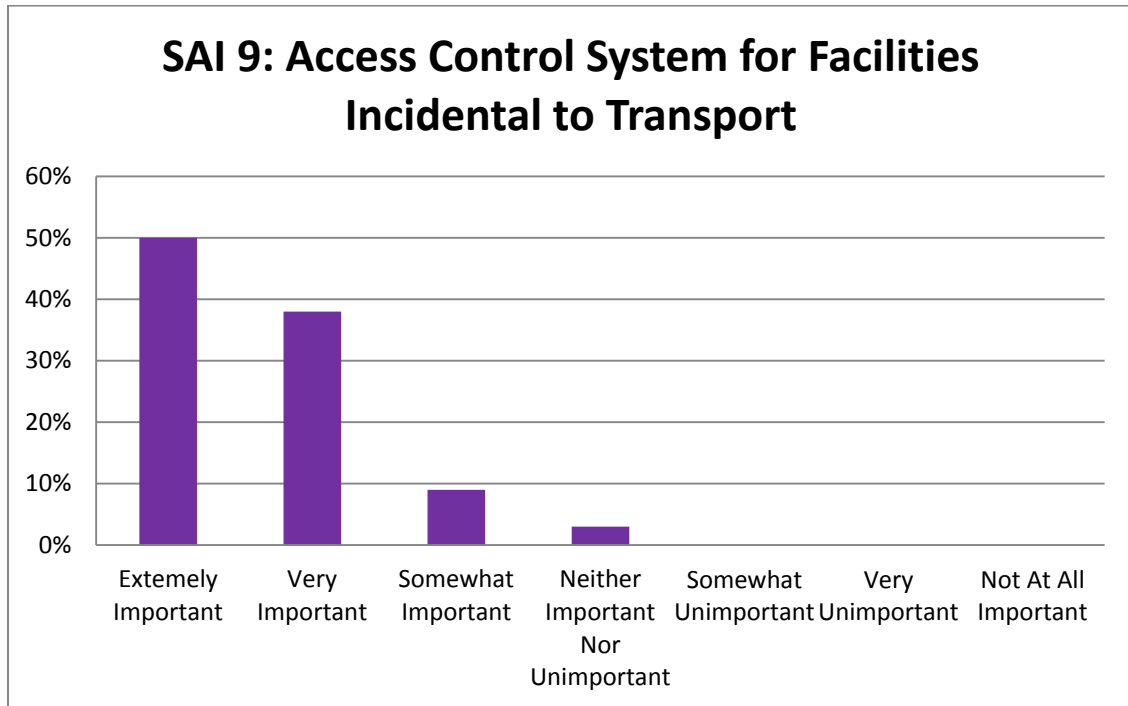


SAI 7 is titled Security Awareness Training for Employees. It suggests that employers should have employees complete TSA-sponsored domain awareness training or equivalent security training programs. 30% of survey respondents ranked this as extremely important, 48% as very important and 22% as somewhat important.

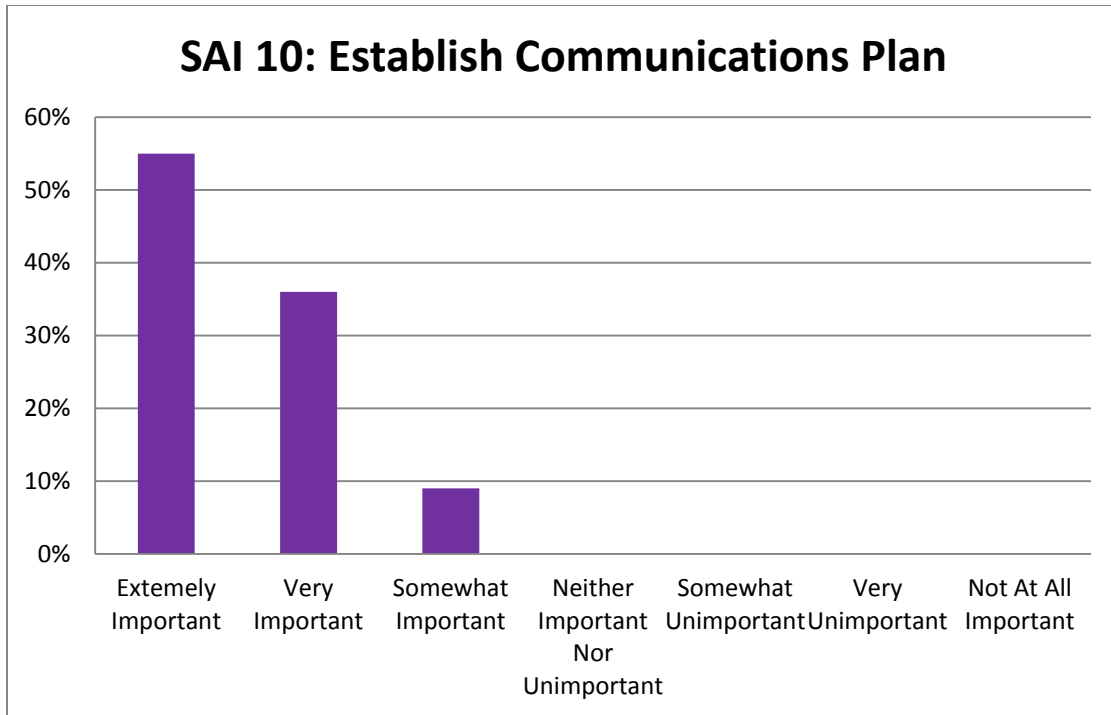
### SAI 8: Access Control System for Drivers



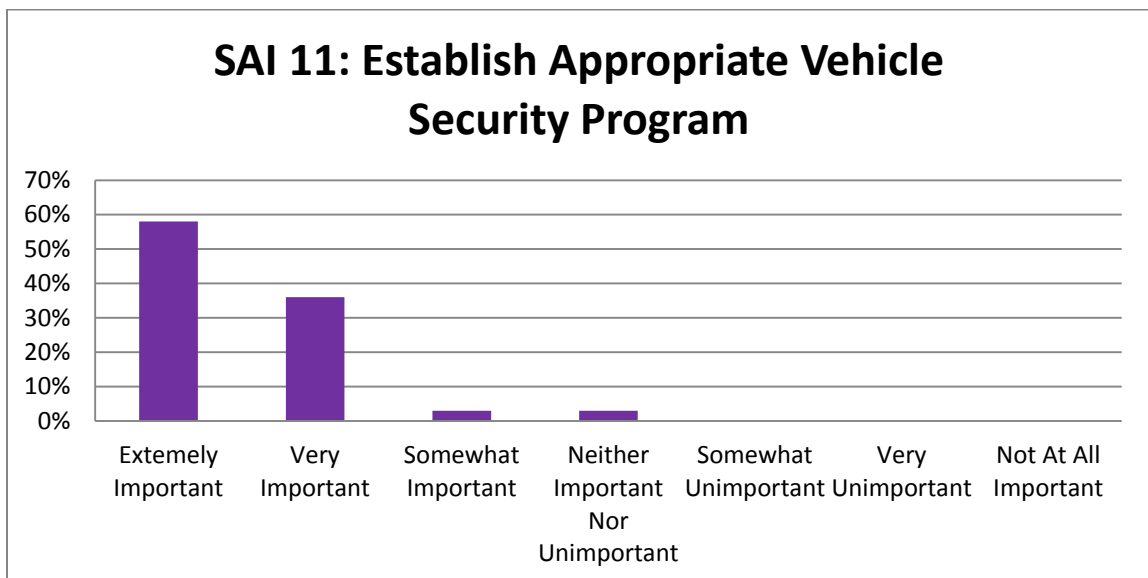
SAI 8 is titled Access Control System for Drivers. It suggests that employers should implement an access control system that includes company ID's for shippers/consignee confirmation, as well as for access to restricted areas such as the key control room. 47% of survey respondents ranked this as extremely important, 44% as very important and 9% as somewhat important.



SAI 9 is titled Access Control System for Facilities Incidental to Transport. It suggests that employers should implement access control systems in restricted areas including plants, data centers and IT systems, loading and unloading facilities, storage facilities, and other critical areas as designated by company management. 50% of survey respondents ranked this as extremely important, 38% as very important, 9% as somewhat important, and 3% felt it was neither important nor unimportant.

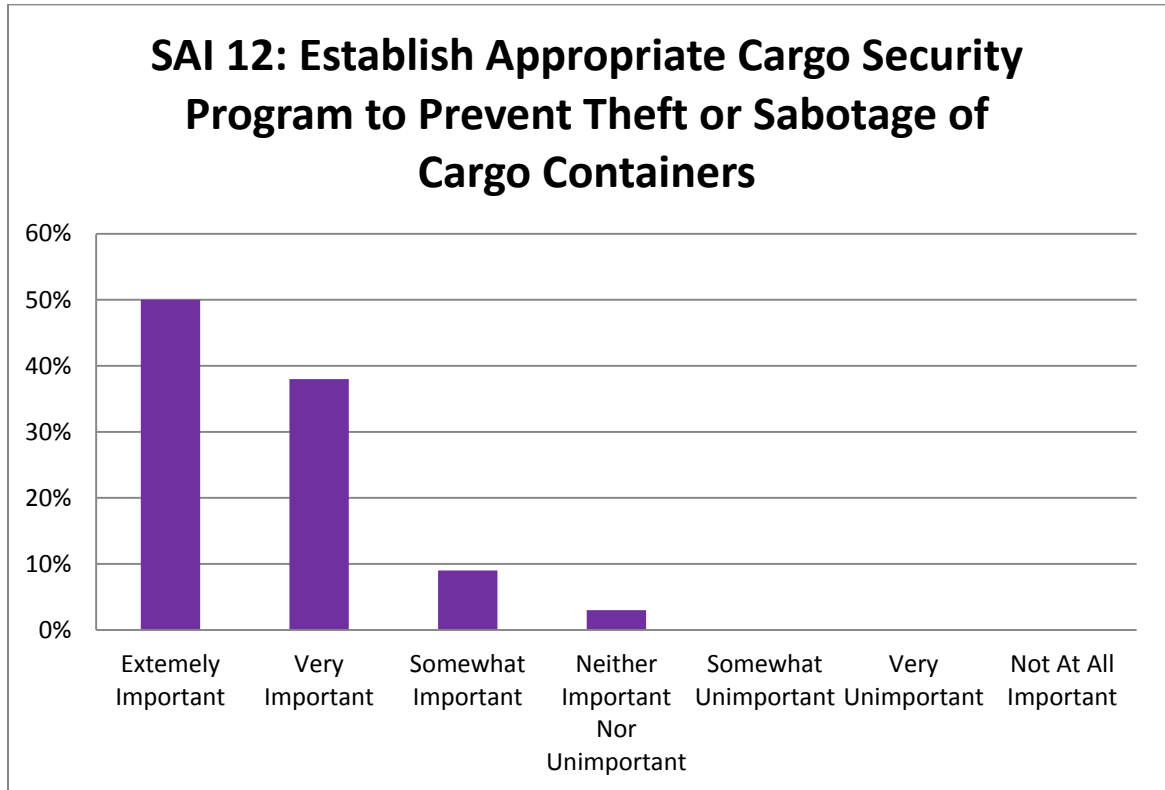


SAI 10 is titled Establish Communications Plan. It suggests that a communications plan should exist between drivers, company personnel and emergency professionals in the event of an incident. 55% of survey respondents ranked this as extremely important, 36% as very important and 9% as somewhat important.



SAI 11 is titled Establish Appropriate Vehicle Security Program. It suggests that employers should ensure that all company vehicles are secured when unattended

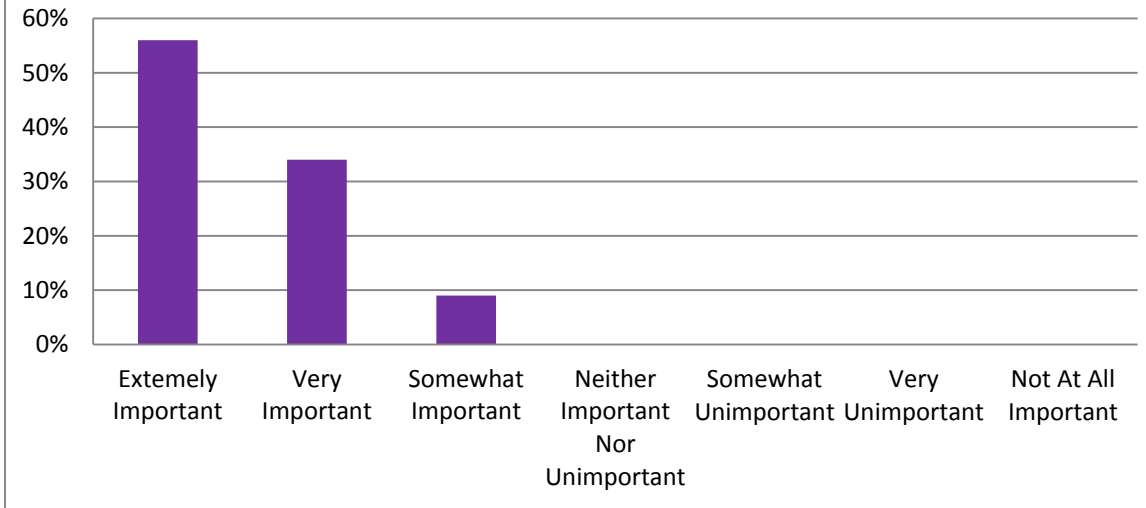
through use of a primary and secondary security system. 58% of survey respondents ranked this as extremely important, 36% as very important, 3% as somewhat important, and 3% as neither important nor unimportant.



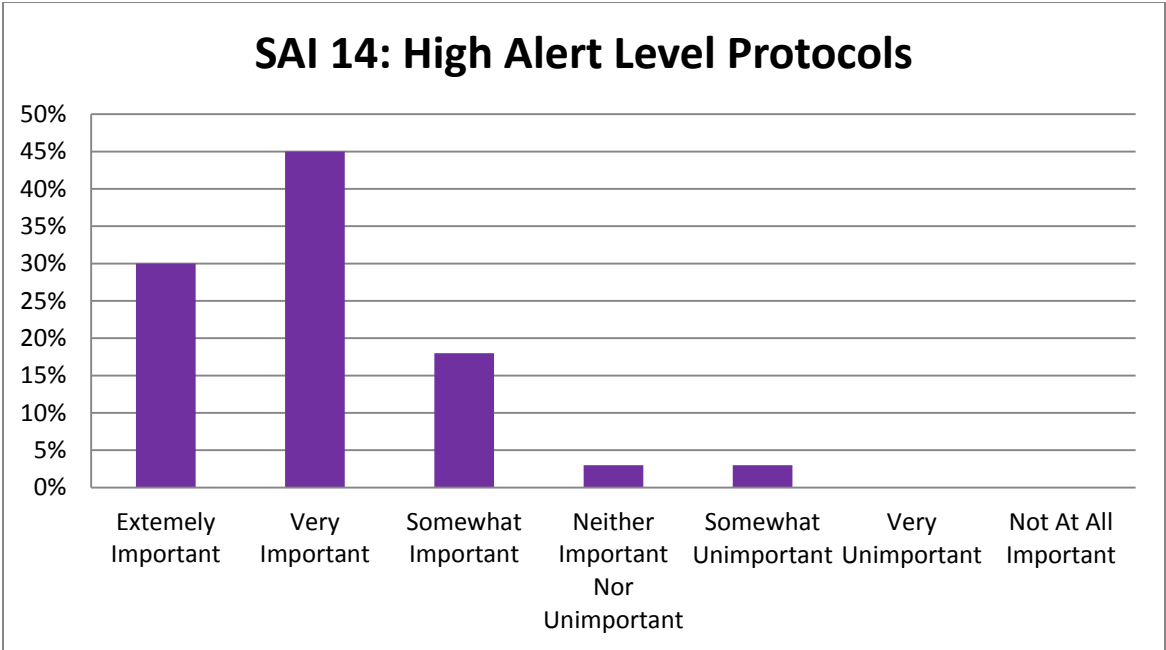
SAI 12 is titled Establish Appropriate Cargo Security Program to Prevent Theft or Sabotage of Cargo Containers. It suggests that employers should ensure that all cargo containers are secured when in use and that a primary and secondary security system protects them when they are left unattended. 50% of survey respondents ranked this as extremely important, 38% as very important, 9% as somewhat important, and 3% as neither important nor unimportant.



### SAI 13: Implement a Seal/Lock Control Program to Prevent Theft or Sabotage of Cargo

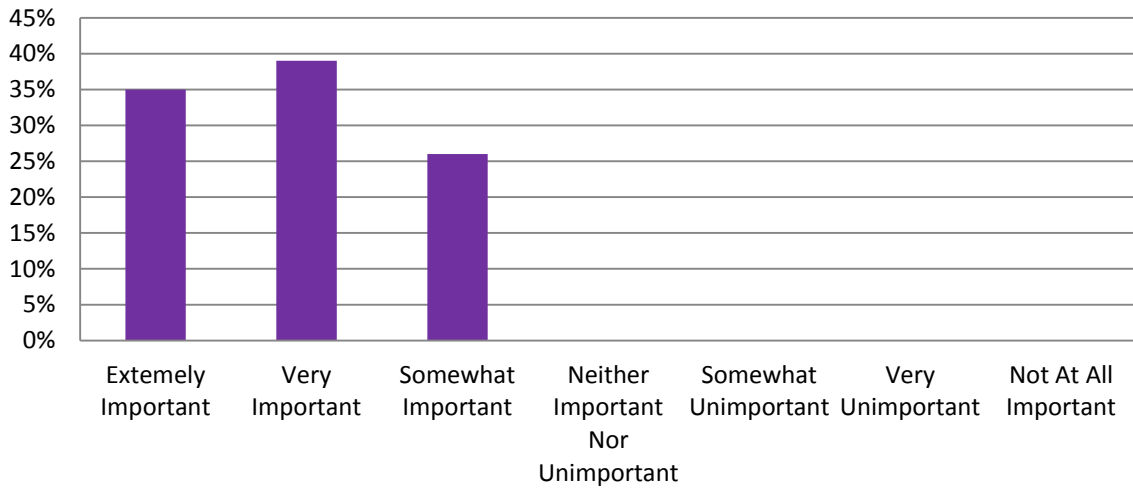


SAI 13 is titled Implement a Seal/Lock Control Program to Prevent Theft or Sabotage of Cargo. It suggests that employers should implement a seal/lock program to prevent theft or sabotage of the contents of cargo containers and cylinders when in transport, when unattended by company personnel, or when at facilities incidental to transport. 56% of survey respondents ranked this as extremely important, 34% as very important and 9% as somewhat important.



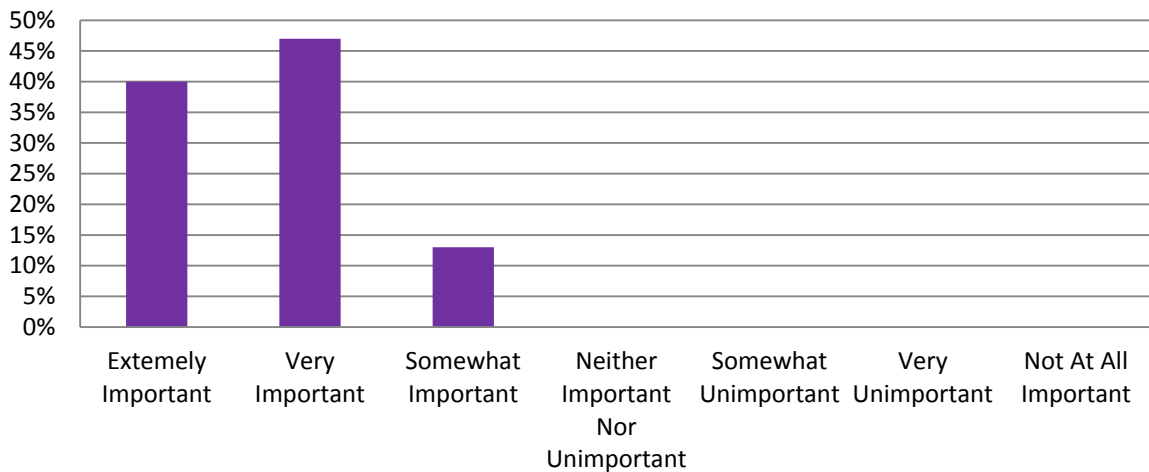
SAI 14 is titled High Alert Level Protocols. It suggests that employers should establish policies that govern operations during periods of elevated threat conditions under the Homeland Security Advisory System. For example, secure locations to seek refuge or local law enforcement escorts. 30% of survey respondents ranked this as extremely important, 45% as very important, 18% as somewhat important, 3% as neither important nor unimportant, and 3% as somewhat unimportant.

### SAI 15: Establish Security Inspection Policy and Procedure

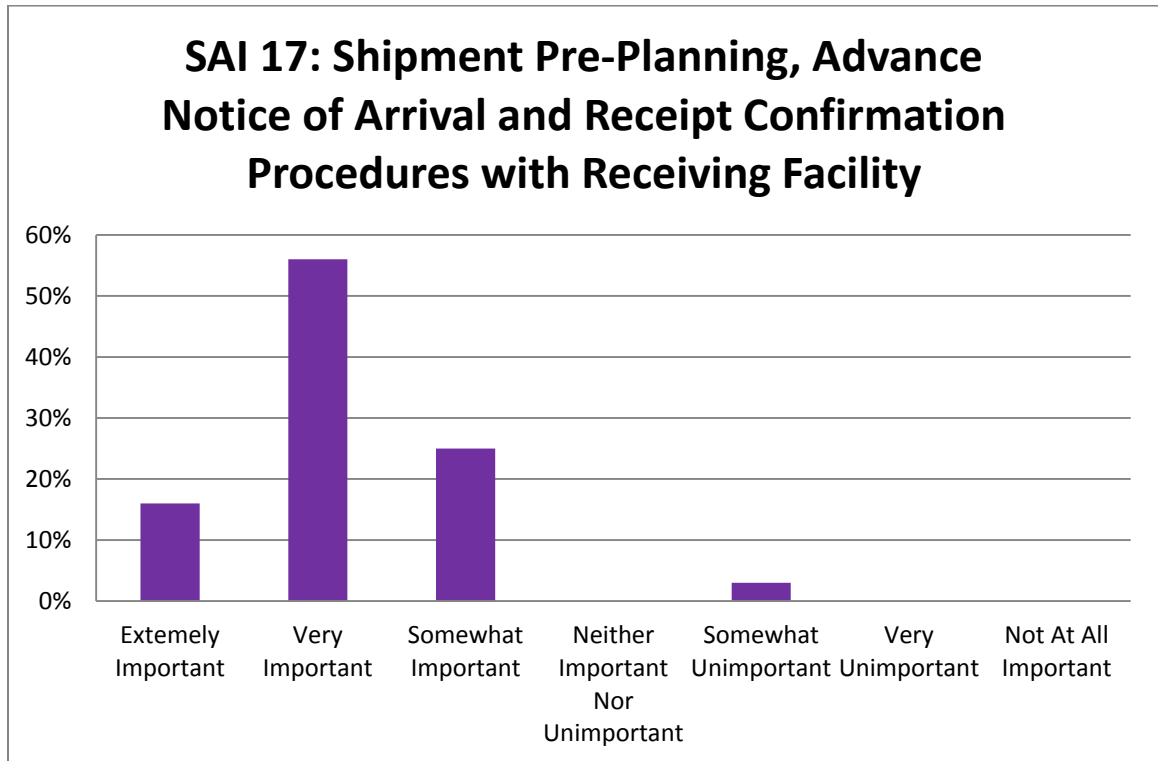


SAI 15 is titled Establish Security Inspection Policy and Procedure. It suggests that employers should establish a security inspection policy as well as procedures drivers follow to conduct security inspections. 35% of survey respondents ranked this as extremely important, 39% as very important and 26% as somewhat important.

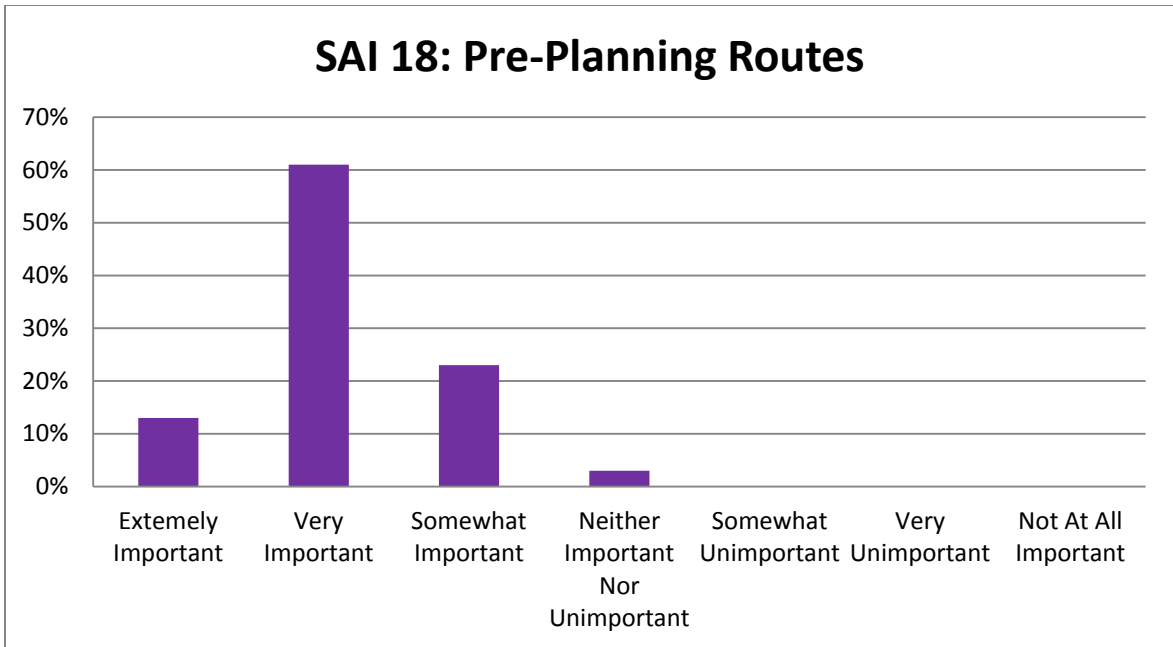
### SAI 16: Establish Reporting Policy and Procedures



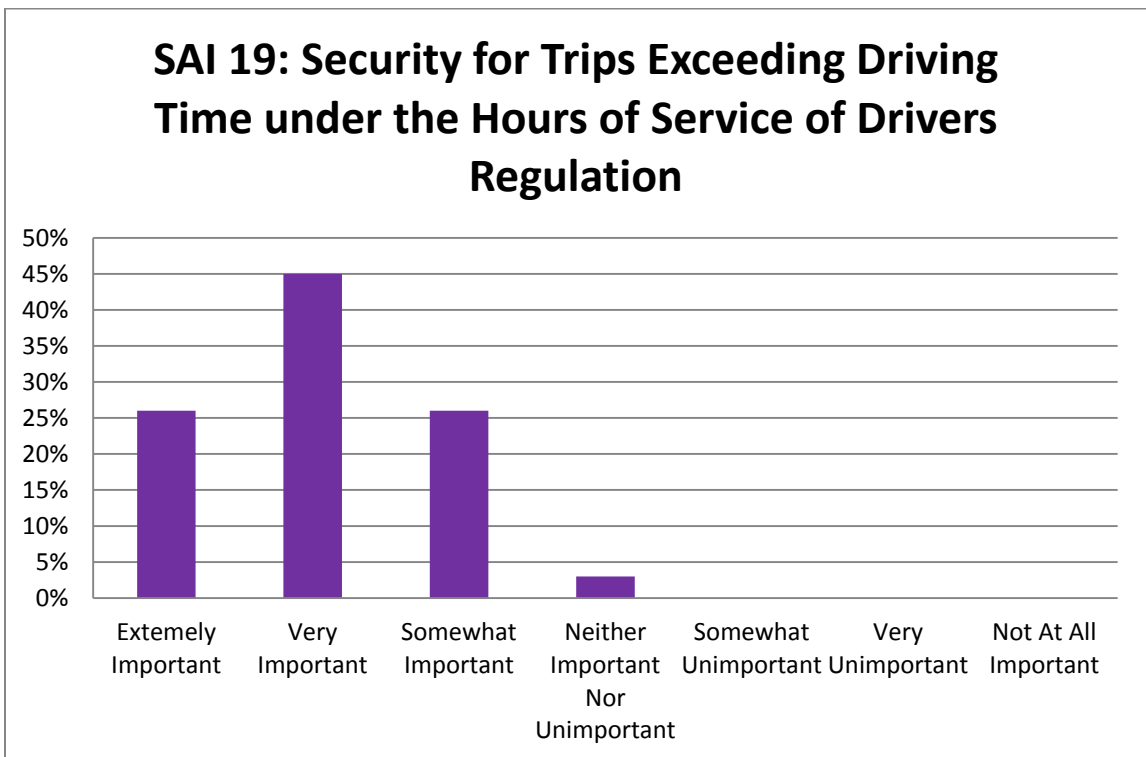
SAI 16 is titled Establish Reporting Policy and Procedures. It suggests that employers should implement reporting procedures that drivers and non-driver employees follow when reporting suspicious incidents, threats, or concerns regarding transportation facilities or company vehicles. 40% of survey respondents ranked this as extremely important, 47% as very important and 13% as somewhat important.



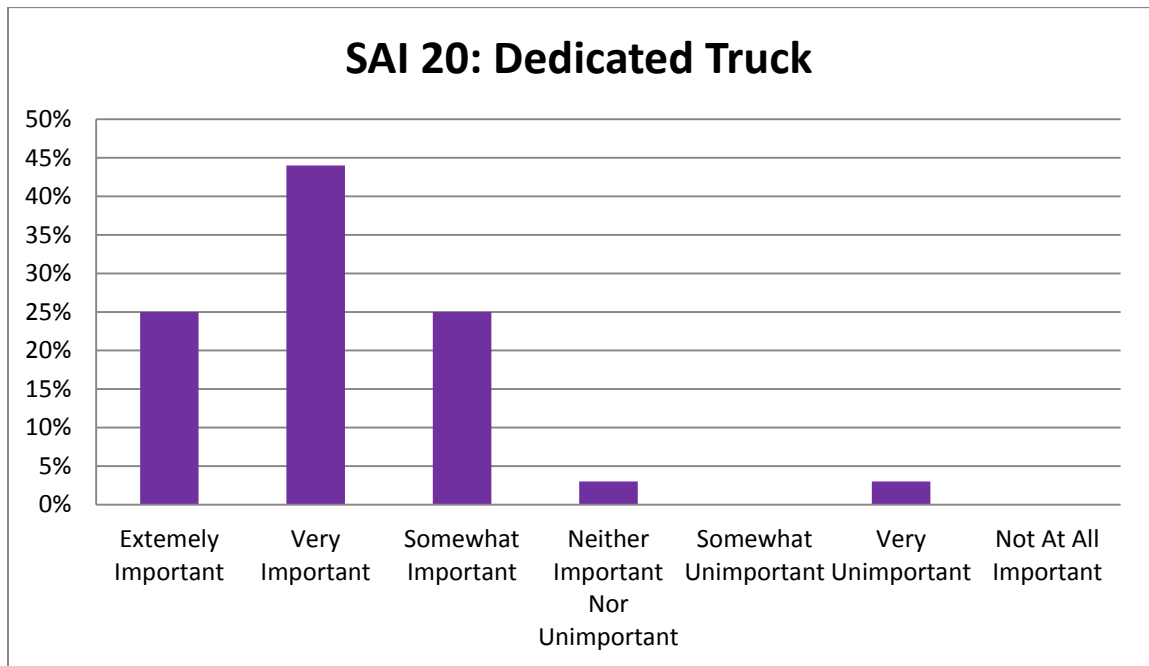
SAI 17 is titled Shipment Pre-Planning, Advance Notice of Arrival and Receipt Confirmation Procedures with Receiving Facility. It suggests that the shipper, carrier, and consignee should conduct shipment pre-planning to ensure shipments are not released to the motor carrier until they can be transported to the destination in a manner that minimizes public exposure and transit delays. 16% of survey respondents ranked this as extremely important, 56% as very important, 25% as somewhat important, and 3% as somewhat unimportant.



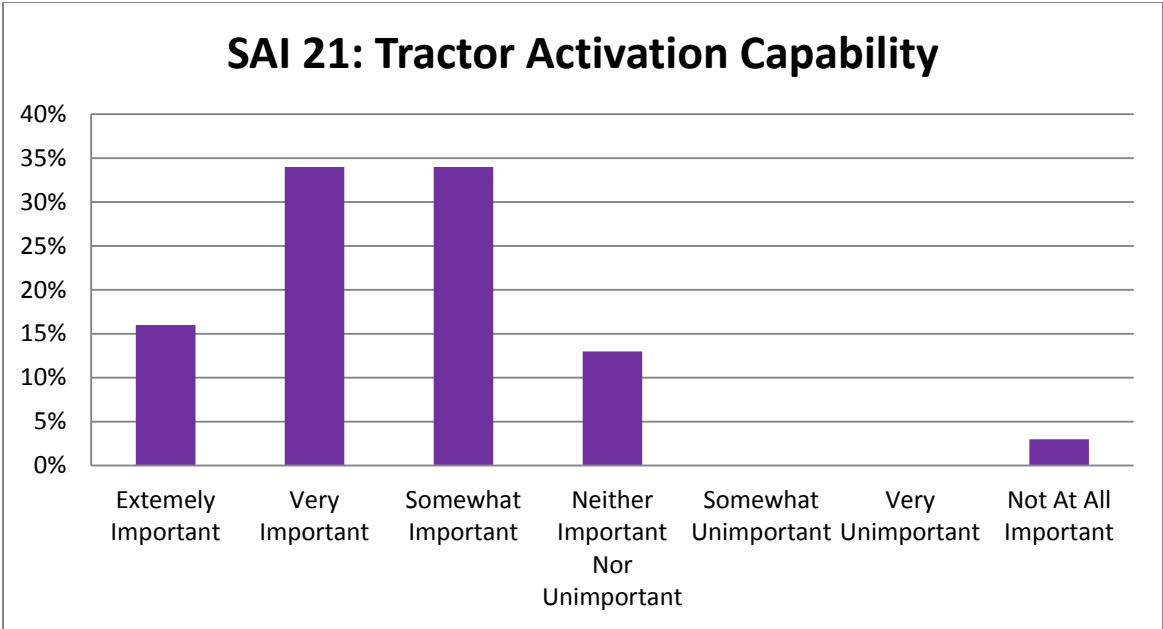
SAI 18 is titled Pre-Planning Routes. It suggests that employers should ensure pre-planning of primary and alternate routes takes place. 13% of survey respondents ranked this as extremely important, 61% as very important, 23% as somewhat important, and 3% as neither important nor unimportant.



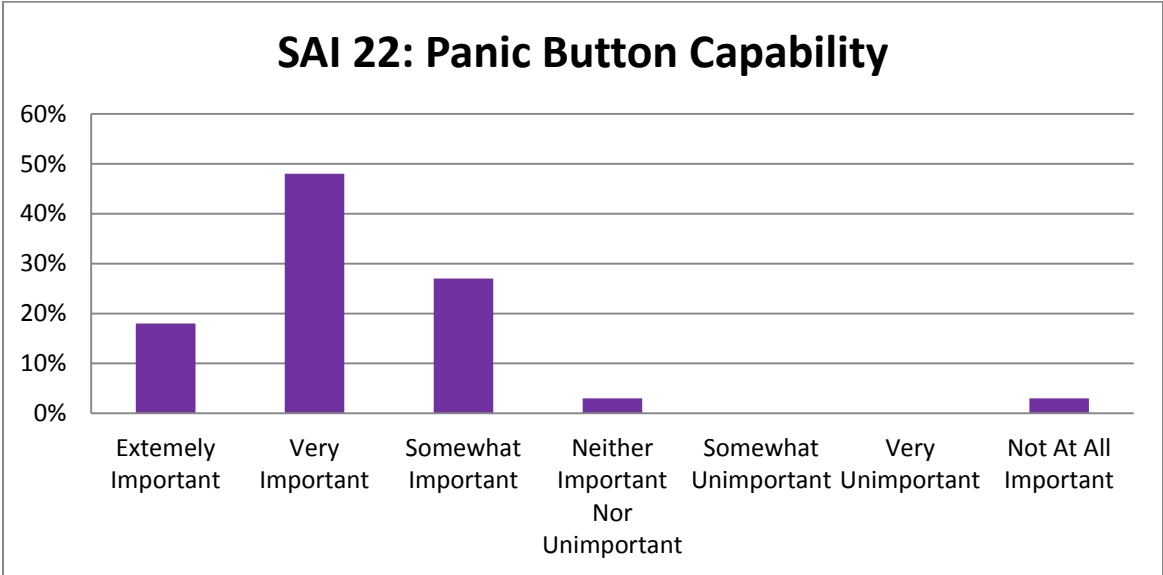
SAI 19 is titled Security for Trips Exceeding Driving Time under the Hours of Service of Drivers Regulation. It suggests that employers should examine security in light of hours of service available and take steps to mitigate the vulnerabilities associated with drivers' extended rest stops. 26% of survey respondents ranked this as extremely important, 45% as very important, 26% as somewhat important, and 3% as neither important nor unimportant.



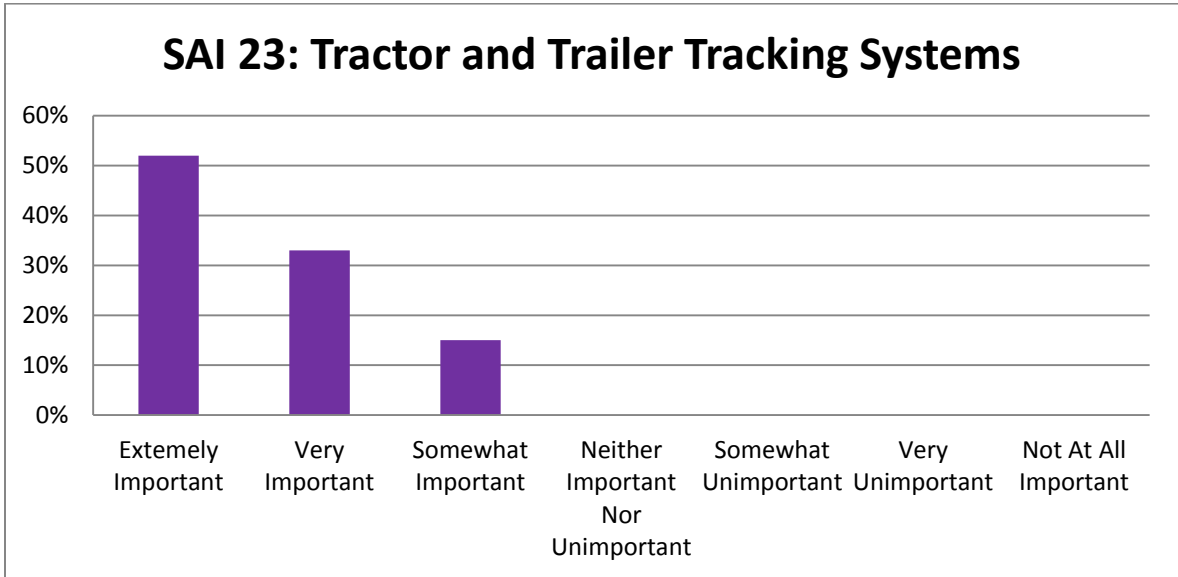
SAI 20 is titled Dedicated Truck. It suggests that employers should implement policies to ensure that, except under emergency circumstances, contracted shipments remain under the authority of the primary carrier and are not subcontracted, driver/team substitutions are not made, and transloading does not occur unless it has been verified that the subcontractor complies with applicable Federal safety and security guidance and regulations and company security policies. 25% of survey respondents ranked this as extremely important, 44% as very important, 25% as somewhat important, 3% as neither important nor unimportant and 3% as very unimportant.



SAI 21 is titled Tractor Activation Capability. It suggests that employers should implement security measures that authenticate driver identification via login and password, or biometric data to drive the vehicles and materials. 16% of survey respondents ranked this as extremely important, 34% as very important, 34% as somewhat important, 13% neither important nor unimportant, and 3% as not at all important.



SAI 22 is titled Panic Button Capability. It suggests that employers should implement means for a driver to transmit an emergency alert notification to dispatch. 18% of survey respondents ranked this as extremely important, 48% as very important, 27% as somewhat important, 3% as neither important nor unimportant and 3% as not at all important.



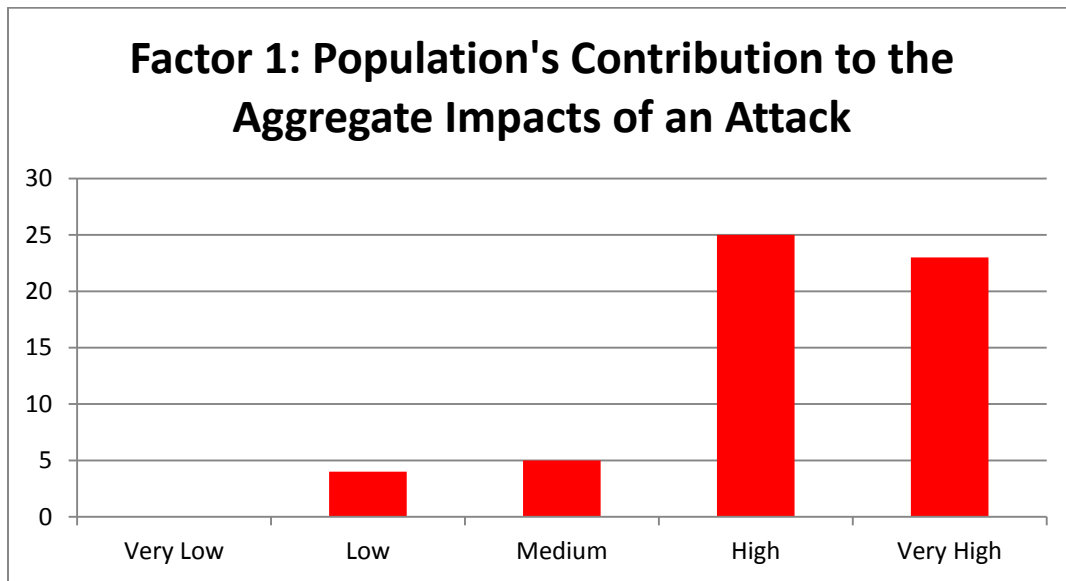
SAI 23 is titled Tractor and Trailer Tracking Systems. It suggests that employers should have the ability to implement methods of tracking the tractor and trailer throughout the intended route with satellite and/or land-based wireless GPS communications systems. 52% of survey respondents ranked this as extremely important, 33% as very important and 15% as somewhat important.



## Section 5: Aggregate Impacts of a Terrorist Attack

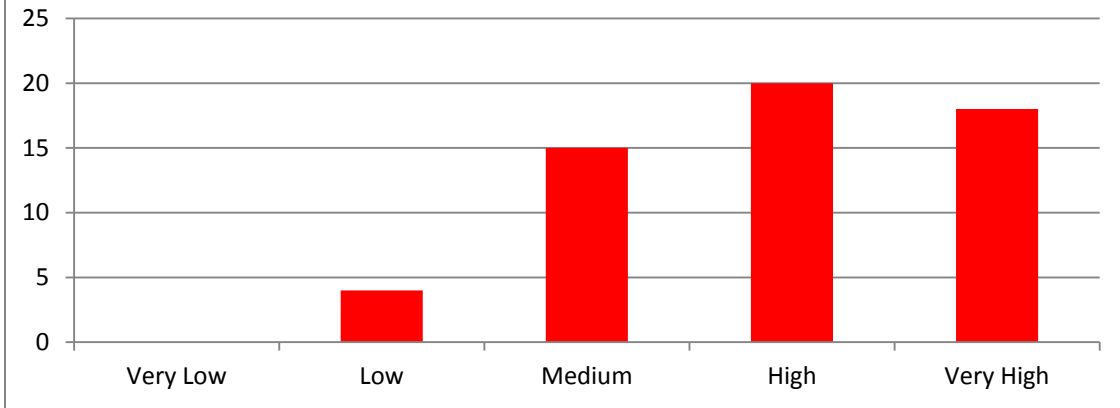
Section 5 presents survey results of the questions pertaining to factors contributing to the aggregate impacts of a terrorist attack. Questions were designed to ask each of the survey participants to rank a variety of potentially affected categories and the overall contribution they make to the aggregated impacts of a terrorist attack. Survey participants were also asked to indicate any variables beyond those provided that should be factored in when evaluating the level of risk associated with hazardous materials shipments. The following list provides additional factors highlighted:

- The length of time the event will last. For example, placing anthrax on a roadway could close the road or facility for months or years
- Impact of a successful attack on enemy cause, strength, and prominence bona fides



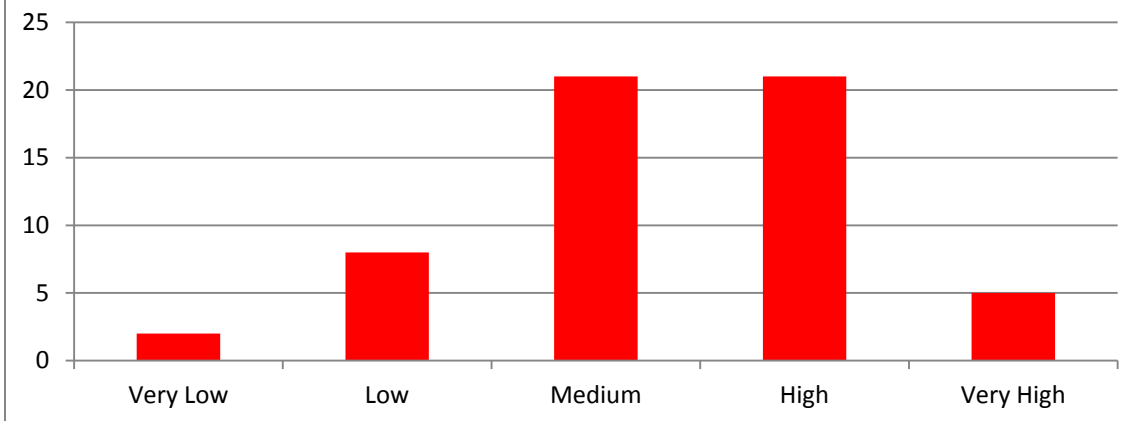
In examining Factor 1, population's contribution to the aggregate impacts of an attack, survey respondents ranked the following. 4 respondents found that population's contribution was low, 5 medium, 25 high, and 23 found the aggregate impacts of population to be very high.

## Factor 2: Critical Infrastructure's Contribution to the Aggregate Impacts of an Attack



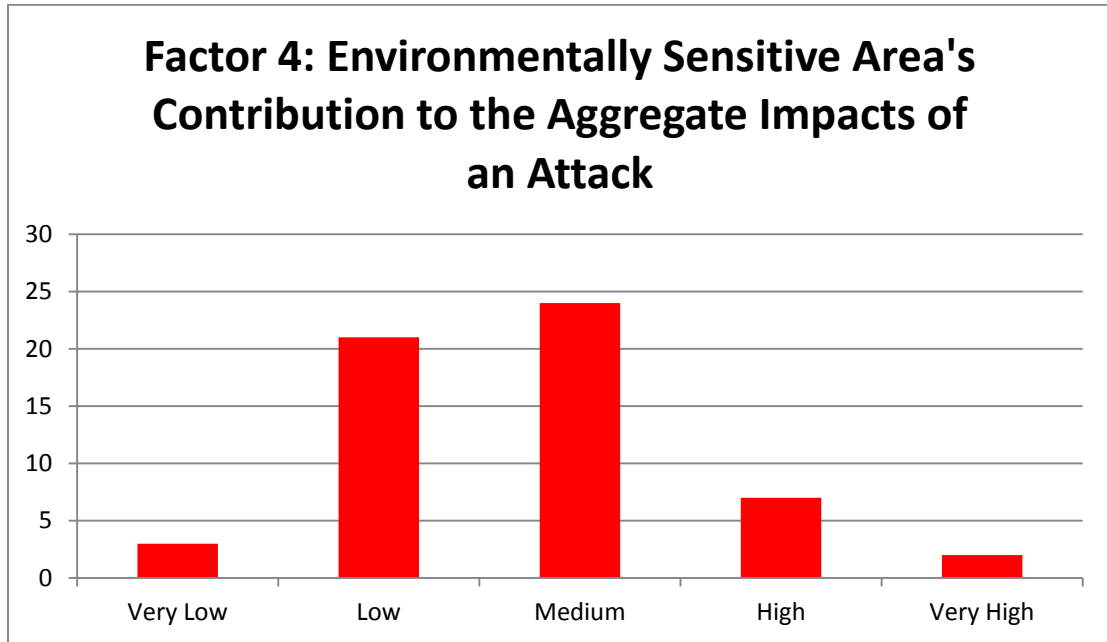
In examining Factor 2, critical infrastructure's contribution to the aggregate impacts of an attack, survey respondents ranked the following. 4 respondents found that critical infrastructure's contribution was low, 15 medium, 20 high, and 18 found the aggregate impacts of critical infrastructure to be very high.

## Factor 3: Key Resources' Contribution to the Aggregate Impacts of an Attack

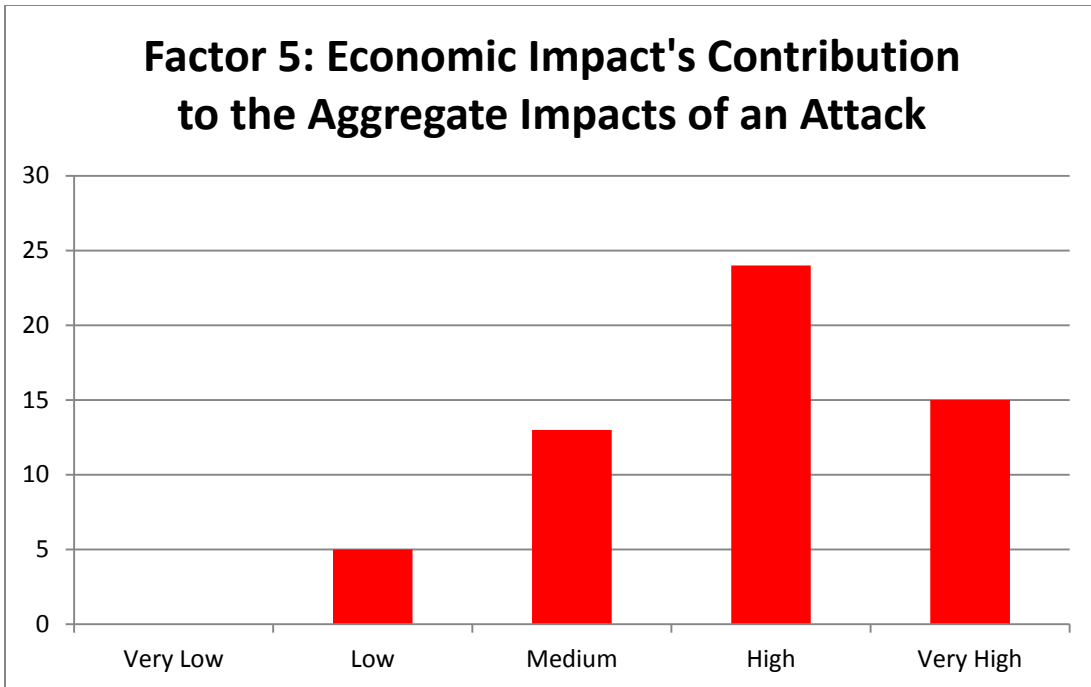


In examining Factor 3, key resources' contribution to the aggregate impacts of an attack, survey respondents ranked the following. 2 respondents found that key resources'

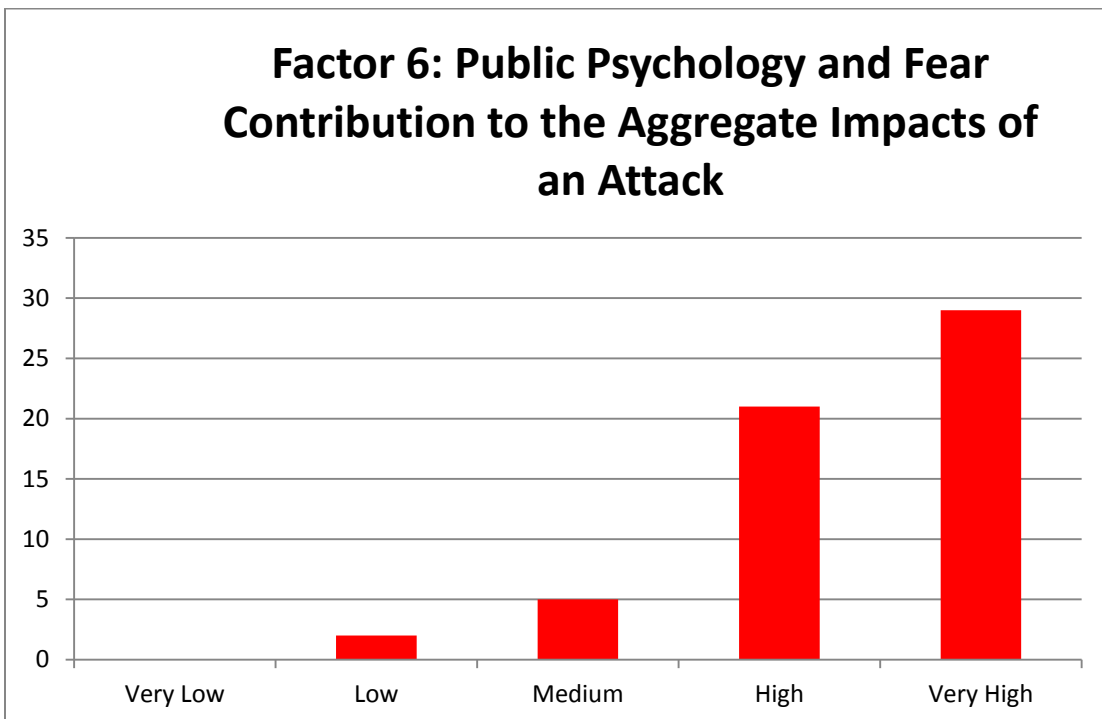
contribution was very low, 8 low, 21 medium, 21 high, and 5 found the aggregate impacts of key resources to be very high.



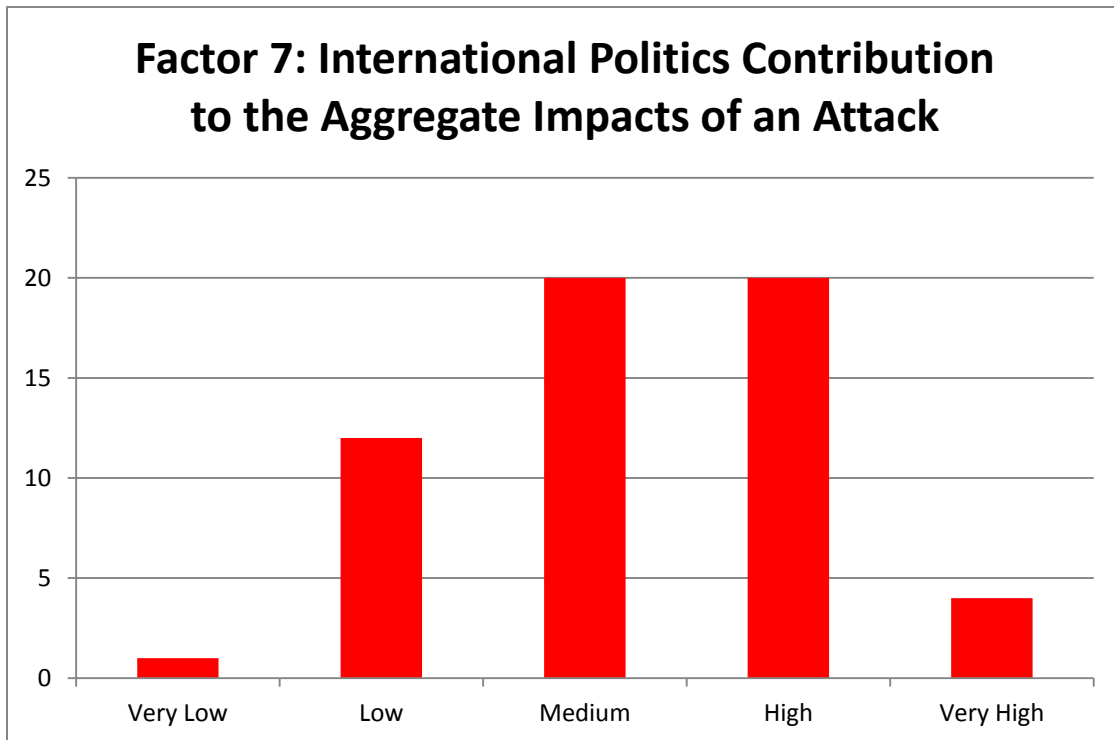
In examining Factor 4, environmentally sensitive area's contribution to the aggregate impacts of an attack, survey respondents ranked the following. 3 respondents found that environmentally sensitive area's contribution was very low, 21 low, 24 medium, 7 high, and 2 found the aggregate impacts of environmentally sensitive areas to be very high.



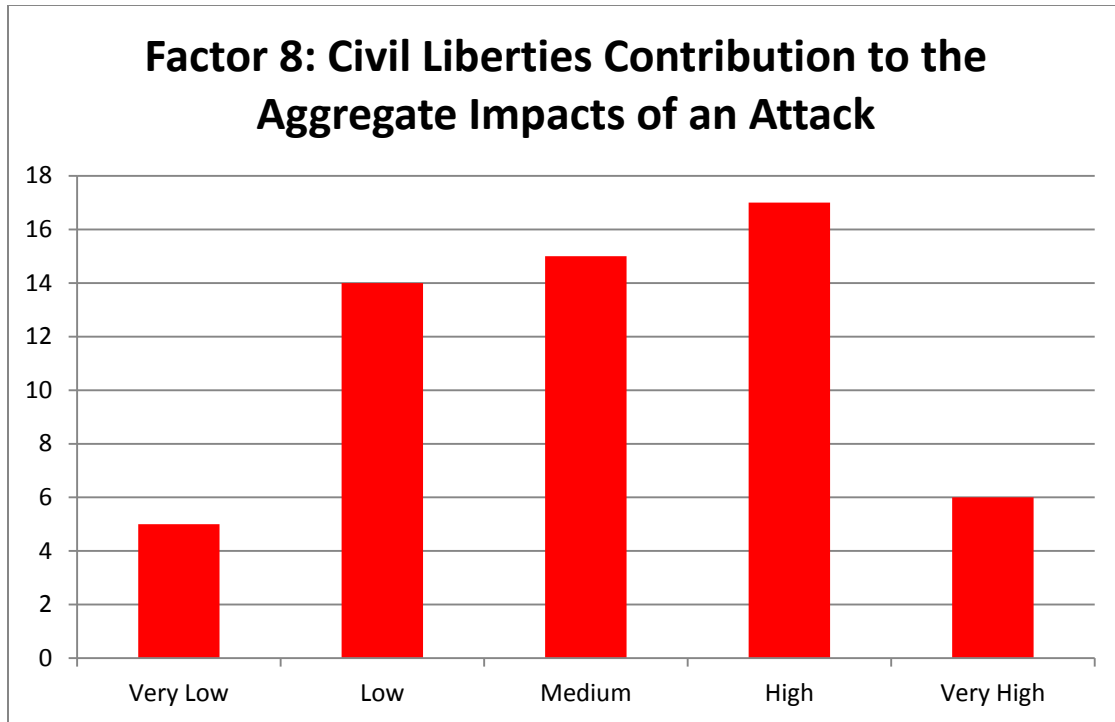
In examining Factor 5, economic impact's contribution to the aggregate impacts of an attack, survey respondents ranked the following. 5 respondents found that environmentally sensitive area's contribution was low, 13 medium, 24 high, and 15 found the aggregate impacts of environmentally sensitive areas to be very high.



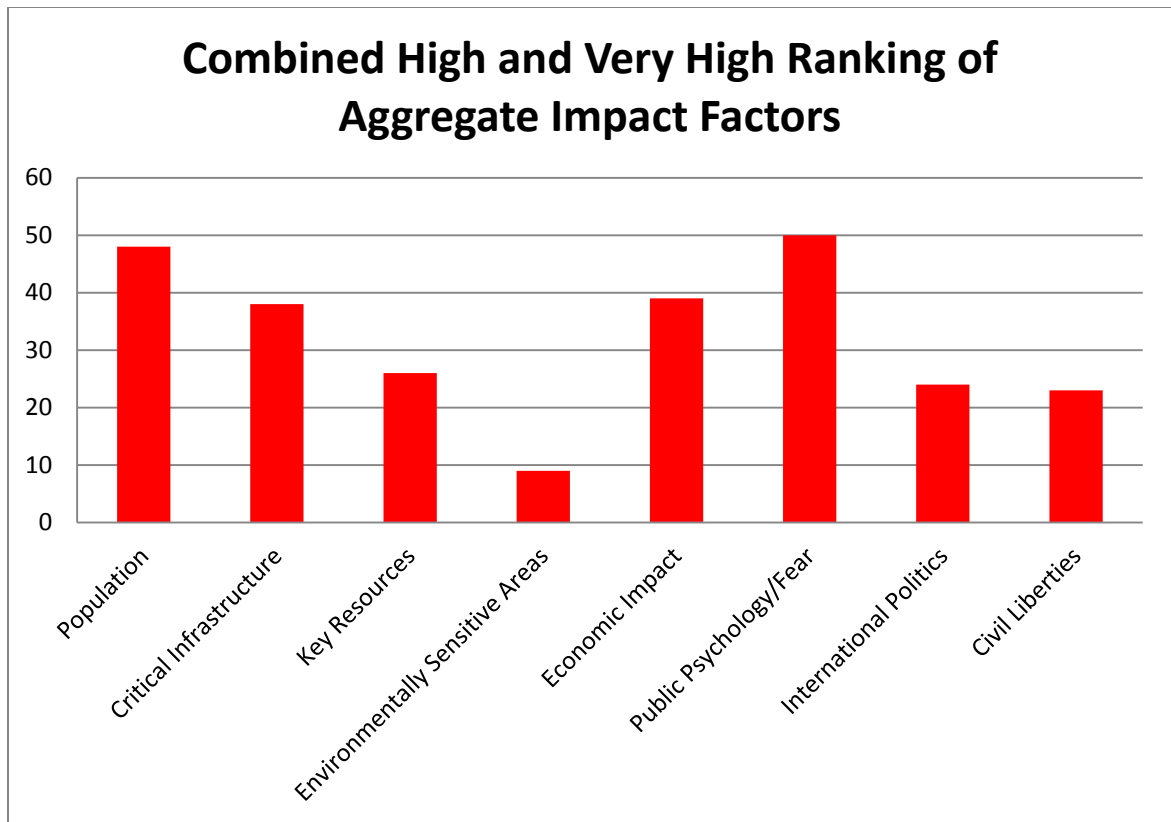
In examining Factor 6, public psychology and fear’s contribution to the aggregate impacts of an attack, survey respondents ranked the following. 2 respondents found that public psychology and fear’s contribution was low, 5 medium, 21 high, and 29 found the aggregate impacts of public psychology and fear to be very high.



In examining Factor 7, international politics’ contribution to the aggregate impacts of an attack, survey respondents ranked the following. 1 respondent found that international politics’ contribution was very low, 14 low, 15 medium, 17 high, and 6 found the aggregate impacts of international politics to be very high.



In examining Factor 8, civil liberties' contribution to the aggregate impacts of an attack, survey respondents ranked the following. 5 respondents found that civil liberties' contribution was very low, 14 low, 15 medium, 17 high, and 6 found the aggregate impacts of population to be very high.

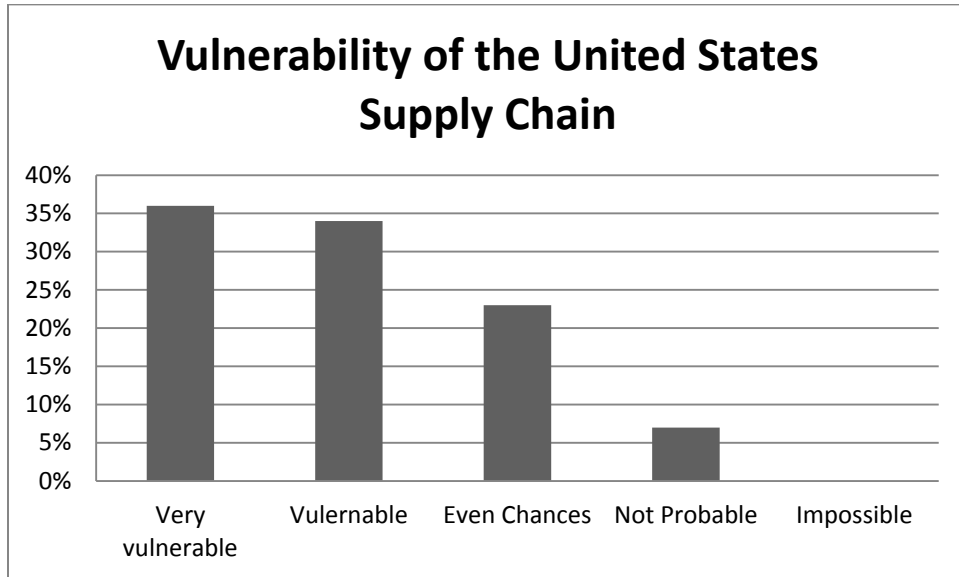


The table above makes a comparison of the combined high and very high rankings of each of the aggregate impact factors identified in the survey. An examination of this table highlights that public psychology and fear, with a combined total of 50, ranks the highest. This is followed closely by population, which has a combined total of 48. Economic impact has a ranking of 39, and critical infrastructure has a ranking of 38. Key resources received 26, international politics 24, and civil liberties 23. Lastly, environmentally sensitive areas received only 9 high or very high aggregate impacts ratings.

## Section 6: Additional Questions

Survey participants were requested to answer a number of additional questions.

Additional Question 1: Survey participants were asked to indicate how vulnerable to attacks they felt the United States highway motor carrier Tier 1 HSSM supply chain is.

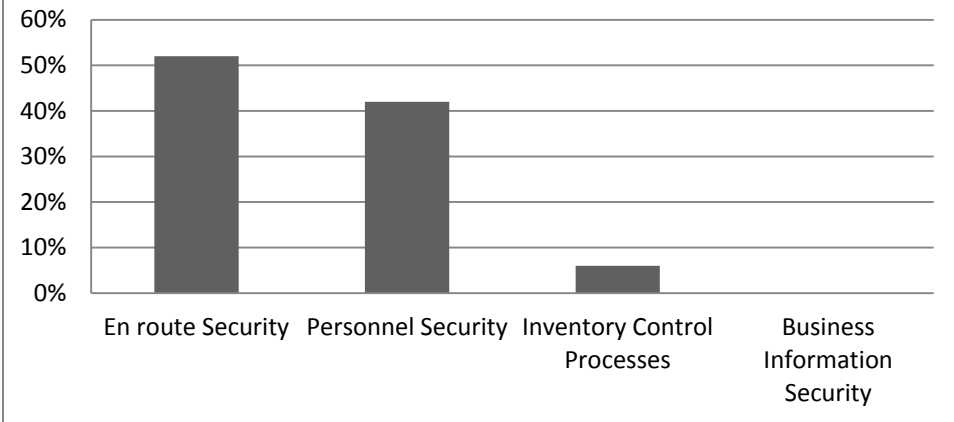


36% of respondents felt the supply chain was very vulnerable, 34 % felt that it was vulnerable, 23% felt that chances of attack are even, and 7% felt that it is not probable. 0% of respondents felt that an attack would be impossible.

Additional Question 2: Survey participants were asked to rank security challenges faced by shippers, carriers, and consignees, when transporting and safeguarding Tier 1 HSSM.



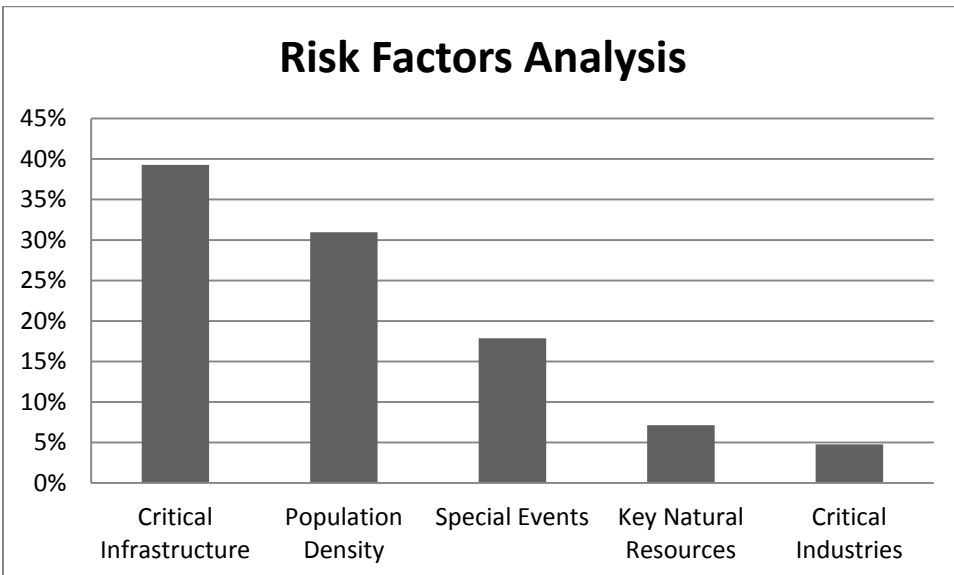
## Greatest Security Challenges Faced by Shippers Carriers and Consignees



52% of respondents felt that en route security posed the biggest challenge, 42% felt that personnel security posed the largest challenge, 6% felt the inventory control processes posed the biggest challenge, and 0% felt the business information security posed the largest challenge.

Additional Question 3: Survey participants were asked to rank five factors contributing to the risk of a particular shipment, with rank level 1 being the greatest contributor to transportation risk, and rank 5 being the least contributor to transportation risk.

## Risk Factors Analysis



The table above combines rank 1 and 2, the top two contributors to shipment risk. 39% of respondents felt that critical infrastructure contributed the greatest risk to Tier 1 HSSM shipments. 31% felt that population density was the greatest risk contributor, 18% highlighted special events, 7% key natural resources, and 5% critical industries. Special events were defined in the question as events such as Super Bowl or a Presidential Inauguration. Critical infrastructure was defined as ports, bridges, tunnels, and water and sewer systems. Critical industries provided examples such as chemical facilities or nuclear power.

A follow-on question asked survey respondents to identify any additional factors that they felt contributed to risk. Numerous factors were mentioned and could be combined into the following list:

- Geography – or the physical environment through which the shipment is travelling
- National-level iconic structures – these should be kept separate to regular critical infrastructure as they include targets such as Golden Gate Bridge, Brooklyn Bridge, Hoover Dam and Sears Tower
- Symbolic Significance – Pentagon, White House, Congress
- Routing – or a lack of attendance for specific shipments
- Driver mental state
- Historical or psychological significance of a target

## **APPENDIX B IRB Review and Approval**

Office of Research Integrity  
IRB, IACUC, RDRC  
315 Kincaid Hall  
Lexington, KY 40506-0057  
859 257-9428  
fax 859 257-8995  
www.research.uky.edu/ori/

Initial Review

Approval Ends  
September 26, 2016

IRB Number  
15-0657-P4S

TO: Steven (Doug) Kreis  
Kentucky Transportation Center  
176 Raymond Building  
0281  
PI phone #: (859) 257-4513 ext. 287

FROM: Chairperson/Vice Chairperson  
Non-medical Institutional Review Board (IRB)

SUBJECT: Approval of Protocol Number 15-0657-P4S

DATE: October 5, 2015


On September 28, 2015, the Non-medical Institutional Review Board approved your protocol entitled:

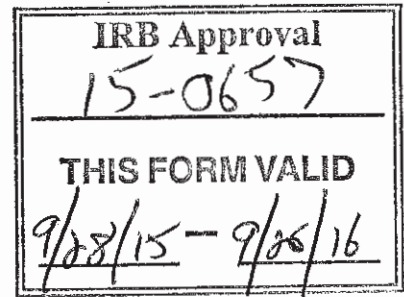
*Tier I Hazardous Materials Shipment Security - Addressing Critical Research Gaps to Secure the United States Supply Chain*

Approval is effective from September 28, 2015 until September 26, 2016 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, attached is the IRB approved consent/assent document(s) to be used when enrolling subjects. **[Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless special waiver has been obtained from the IRB.]** Prior to the end of this period, you will be sent a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigators responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" from the Office of Research Integrity's IRB Survival Handbook web page [<http://www.research.uky.edu/ori/IRB-Survival-Handbook.html#PIresponsibilities>]. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site [<http://www.research.uky.edu/ori>]. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at (859) 257-9428.

  
Chairperson/Vice Chairperson



Consent to Participate in a Research Study

**Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

**WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

You are being invited to take part in a research study about the shipment of Tier 1 hazardous materials by highway motor carriers. The purpose of the study is to assess the need and technology available to design a truck tracking and risk management system. You are being invited to take part in this research study because of your subject matter expertise in relation to truck telematics. If you volunteer to take part in this study, you will be one of about five people to provide information on truck telematics systems available in North America.

**WHO IS DOING THE STUDY?**

The person in charge of this study is Steven Douglas (Doug) Kreis (*Principal Investigator, PI*) of University of Kentucky Department of Civil Engineering. Doug is a doctoral candidate in the Department of Civil Engineering, and he is being guided in his research by Dr. Tim Taylor (Advisor).

**WHAT IS THE PURPOSE OF THIS STUDY?**

By doing this study, we hope to learn about the range of telematics providers available to the trucking industry, and the range of services that those providers offer. The hope is to ascertain the current technology available, and the cost of this technology to the individual truck driver.

**ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?**

No.

**WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?**

The research procedures will be conducted at College of Engineering, in the University of Kentucky. The interview will be conducted over the phone, and it is estimated to take 45-60 minutes of your time. You will be contacted during regular business hours, at a time that is most convenient to you.

**WHAT WILL YOU BE ASKED TO DO?**

You will be asked questions about the telematics system that your company offers to the trucking industry. These questions will cover aspects such as cost of initial installation, monthly costs, system operations requirements and/or platforms, tracking capabilities and technology employed (e.g. GPS, or satellite) and any additional features or services offered as a part of your device.



### **WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

### **WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

You will not get any personal benefit from taking part in this study.

### **DO YOU HAVE TO TAKE PART IN THE STUDY?**

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

### **IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you do not want to be in the study, there are no other choices except not to take part in the study.

### **WHAT WILL IT COST YOU TO PARTICIPATE?**

There are no costs associated with taking part in the study.

### **WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.

### **WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep confidential all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. The data generated during the course of the study will be stored on the PI's desktop computer. This data will be password protected, and no one will have access to the desktop or the office except the PI. The data will be destroyed 6 years after completion of the project. PI generated notes pertaining to conversations will be kept in a locked file cabinet, inside the PI's locked office on the University of Kentucky campus. After the 6 years of holding the records has lapsed, the desktop hard drive will be wiped by the College of Engineering's computer technician. Additionally, no information or data generated during the course of the study will be sent to anyone via email.

We may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.

### **CAN YOUR TAKING PART IN THE STUDY END EARLY?**



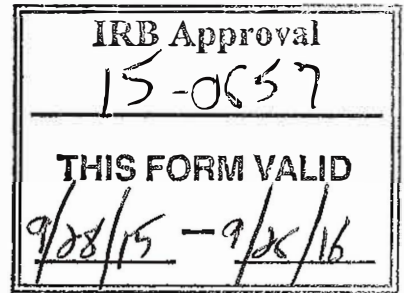
If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

#### **WHAT ELSE DO YOU NEED TO KNOW?**

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.

#### **WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Doug Kreis at 859-257-6898. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky between the business hours of 8am and 5pm EST, Mon-Fri. at 859-257-9428 or toll free at 1-866-400-9428.



Consent to Participate in a Research Study

**Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

**WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

You are being invited to take part in a research study about the shipment of Tier 1 hazardous materials by highway motor carriers. The purpose of the study is to assess the need and technology available to design a truck tracking and risk management system. You are being invited to take part in this research study because of your subject matter expertise in relation to the Hazmat Truck Security Pilot (HTSP) conducted beginning October 2005. If you volunteer to take part in this study, you will be one of about four people to provide information on the HTSP.

**WHO IS DOING THE STUDY?**

The person in charge of this study is Steven Douglas (Doug) Kreis (*Principal Investigator, PI*) of University of Kentucky Department of Civil Engineering. Doug is a doctoral candidate in the Department of Civil Engineering, and he is being guided in his research by Dr. Tim Taylor (*Advisor*).

**WHAT IS THE PURPOSE OF THIS STUDY?**

By doing this study, we hope to evaluate the HTSP, and develop a list of lessons learned during the initial pilot study. These lessons learned will be used to inform our system architecture for a truck tracking and risk management system that would serve the shippers, carriers and consignees involved in the hazardous material supply chain.

**ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?**

No.

**WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?**

The research procedures will be conducted at College of Engineering, in the University of Kentucky. The interview will be conducted over the phone, and it is estimated to take 45-60 minutes of your time. You will be contacted during regular business hours, at a time that is most convenient to you.





### **WHAT WILL YOU BE ASKED TO DO?**

You will be asked questions about your involvement in the HTSP. You will be asked to give your opinion on both the successes and failures of the original project. You will also be asked your opinion on the original study methods.

### **WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

### **WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

You will not get any personal benefit from taking part in this study.

### **DO YOU HAVE TO TAKE PART IN THE STUDY?**

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

### **IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you do not want to be in the study, there are no other choices except not to take part in the study.

### **WHAT WILL IT COST YOU TO PARTICIPATE?**

There are no costs associated with taking part in the study.

### **WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.

### **WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep confidential all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. The data generated during the course of the study will be stored on the PI's desktop computer. This data will be password protected, and no one will have access to the desktop or the office except the PI. The data will be destroyed 6 years after completion of the project. PI generated notes pertaining to conversations will be kept in a locked file cabinet, inside the PI's locked office on the University of Kentucky campus. After the 6 years of holding the records has lapsed, the desktop hard drive will be wiped by the College of Engineering's computer technician. Additionally, no information or data generated during the course of the study will be sent to anyone via email.

We may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.



### **CAN YOUR TAKING PART IN THE STUDY END EARLY?**

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

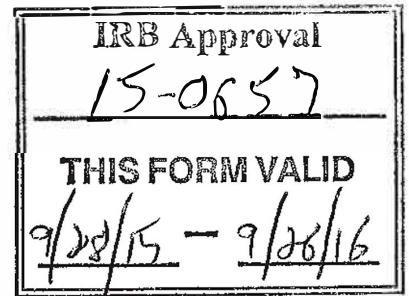
### **WHAT ELSE DO YOU NEED TO KNOW?**

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.

### **WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Doug Kreis at 859-257-6898. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky between the business hours of 8am and 5pm EST, Mon-Fri. at 859-257-9428 or toll free at 1-866-400-9428.

## Kreis Survey Cover Letter



To XXXXX:

You are being invited to participate in an online survey for a project titled “Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain”. This survey is being completed as a part of a doctoral dissertation that seeks to develop a risk analysis and management protocol for Tier 1 highway security sensitive materials that will improve both the safety and security of highway based freight. This survey is being sent to subject matter experts in the field of highway security sensitive materials nationwide, including representatives from government agencies, private industry and academia. The purpose of the survey is to request your feedback and based upon your expertise rank a number of fields that will assist the PI Steven Kreis in developing a semi-quantitative risk equation. This equation will be used to analyze the risk of a particular shipment of hazardous material in both space and time. That is to assist in determining how the risk profile of a shipment will change as it moves across the country (rural as opposed to urban locations) and in time (daytime or rush hour as opposed to nighttime).

Although you will not get personal benefit from taking part in this research study, your responses may help us understand more about these shipments and the biggest risks associated with them, as perceived by our Nation’s leading experts and practitioners in this field.

We hope to receive completed questionnaires from about 200 people, so your answers are important to us. Of course, you have a choice about whether or not to complete the survey/questionnaire, but if you do participate, you are free to skip any questions or discontinue at any time.

The survey/questionnaire will take about 30 minutes to complete.

There are no known risks to participating in this study.

Although we have tried to minimize this, some questions may be beyond your area of expertise or you may feel uncomfortable providing a response. If this is the case you have the option to quit the survey, or preferably skip the question and continue with the questions you do feel comfortable answering.

Your response to the survey will be kept confidential to the extent allowed by law. When we write about the study you will not be identified.

Please be aware, while we make every effort to safeguard your data once received from the online survey/data gathering company, given the nature of online surveys, as with anything involving the Internet, we can never guarantee the confidentiality of the data while still on the survey/data gathering company’s servers, or while en route to either them or us. It is also possible the raw data collected for research purposes may be used for marketing or reporting purposes by the survey/data gathering company after the research is concluded, depending on the company’s Terms of Service and Privacy policies.

Survey/Questionnaire Cover Letter Template [F1.0355]

If you have questions about the study, please feel free to ask; my contact information is given below. I am a PhD candidate at the University of Kentucky, and this research will be used as a part of my doctoral degree. Study questions can also be directed to my faculty advisory Dr. Timothy Taylor, who can be contacted at the University of Kentucky [tim.taylor@uky.edu](mailto:tim.taylor@uky.edu) or 859 323 3680. If you have complaints, suggestions, or questions about your rights as a research volunteer, contact the staff in the University of Kentucky Office of Research Integrity at 859-257-9428 or toll-free at 1-866-400-9428.

Thank you in advance for your assistance with this important project. I would appreciate if you could respond at any time in the coming two weeks.

Sincerely,

Steven Douglas Kreis  
*College of Engineering,*  
University of Kentucky  
PHONE: 859-257-6898  
E-MAIL: [dougreis@uky.edu](mailto:dougreis@uky.edu)

# COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

## COURSEWORK REQUIREMENTS REPORT\*

\* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** Steven Kreis II (ID: 5081322)
- **Email:** dougkreis@uky.edu
- **Institution Affiliation:** University of Kentucky (ID: 409)
  
- **Curriculum Group:** Human Research
- **Course Learner Group:** Group 2 Social/Behavioral Investigators and Key Personnel
- **Stage:** Stage 2 - Refresher Course
  
- **Report ID:** 17323771
- **Completion Date:** 09/15/2015
- **Expiration Date:** 09/14/2018
- **Minimum Passing:** 80
- **Reported Score\*:** 100

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
SBE Refresher 1 – Instructions (ID: 943)	09/15/15	No Quiz
SBE Refresher 1 – History and Ethical Principles (ID: 936)	09/15/15	2/2 (100%)
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects (ID: 937)	09/15/15	2/2 (100%)
SBE Refresher 1 – Informed Consent (ID: 938)	09/15/15	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality (ID: 15035)	09/15/15	2/2 (100%)
SBE Refresher 1 – Assessing Risk (ID: 15034)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research with Prisoners (ID: 939)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research with Children (ID: 15036)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings (ID: 940)	09/15/15	2/2 (100%)
SBE Refresher 1 – International Research (ID: 15028)	09/15/15	2/2 (100%)
Internet-Based Research - SBE (ID: 510)	09/15/15	5/5 (100%)
Biomed Refresher 1 - Instructions (ID: 960)	09/15/15	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

### CITI Program

Email: [citisupport@miami.edu](mailto:citisupport@miami.edu)

Phone: 305-243-7970

Web: <https://www.citiprogram.org>

# COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

## COURSEWORK TRANSCRIPT REPORT\*\*

\*\* NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** Steven Kreis II (ID: 5081322)
- **Email:** dougkreis@uky.edu
- **Institution Affiliation:** University of Kentucky (ID: 409)
  
- **Curriculum Group:** Human Research
- **Course Learner Group:** Group 2 Social/Behavioral Investigators and Key Personnel
- **Stage:** Stage 2 - Refresher Course
  
- **Report ID:** 17323771
- **Report Date:** 09/15/2015
- **Current Score\*\*:** 100

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
SBE Refresher 1 – History and Ethical Principles (ID: 936)	09/15/15	2/2 (100%)
Biomed Refresher 1 - Instructions (ID: 960)	09/15/15	No Quiz
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects (ID: 937)	09/15/15	2/2 (100%)
SBE Refresher 1 – Informed Consent (ID: 938)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research with Prisoners (ID: 939)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings (ID: 940)	09/15/15	2/2 (100%)
SBE Refresher 1 – Instructions (ID: 943)	09/15/15	No Quiz
SBE Refresher 1 – International Research (ID: 15028)	09/15/15	2/2 (100%)
SBE Refresher 1 – Assessing Risk (ID: 15034)	09/15/15	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality (ID: 15035)	09/15/15	2/2 (100%)
SBE Refresher 1 – Research with Children (ID: 15036)	09/15/15	2/2 (100%)
Internet-Based Research - SBE (ID: 510)	09/15/15	5/5 (100%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

### CITI Program

Email: [citisupport@miami.edu](mailto:citisupport@miami.edu)

Phone: 305-243-7970

Web: <https://www.citiprogram.org>



**FORM A-1****EXPEDITED CERTIFICATION FORM**

To Be Completed Only If Protocol is to Receive Expedited Review

Please Read Carefully Before Answering the Questions

08/03/15

Date

Name of Principal Investigator:

Steven Douglas (Doug) Kreis

Title of Research Project:

Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain

**Applicability**

- (A) Research activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the following categories, may be reviewed by the IRB through the expedited review procedure authorized by 45 CFR 46.110 and 21 CFR 56.110. The activities listed should not be deemed to be of minimal risk simply because they are included on this list. Inclusion on this list merely means that the activity is eligible for review through the expedited review procedure when the specific circumstances of the proposed research involve no more than minimal risk to human subjects.
- (B) The categories in this list apply regardless of the age of subjects, except as noted.
- (C) The expedited review procedure may not be used where identification of the subjects and/or their responses would reasonably place them at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, insurability, reputation, or be stigmatizing, unless reasonable and appropriate protections will be implemented so that risks related to invasion of privacy and breach of confidentiality are no greater than minimal.
- (D) The expedited review procedure may not be used for classified research involving human subjects.
- (E) IRBs are reminded that the standard requirements for informed consent (or its waiver, alteration, or exception) apply regardless of the type of review—expedited or convened—utilized by the IRB.
- (F) Categories one (1) through seven (7) pertain to both initial and continuing IRB review.

Does this study present more than minimal risk to the subjects?\*:  YES  NO

\*"Minimal risk" means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves from those ordinarily encountered in daily life or during the performance of routine physical or psychological examination or tests. 45 CFR 46.102(i)

## **Research Categories**

Please indicate which of the following categories are applicable to your research.

- 1) \_\_\_\_ Clinical studies of drugs and medical devices only when condition (a) or (b) is met.
- (a) \_\_\_\_ Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.)
- (b) \_\_\_\_ Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.
- 2) \_\_\_\_ Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows:
- (a) \_\_\_\_ From healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or
- (b) \_\_\_\_ From other adults and children<sup>1</sup> considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.
- NOTE: Intravenous (IV), Port, Central, or any other lines are NOT eligible under this category even if the research involves “minimal risk”.
- 3) \_\_\_\_ Prospective collection of biological specimens for research purposes by noninvasive means. Examples: (a) Hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.
- 4) \_\_\_\_ Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.) Examples: (a) Physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject’s privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.
- 5) \_\_\_\_ Research involving materials (data, documents, records, or specimens) that have been collected or will be collected solely for nonresearch purposes (such as medical treatment or



(Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

- 6)  Collection of data from voice, video, digital, or image recordings made for research purposes.
- 7)  Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects 45 CFR 46.101 (b)(2) and (b)(3). This listing refers only to research that is not exempt.)
- 8)  Continuing review of research previously approved by the convened IRB as follows:  
 (a)  Where (i) the research is permanently closed to the enrollment of new subjects; (ii) all subjects have completed all research-related interventions; and (iii) the research remains active only for long-term follow-up of subjects; or  
 (b)  Where no subjects have been enrolled and no additional risks have been identified; or  
 (c)  Where the remaining research activities are limited to data analysis.
- 9)  Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories two (2) through eight (8) do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified.

**\*THE CATEGORIES OF RESEARCH THAT MAY BE REVIEWED BY THE INSTITUTIONAL REVIEW BOARD (IRB) THROUGH AN EXPEDITED REVIEW PROCEDURE BECAME EFFECTIVE *NOVEMBER 9, 1998*.**

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<sup>1</sup> In Kentucky, “child/children” refers to all individuals less than 18 years of age unless the individual(s) is/are legally emancipated. (See Informed Consent SOP for discussion of “Emancipated Individuals” under Kentucky state law.) Individuals less than 18 years of age who are not emancipated meet the federal definition for “child” (e.g., DHHS, FDA, and U.S. Department of Education). Children are defined in the HHS regulations as “persons who have not attained the legal age for consent to treatments or procedures involved in the research, under the applicable law of the jurisdiction in which the research will be conducted.” 45 CFR 46.402(a) If conducting research outside the state of Kentucky, you are responsible for complying with applicable state law.

**FORM A**  
**GENERAL INFORMATION SHEET: NONMEDICAL IRB**

F2.0050

IRB # \_\_\_\_\_

*THIS FORM MUST BE TYPED*

**Note: For best results in opening links contained within this document, it is recommended that you first save this document to the location of your choice. Open the document from that location, then right-mouse click on a link and select "open hyperlink".**

This application is described by (check one):

- A. New IRB Research Protocol (Not previously reviewed)
- B. Previously Approved Study for which IRB Approval has Lapsed : Previous IRB # \_\_\_\_\_  
*Please include with your submission either a written statement that verifies no research activities (recruitment or enrollment of new subjects; interaction, intervention, or data collection from currently enrolled subjects; or data analysis) have occurred since the lapse in approval, or a summary of events that occurred in the interim.*
- C. Modification to Currently Approved Protocol

1. Check type of review: Expedited  Full: \_\_\_\_\_ Check IRB: Medical \_\_\_\_\_ Nonmedical

2. Name and Address of Principal Investigator (PI) (where mail can most easily reach PI): If research is being submitted to or supported by an extramural funding agency such as NIH, or a private foundation, the PI listed on the grant application must be the same person listed below. If the PI is completing this project to meet the requirements of a University of Kentucky academic program, also list name and campus address of faculty advisor.

PI Name: Steven Douglas Kreis  PI is R.N.

Department: Civil Engineering- KTC

\*Room # & Bldg.: 176 Raymond Building

Speed Sort #: 0281

\*Students should list preferred mailing address (i.e., an address where mail will most quickly reach them).

3. PI's Link Blue: sdkrei00 Degree and Rank: PhD Candidate  
*("username" to log in to your UK network account, i.e., jdoe)*

PI's Telephone #: 859 257 6898 Dept. Code: 8h060

PI's e-mail address: dougreis@uky.edu PI's FAX Number: 859 257 1815

4. Title of Project: (If applicable, use the exact title listed in the grant/contract application. **When applicable to your research, it is important that you add to the beginning of your title the following: "UK/P" if your research involves prisoners; "UK/D" if your research is supported by the Department of Defense".**

Tier 1 hazardous materials shipment security – addressing critical research gaps to secure the United States supply chain

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**FORM A**  
**GENERAL INFORMATION SHEET: NONMEDICAL IRB**

F2.0050

5. Indicate which of the categories listed below accurately describes this protocol:

<input checked="" type="checkbox"/>	Not greater than minimal risk
<input type="checkbox"/>	Greater than minimal risk, but presenting the prospect of direct benefit to individual subjects
<input type="checkbox"/>	Greater than minimal risk, no prospect of direct benefit to individual subjects, but likely to yield generalizable knowledge about the subject's disorder or condition
<input type="checkbox"/>	Research not otherwise approvable which presents an opportunity to understand, prevent, or alleviate a serious problem affecting the health or welfare of subjects

6. Anticipated Beginning and Ending Date of Research Project:                     09/01/15                     /                     12/01/16                      
Month/Day/Year Month/Day/Year

7. Number and age level of human subjects:                     200                     /                     40-70                      
Number Age Range

Indicate the categories of subjects and controls to be included in the study. You may be required to complete additional forms depending on the subject category applicable to your research. Check ALL that apply:

<input type="checkbox"/> Children (17 yrs or less) <a href="#">[attach Form W]</a> <input type="checkbox"/> Wards of the State <a href="#">[attach Form W]</a> <input type="checkbox"/> Emancipated Minors <input type="checkbox"/> Impaired Consent Capacity <a href="#">[attach Form T]</a> <input type="checkbox"/> Impaired Consent Capacity (Institutionalized) <a href="#">[attach Form T]</a> <input type="checkbox"/> Neonates <a href="#">[attach Form U]</a> <input type="checkbox"/> Pregnant Women <a href="#">[attach Form U]</a> <input type="checkbox"/> Military Personnel or DoD Civilian Employees <a href="#">[DoD SOP may apply]</a>	<input type="checkbox"/> Prisoners <a href="#">[attach Form V]</a> <input type="checkbox"/> Non-English Speaking [see Form H info ( <a href="#">HTML</a> )] <input type="checkbox"/> International Citizens <a href="#">[DoD SOP may apply]</a> <input type="checkbox"/> Students <input checked="" type="checkbox"/> Normal Volunteers <input type="checkbox"/> Patients <input type="checkbox"/> Appalachian Population
---	---

8. Does this study focus on subjects with any of the clinical conditions listed below that present a high likelihood of impaired consent capacity or fluctuations in consent capacity?

No

Yes

If yes, does the research involve interaction or intervention with subjects?

- No, direct intervention/interaction is not involved (e.g., record-review research, secondary data analysis)  
 Yes - direct intervention/interaction is involved - complete and attach [Form T](#) to your IRB application.

Examples of such conditions include:

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Traumatic brain injury or acquired brain injury</li> <li>• Severe depressive disorders or Bipolar disorders</li> <li>• Schizophrenia or other mental disorders that involve serious cognitive disturbances</li> <li>• Stroke</li> <li>• Developmental disabilities</li> <li>• Degenerative dementias</li> <li>• CNS cancers and other cancers with possible CNS involvement</li> <li>• Late stage Parkinson's Disease</li> </ul> | <ul style="list-style-type: none"> <li>• Late stage persistent substance dependence</li> <li>• Ischemic heart disease</li> <li>• HIV/AIDS</li> <li>• COPD</li> <li>• Renal insufficiency</li> <li>• Diabetes</li> <li>• Autoimmune or inflammatory disorders</li> <li>• Chronic non-malignant pain disorders</li> <li>• Drug effects</li> <li>• Other acute medical crises</li> </ul> |
|---|---|

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9. Indicate the targeted/planned enrollment of the following members of minority groups and their subpopulations [**Please note: the IRB will expect this information to be reported at Continuation Review time**]:

Ethnic Origin	# Male	# Female		Ethnic Origin	# Male	# Female
American Indian/ Alaskan Native				Hispanic/Latino		
Asian				Native Hawaiian/Pacific Islander		
Black/African American				White/Caucasian		
				Other or unknown		

10. Indicate the items below that apply to your research. Depending on the items applicable to your research, you may be required to complete additional forms or meet additional requirements. Contact the ORI (859-257-9428) if you have questions about additional requirements. Check ALL that apply.

<input checked="" type="checkbox"/> Academic Degree / Required Research <input type="checkbox"/> Aging Research <input type="checkbox"/> Alcohol Abuse Research <input type="checkbox"/> <a href="#">Cancer Research</a> <input type="checkbox"/> <a href="#">Certificate of Confidentiality</a> <input type="checkbox"/> <a href="#">CCTS (Center for Clinical &amp; Translational Science)</a> <input type="checkbox"/> <a href="#">Clinical Research</a> <input type="checkbox"/> <a href="#">Clinical Trial</a> <input type="checkbox"/> Multicenter Clinical Trial (excluding NIH Cooperative Groups) <input type="checkbox"/> NIH cooperative groups (i.e., SWOG, RTOG) <input type="checkbox"/> Placebo Controlled Trial <input type="checkbox"/> UK only <input type="checkbox"/> <a href="#">Community-Based Participatory Research</a> <input type="checkbox"/> <a href="#">Data &amp; Safety Monitoring Board</a> <input type="checkbox"/> <a href="#">Data &amp; Safety Monitoring Plan</a>	<input type="checkbox"/> Deception <a href="#">[attach Form E]</a> <input type="checkbox"/> Drug/Substance Abuse Research <input type="checkbox"/> Educational/Student Records (e.g., GPA, test scores) <input type="checkbox"/> <a href="#">Genetic Research</a> <input type="checkbox"/> NIH GWAS (Genome-Wide Association Study) <input type="checkbox"/> <a href="#">UK HIPAA Authorization</a> <input type="checkbox"/> <a href="#">UK HIPAA Waiver of Authorization</a> <input type="checkbox"/> UK HIPAA De-Identification <input type="checkbox"/> <a href="#">HIV/AIDS Research</a> <input type="checkbox"/> <a href="#">Screening for Reportable Diseases</a> <input type="checkbox"/> <a href="#">International Research</a> [see Form H info ( <a href="#">HTML</a> )] <input type="checkbox"/> <a href="#">Internet Research</a> <input type="checkbox"/> Psychology Dept. Subject Use & Research Ethics (SURE) Committee <input type="checkbox"/> Survey Research <input type="checkbox"/> Waiver of Informed Consent <a href="#">[attach Form E]</a> <input checked="" type="checkbox"/> Waiver of Requirement for Documentation of Informed Consent <a href="#">[attach Form F]</a>
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11. If the research is being submitted to, supported by, or conducted in cooperation with an external or internal agency or funding program, indicate below all the categories that apply:

<input checked="" type="checkbox"/> Not applicable <input type="checkbox"/> Grant application pending <input type="checkbox"/> <a href="#">(HHS) Dept. of Health &amp; Human Services</a> <input type="checkbox"/> <a href="#">(NIH) National Institutes of Health</a> <input type="checkbox"/> <a href="#">(CDC) Centers for Disease Control &amp; Prevention</a> <input type="checkbox"/> <a href="#">(HRSA) Health Resources and Services Administration</a> <input type="checkbox"/> <a href="#">(SAMHSA) Substance Abuse and Mental Health Services Administration</a> <input type="checkbox"/> Federal Agencies Other Than Those Listed Here <input type="checkbox"/> Industry (Other than Pharmaceutical Companies) <a href="#">IRB Fee Info</a> <input type="checkbox"/> Internal Grant Program w/ proposal <input type="checkbox"/> Internal Grant Program w/o proposal	<input type="checkbox"/> <a href="#">National Science Foundation</a> <input type="checkbox"/> Other Institutions of Higher Education <input type="checkbox"/> Pharmaceutical Company <input type="checkbox"/> Private Foundation/Association <input type="checkbox"/> State <input type="checkbox"/> (DoEd) U.S. Department of Education (See <a href="#">DoEd Guidance</a> for details) <input type="checkbox"/> (DoJ) Department of Justice (e.g., <i>National Institute of Justice; Bureau of Prisons</i> ) (See <a href="#">DoJ Guidance</a> for details) <input type="checkbox"/> (DoE) Department of Energy (See <a href="#">DoE Guidance</a> for details) <input type="checkbox"/> (EPA) Environmental Protection Agency (See <a href="#">EPA Guidance</a> for details) <input type="checkbox"/> Other: _____
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12. Specify the funding source and/or cooperating organization(s): (e.g., National Cancer Institute, Ford Foundation, Eli Lilly & Company, South Western Oncology Group, Bureau of Prisons, etc.) **If your project is funded, please see Form AA – DD in Section 6 of the IRB application for applicability of attachments.**

Not Funded

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13.  Yes  No The research is supported by the Department of Defense (DoD).  
**If yes, attach to your IRB application materials addressing the specific processes described in the Department of Defense IRB/ORI Coordination SOP** [[http://www.research.uky.edu/ori/human/SOPs\\_&\\_Policies.htm#6](http://www.research.uky.edu/ori/human/SOPs_&_Policies.htm#6)].

14. a) Check all the applicable sites listed below at which the research will be conducted.

<input checked="" type="checkbox"/> Not applicable <input type="checkbox"/> Bluegrass Regional Mental Health Retardation Board <input type="checkbox"/> Cardinal Hill Hospital <input type="checkbox"/> Correctional Facilities <input type="checkbox"/> Eastern State Hospital <input type="checkbox"/> Fayette Co. School Systems <input type="checkbox"/> Home Health Agencies <input type="checkbox"/> Institutions of Higher Education (other than UK) <input type="checkbox"/> International Sites <input type="checkbox"/> Nursing Homes	<input type="checkbox"/> Other Hospitals and Med. Centers <input type="checkbox"/> Other State/Regional School Systems <input type="checkbox"/> Shriner's Children's Hospital <input type="checkbox"/> UK Classroom(s)/Lab(s) <input type="checkbox"/> UK Clinics in Lexington <input type="checkbox"/> UK Clinics outside of Lexington <input type="checkbox"/> UK Healthcare Good Samaritan Hospital <input type="checkbox"/> UK Hospital <input type="checkbox"/> Norton Healthcare <input type="checkbox"/> Veterans Affairs Medical Center <input type="checkbox"/> Other: _____
--	---

List all other non-UK owned/operated locations where the research will be conducted\*:


Attach additional sheets if necessary.

\*A letter of support and local context is required from non-UK sites. Click [here](#) for more information.

b) Is this a multi-site study for which you are the lead investigator or UK is the lead site? \_\_\_\_\_ Yes  No

If **yes**, you must describe the plan for the management of reporting unanticipated problems, noncompliance, and submission of protocol modifications and interim results from the non-UK sites in question #8 of the Research Description (Form B).

If the non-UK sites or non-UK personnel are **engaged** in the research, there are additional federal and university requirements which need to be completed for their participation, such as the establishment of a cooperative IRB review agreement with the non-UK site. Questions about the participation of non-UK sites/personnel should be discussed with the ORI staff at (859) 257-9428.

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**15. Disclosure of Financial Interest (DFI):**

Do you, any of your investigators, or key personnel have a [significant financial interest](#) requiring disclosure (per the UK administrative regulation: <http://www.uky.edu/regs/files/ar/ar7-2.pdf>)

YES  NO

**AND**

the interest(s) relate(s) to this project?

YES  NO

(to make this determination, see [OSPA](#) [<http://www.research.uky.edu/ospa/coi.html>] and/or download a sample form to view the questions required to make this determination [[PDF](#)])

**If YES to both questions above**, do you, any of your investigators, or key personnel need to update (or submit) an [online financial disclosure](#)?

[instructions:

<http://www.research.uky.edu/ospa/info/docs/INSTRUCTIONS%20FOR%20COMPLETING%20THE%20FINANCIAL%20DISCLOSURE%20FORM.pdf>]

YES

NO UPDATE REQUIRED (e.g., disclosure is already up-to-date)

If YES, please identify who has submitted an updated (or new) online financial disclosure:

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Note: The IRB cannot issue final IRB approval without reviewing the final approved management plan, if one has been deemed necessary.

**16. Additional Certification:** (If your project is federally funded, your funding agency may request an Assurance/Certification/Declaration of Exemption form.) Check the following if needed:

Protection of Human Subjects Assurance/Certification/Declaration of Exemption (Formerly Optional Form – 310)

**17. Identify other STUDY personnel assisting in research project (attach additional sheets if necessary).** (In the space provided, specify which personnel are authorized by the principal investigator to obtain informed consent.)

**NOTE: Study personnel are required to receive human research protection training before implementing any research procedures** (e.g., [CITI](#)). For information about mandatory training requirements for study personnel, visit UK's web page [FAQ's on Mandatory Training](#) [[http://www.research.uky.edu/ori/human/Human\\_Research\\_Mandatory\\_Education.htm](http://www.research.uky.edu/ori/human/Human_Research_Mandatory_Education.htm)] or contact ORI at 859-257-9428.

If you are using this sheet to request changes in study personnel (SP) that have not been previously reported to the IRB, please include with your Modification Request Form two copies of a current list of **all** study personnel, denoting the changes.

\*If the research is being completed to meet academic requirements, the faculty advisor is also considered study personnel.

Study personnel assisting in research project:

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
Name, Rank/Degree: <u>Timothy Taylor PhD</u>	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project: <u>Faculty Advisor</u>	Rank/Degree: _____	Primary Phone: _____	
E-mail address: <u>tim.taylor@uky.edu</u>	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): <u>tbtayl0</u>	E-mail address(s): _____		
Authorized to Obtain Consent: <u>Yes</u> <input checked="" type="checkbox"/> <u>No</u> <input type="checkbox"/>	Authorized to Obtain Consent: <u>Yes</u> <input type="checkbox"/> <u>No</u> <input type="checkbox"/>		

**FORM A**  
**GENERAL INFORMATION SHEET: NONMEDICAL IRB**

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<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
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**GENERAL INFORMATION SHEET: NONMEDICAL IRB**

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Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
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Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
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Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		

<b>UK Affiliated</b> individuals assisting in research project as study personnel:	<b>NON-UK Affiliated</b> individuals assisting in research project as study personnel [see question #8 of the Research Description (Form B) to provide a description of the role of these personnel]. (Note that phone # and e-mail address(s) are being requested for data matching/identification purposes and access to that data will be limited to staff working under the auspices of the Office of the Vice President for Research.)		
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Name, Rank/Degree: _____	First Name: _____	Middle Name: _____	Last Name: _____
Responsibility in Project : _____	Rank/Degree: _____	Primary Phone: _____	
E-mail address: _____	Responsibility in Project: _____		
Link Blue (e.g., jdoe4): _____	E-mail address(s): _____		
Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No	Authorized to Obtain Consent: <input type="checkbox"/> Yes <input type="checkbox"/> No		



**FORM A**  
**GENERAL INFORMATION SHEET: NONMEDICAL IRB**

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## **Form B: Nonmedical IRB Research Description**

### **Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

#### **1. Background:**

The terrorist attacks of September 11, 2001 brought renewed attention to the problem of domestic terrorism. These attacks provided a vivid example of passenger airplanes – an integral component of the United States' transportation network – being transformed into weapons, which resulted in significant loss of human life and economic damage. Maybe the most enduring legacy of the 9/11 attacks was the subsequent transformation of how the US government and policymakers deal with questions of transportation security. Almost immediately, security was heightened at airports as attention understandably turned to the mode of transportation most directly implicated in the attacks. By November 2001, with the passage of the Aviation and Transportation Security Act, the Transportation Security Administration (TSA) had been created. The TSA's mandate includes overseeing the security of airports, highways, railroads, mass transit systems, and ports.

The creation of the TSA highlights the changing security landscape in the aftermath of the 9/11 attacks. While security-related policies had tended to gloss over infrastructure and transportation before 9/11, those attacks raised awareness that transportation assets could be used as weapons, serve as targets, or act as delivery mechanism for terrorist attacks (Edwards and Goodrich 2012). In 2002, President Bush's signing of the Homeland Security Act brought about the creation of the Department of Homeland Security (DHS). After its formation, the DHS absorbed 22 separate government offices and agencies, each of which shared the common goal of securing the United States against future terrorist attacks. Included among these was the TSA. However, activities designed to increase transportation security were not confined to the policy and governance. Acknowledging that research gaps could potentially hamper efforts to improve security practices, the National Cooperative Highway Research Program (NCHRP), in 2002, began a dedicated program to address security-related transportation research. This program remains operational today, attesting to the need for timely and focused research products that inform new policies and practices that will help prevent, prepare, mitigate, or recover from security-related incidents.

Following on the heels of DHS absorbing TSA and other offices, a number of legislative and presidential directives transformed the nature of the hazardous materials landscape. Beginning in March 2003, TSA introduced new regulations that apply to drivers and other personnel involved in hazardous materials shipments. It required that hazmat employees receive security awareness training. Then in December 2003 President Bush issued a presidential directive that required Federal departments and agencies to identify and protect critical infrastructure assets deemed vulnerable to terrorist attacks. One portion of this directive stipulated that the U.S. Department of Transportation and DHS would coordinate the regulation of hazardous materials transported by any mode (including pipelines).

Clearly, in the initial scramble after 9/11 policy changes focused on airports and air transportation more broadly; in the ensuing years attention gradually turned to a wider range of transportation networks. Specifically, surface transportation security garnered more scrutiny as legislators and policymakers sought to protect highways and motor vehicles from potential terrorist attacks. Certainly it is possible for any vehicle to be weaponized, but it is undeniable that some vehicles present a more attractive target than others. For instance, vehicles carrying hazardous materials can pose a significant threat if a terrorist commandeers them for malicious purposes. Any vehicle moving hazardous materials is a viable target, but those transporting the most dangerous and toxic goods, if weaponized, would cause severe damage to human health, the environment, and local. One category of hazardous materials, however, is particularly vulnerable. If released, they would instigate a chain of events leading to catastrophic damage – Tier 1 Highway Security Sensitive Materials (HSSM).

Although hazardous materials shipments have received much attention since the 1980s, researchers and policymakers refocused their attention toward them following 9/11 (e.g. Huang et al. 2005; Lee and Whang 2005). Tier I HSSMs are used in a number of manufacturing and construction processes and constitute a key part of multiple supply chains. Formally, Tier 1 HSSMs are defined as highway sensitive-security materials transported by motor vehicles which, if released through a terrorist act or another accident would have highly significant level of adverse effects on human life, environmental damage, transportation system disruption, or economic disruption. Included among Tier 1 HSSMs are explosives, radioactive materials, chemical weapons, and flammable and non-flammable gases. Although toxic chemicals and many gasses often play little if any role in construction projects, many highway security-sensitive materials are integral to supply chains. For example, explosives can play a critical role in road construction projects (e.g., clearing rock debris to clear a path for the road) and demolition activities that are a precursor to new construction projects. Included among Tier 1 HSSMs are – explosives, radioactive materials, chemical weapons, and various liquids and gasses that are extremely toxic if humans are exposed to them, either through inhalation or other means. A commonly used Tier 1 HSSM is anhydrous ammonia, which is used as a fertilizer to supply nitrogen to plants. An April

## **Form B: Nonmedical IRB Research Description**

### **Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

2013 fertilizer plant explosion near Waco, Texas exemplified the danger it poses when not handled properly – or if it were used with malicious intent. While Tier 1 HSSMs represent a small fraction of all hazardous materials shipped daily in the United States, they merit a heightened level of oversight and protection due to the grave consequences that would result from their release.

Despite the recognition that hazardous materials could be used in terrorist attacks and produce social, security, and economic disruptions if released, not until 2007, when the Implementing Recommendations of the 9/11 Commission Act of 2007 (hereafter the 9/11 Act) was signed into law, did a concerted effort get underway to investigate the potential of developing a centralized system to monitor and track hazardous materials shipments. Section 1554 of the 9/11 Act instructs the TSA to develop a program that would facilitate the tracking of security-sensitive materials shipped by motor carriers. In 2006 and 2008, the TSA introduced new regulations designed to enhance the security of freight and passenger rail systems. In 2008, it announced security guidelines for motor carriers that were to be adopted by stakeholders on a voluntary basis. These security action items (SAIs) focused on improving the security of trucks or other vehicles transporting hazardous materials. The SAIs made recommendations about enhancing overall motor carrier security, eliminating unauthorized access to hazardous materials, conducting security threat assessments, and developing robust security plans. Before the 9/11 Act became law, the Federal Motor Carrier Safety Administration (FMCSA) conducted a brief field operations test in 2004 to assess the effectiveness of truck telematics systems to determine if they could be implemented to bolster security of the hazardous materials supply chain.

As part of Section 1554 requirements, the TSA was asked to work on a truck tracking system that would account for the FMCSA's previous field study as well as the Hazmat Truck Security Pilot Program it was responsible for administering. As commentators noted at the time, despite the stated urgency of improving transportation security, limited progress had been made on this front, especially in area of surface transportation (Johnstone 2007). Land transportation security programs suffered anemic funding, which hampered the DHS and TSA in their mission to protect surface transportation modes. Arguably, the 9/11 Act served as a partial corrective, and in particular motivated the TSA to direct more attention toward the issue of hazardous materials shipments. Solving this problem would be difficult due to the immense heterogeneity and complexity of the hazardous materials transport system. Multiple stakeholders are involved in this system – manufacturers of hazardous materials, shippers, and consignees, and so any effort to institute a robust system to monitor it would require a highly coordinated approach (ICF 2000).

Eight years after the 9/11 Act was passed, no formal system has been installed to monitor and track security-sensitive materials transported across the nation's highways – this has produced lingering gaps in the United States' hazardous materials supply chain that demand an immediate closure. This has had negative consequences for risk management. Lacking a dynamic, real-time geospatial risk analysis system, government agencies remain in the dark regarding vulnerabilities Tier 1 HSSMs experience as they move across the landscape. As Prentice (2008) argues, robust transportation security measures carry tangible and intangible benefits. Perhaps the most critical tangible benefit is the reduction in terrorism threats.

## **2. Objectives:**

The objective of this dissertation is to develop a risk analysis and management protocol for Tier 1 HSSMs that improve the safety of highway-based freight. Reducing the threat level posed by these materials will protect critical infrastructure, key environmental assets, and human life. As such, while the project will make a scholarly contribution through the development of new techniques to map and analyze risk, it will also achieve the practical goal of improving infrastructure safety and enhancing hazard mitigation techniques. Scholarly objectives will be accomplished through the development of three papers suitable for publication. Each paper will make the following contributions:

- 1) Paper 1 will combine a literature synthesis on hazardous materials and hazardous transportation security with a detailed case study reviewing a previous – unsuccessful – attempt to create a comprehensive risk analysis and mapping system for Tier 1 HSSMs. The purpose of this case study will be to identify lessons learned from past failures. Identifying previous missteps serves a valuable function in that it improves our ability to adapt theoretical knowledge in an applied setting.
- 2) Paper 2 will leverage a survey of experts in the hazardous materials transportation field to create a semi-quantitative risk equation. This equation can be used to dynamically assess the level of risk associated with the movement of hazardous materials throughout the U.S. highway network. By using the feedback from subject matter experts, this paper will develop spatially and temporally dynamic approach to risk analysis that

**Form B: Nonmedical IRB Research Description**  
**Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

evaluates the risk of individual shipments instead of individual road segments, which has been a common practice in the past.

- 3) Paper 3 will identify cost effective, appropriate telematics technologies to equip trucks carrying Tier 1 HSSMs with and determine optimal methods to report and represent this information. It will describe the practical barriers and limitations of installing telematics systems across fleets as well as the strengths and weaknesses of different technologies.

### **3. Study Design:**

The study involves utilizing a number of different techniques to collect the necessary information. Techniques include semi-structured phone interviews, and an online survey of subject matter experts. The semi-structured interviews will be employed to ascertain information about the General Dynamics previous attempt to create a tracking and monitoring system, and to collect information regarding the range of telematics available to the trucking industry. The online survey will be used to gather information from subject matter experts in the field of hazardous materials. These experts will be selected to represent different facets of government stakeholders (such as State Police, Emergency Response, Department of Homeland Security, Transportation Security Administration), private industry (such as the Institute for the Makers of Explosives) and various academics focused on hazardous material transportation and/or terrorism. Phone interviews with telematics providers will also be conducted to ascertain the range of tracking technology currently available to the trucking industry. Participants will not be randomly selected, nor will there be deception involved in the study.

Immediately after 9/11, General Dynamics received a contract to create a tracking and monitoring system for hazardous materials shipments. After a period of sustained development, General Dynamics terminated the project because the products delivered to the US Government did not provide a robust means for dynamically evaluating risk. Even though General Dynamics' risk monitoring and tracking program was inadequate, it can still offer valuable lessons to inform the design and implementation of future risk assessment protocols.

The benefits of using a semi-structured interview format are numerous. First, it allows for a mixture of structured (or targeted) questions and less rigid inquiries that give the interviewee the opportunity to expound upon his or her answer. Second, it lets the interviewer decide how to conduct an interview to preserve flow and keep the discussion as conversational as possible. Third, unlike structured interviews, which requires a strict list of questions that are directed toward each participant, semi-structured methods let the researcher identify unexpected or emergent themes that could prove critical in understanding a particular situation (Merriam, 2006). The goal of analysis will be to derive key insights about why the General Dynamics project failed; all information will be distilled into a comprehensive discussion outlining the lessons learned and how the current project can avoid the pitfalls that afflicted General Dynamics. The main purpose of the survey will be to understand how stakeholders conceptualize risk. However, it will also elicit information about the critical issues facing the hazardous materials supply chain, and hazmat transportation more broadly. Based on interview and survey results, findings will be used to outline strategies to develop a tracking and monitoring system for Tier I Hazmat shipments.

### **4. Study Population:**

Semi-structured phone interviews will be utilized to catalogue the lessons learned from the General Dynamics failed system. I will collaborate with project designers, systems engineers, and other individuals from General Dynamics' organization to highlight the successes and failures of their pilot program. A comprehensive list of lessons learned will be invaluable for developing the Tier I Hazmat Monitoring and Tracking System proposed here. To collect this information, I will conduct semi-structured interviews with organizational stakeholders with an eye toward producing a detailed case study. Appendix A contains a list of questions that will be used during interviews. The interviewees will be selected based upon their participation in the original study, and will not be selected based upon sex/gender or race/ethnicity. The proposed dates for conducting the interviews will be between November 2015 and February 2016.

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Semi-structured phone interviews will also be utilized to contact representatives from the telematics industry. Each of the companies will be contacted to ascertain the abilities/capabilities of the equipment they currently provide to the trucking industry. This information will inform the study in so far as it will determine the baseline of technology currently available for use in a tracking system. The selection criteria for participants will be based upon an internet search of available telematics providers. The interviewees will be selected based upon the contact information provided on each telematics provider's website. Interviewee selection will not be based upon sex/gender or race/ethnicity. The proposed dates for conducting these interviews will be January 2016 to March 2016.

An online survey will be utilized to ascertain opinions of subject matter experts in the field of homeland security, highway motor carrier transportation and terrorism. This is a select group of individuals who will be contacted based upon the information available online. For example, a representative from State Police and/or Commercial Vehicle Enforcement from each state will be invited to participate. The same process will be conducted for a number of state and federal agencies such as the Federal Motor Carriers Administration; Pipeline and Hazardous Materials Administration; State Transportation Agencies; State Emergency Management; Transportation Security Administration and the Department of Homeland Security. Survey participants will also be invited from select industry groups that deal specifically with the transportation of Tier 1 hazardous materials. An example of such a group includes the Institute of Makers of Explosives. Additionally, survey participants will be invited to participate from academia. These academics will be selected based upon their affiliations and publications in the field of hazardous materials transportation. The subject matter experts will be selected purely for their expertise and will not be selected based upon sex/gender or race/ethnicity. The proposed dates for conducting the survey are January 2016 to April 2016. I anticipate that in excess of 250 participants will be invited to participate in total. Ideally I will receive a 20% response rate to make my findings statistically significant.

#### **5. Subject Recruitment Methods and Privacy:**

Subjects will be recruited in a number of ways. Firstly the General Dynamics staff that participated in the original research will be contacted and recruited to participate in the semi-structured interviews. The contacted members will be based upon the published report. Initial contact will be made via phone.

Phone interviews will also be conducted with the telematics provider's representative. In this instance, sales personnel from each of the companies should be able to provide all the necessary information. The contact information for these representatives will be taken from the contact information available on each of the companies websites.

The online survey requires a broader range of participants. Each of these participants will be contacted via email to participate in the study. Each of these emails will be obtained from online sources, such as the contact page for each of the agencies. In the case of academics, contact information of individuals is typically listed on published material.

Each recruitment method involves publically available information.

#### **6. Informed Consent Process:**

Informed consent will be different for the interview subjects and the survey participants. The interview subjects will be provided written informed consent. A copy of the consent form will be emailed to the survey participant ahead of time so they can read it. The consent will be confirmed over the phone by the PI Doug Kreis. At that point in time Doug will answer any questions the interview participants may have. Informed consent will be obtained only by the PI. No one except the participant may give consent, and no one but the PI is authorized in this study to receive it. The informed consent will be confirmed at the beginning of the interview.

For the online survey, informed consent will be provided via the initial email contact that is made with the survey participant in the form of a survey cover letter.

#### **7. Research Procedures:**

The research procedures to be followed for the semi-structured interviews will be to have detailed questions prepared for the interview, and then to allow the interviewee to direct the conversation, adhering to the questions only if the conversation loses focus.



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For the online survey, the participants will be invited via email. The email addresses will have been gathered through publically available information on each of the organizations websites. In some cases, the email will be sent to an individual identified as being responsible, or to a general information request. Follow-up contact will be made to each email address 2 weeks after initial contact, and again 2 weeks later to request participation. At this point no further contact will be made.

**8. Resources:**

The online survey will be designed using the Qualtrics survey tool available to all University of Kentucky researchers. The survey will be distributed and administered by the PI Doug Kreis. The PI will be the only person with access to the survey and the survey responses.

Phone interviews will be conducted by the PI Doug Kreis. In the case of the General Dynamics staff, the original study participants are known to the PI, and conducting the interviews over the phone will elicit the necessary information. The interview contents will not be disclosed and the individual participant responses will remain confidential.

**9. Potential Risks:**

There are no risks associated with this research project. Information will remain confidential, and responses are gathered to inform the research equation and truck tracking framework. Individuals will not be identifiable through the end result.

**10. Safety Precautions:**

All data collected through the course of this research project will be kept in electronic files on the researcher's university issued desktop computer, used only for the purpose of this project. Data collected containing any identifiers will not be shared amongst participants or any other individual. Identifiers will not be used in any public presentation of the research material. Identifiers will only be collected if the survey and or interview participants give their consent.

**11. Benefit vs. Risk:**

The conceptual system outlined for use here could be used by governmental agencies, such as the TSA, to monitor and track the changing risk profiles of Tier 1 HSSMs as they crisscross the vast network of U.S. surface infrastructure. Improving our situational awareness of the location of Tier 1 HSSMs will provide local, state, and federal agencies tasked with securing them and responding in the case of a release – whether intentional or accidental – with critical knowledge to execute their designated functions. The benefits of such a system to enhancing safety and security of the US highway system would be enjoyed by both the general public and government agencies. There are no risks to the research participants.

**12. Available Alternative Treatment(s):**

Not Applicable

**13. Research Materials, Records, and Privacy:**

The research material obtained will be sourced through the online survey and the phone interviews. The information recorded in the survey will be the responses to the survey questions (attached in Appendix B). The information obtained in the phone interviews will be documented by the PI.

The information from the online survey is necessary to gather subject matter expert opinion in relation to the riskiness of particular shipments and potential attack modes. This information will be utilized to inform the equation that will measure the risk of a particular shipment as it moves across the highway. The qualtrics web-based survey is an independent proprietary survey program that is subscribed to by the University of Kentucky.

The information gathered in the phone interviews with general dynamics staff will be used to ascertain what will and will not work in designing the system architecture for a truck tracking and risk management system.

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The information gathered in the phone interviews with the telematics provider's will be used to determine the current technology available to the trucking industry, and identify any technology gaps that may exist for the implementation of a truck tracking and risk management system.

**14. Confidentiality:**

The data generated during the course of the study will be stored on the PI's desktop computer. This data will be password protected, and no one will have access to the desktop or the office except the PI. The data will be destroyed 6 years after completion of the project. PI generated notes pertaining to conversations will be kept in a locked file cabinet, inside the PI's locked office on the University of Kentucky campus. After the 6 years of holding the records has lapsed, the desktop hard drive will be wiped by the College of Engineering's computer technician.

Additionally, no information or data generated during the course of the study will be sent to anyone via email.

**15. Payment:**

Not Applicable

**16. Costs to Subjects:**

Not Applicable

**17. Data and Safety Monitoring:**

Not Applicable

**18. Subject Complaints:**

Interviewees and survey participants will be given contact information for the Department of Civil Engineering, the PI's advisor, and the Office of Research Integrity at UK so that the participants can discuss problems, concerns and question, and obtain information about the project from someone other than the PI.

**19. Research Involving Non-English Speaking Subjects or Subjects from a Foreign Culture:**

Not Applicable

**20. HIV/AIDS Research:**

Not Applicable

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### Appendix A

In October 2005, General Dynamics began work on a Hazmat Truck Security Pilot (HTSP). The purpose of this program was to demonstrate whether “smart truck” technology could be incorporated into an effective and efficient system for tracking hazmat shipments. While this study verified a tracking system could be implemented, there were many shortcomings with the system design that would have prevented the General Dynamics system from being implemented on a nationwide scale. Some of these issues were related to system architecture, while others stemmed from the system malfunctioning during testing. This set of interview questions will be administered during conversations with General Dynamics personnel, the U.S. Transportation Security Administration’s independent verification and validation contractor – which evaluated the prototype for the federal government, – U.S. Department of Homeland Security staff, and private sector stakeholders to identify a set of lessons learned from the HTSP. While these questions are concerned with understanding how engineering principles are used in an applied context, this knowledge is of academic value in that it can inform literature focused on the design and implementation of complex systems. Interviews will use a semi-structured format. That is, all participants, regardless of background, will be asked the questions listed below; however, when a participant brings up a point that requires further exploration because it promises to deepen our conceptual knowledge, I will pursue those lines of inquiry in a more unstructured manner. Follow-up questions that depart from the list below will be recorded in interview notes.

### *Questions*

1. Describe your involvement in the HTSP (e.g. designer, engineer, evaluator).
2. From your perspective, did this program adequately demonstrate that “smart truck” technology could be used to track and monitor hazardous materials shipments?
3. A key component of HTSP development was the Transportation Event Analysis and Management System (TEAMS), an event-based system that stored and displayed information relating to potential transportation security incidents. What were the major shortcomings TEAMS and HTSP technology prototypes more generally?
  - a. How did these defects impact overall system performance?
  - b. Were any components of the system particularly vulnerable to failure?
  - c. During prototype testing, what were the most significant problems?
    - i. Would any of these problems inhibit the implementation of a truck-tracking system?  
If so, which ones?
4. Did the HTSP technology prototype meet the needs of a wide range of users (e.g. security specialists, private sector entities, state and federal governments)? If not, what design changes would be necessary to make the system more accommodating?
5. TEAMS used several geo-fencing algorithms to identify when and where a potential transportation security incident was underway. Were the assumptions underpinning geo-fencing conceptually and empirically sound? If not, what changes would be necessary to implement a more robust tracking and monitoring system?
  - a. Should geographic information systems (GIS) be used more extensively when refining geo-fencing solutions?
6. The HTSP technology prototype used an already-existing commercial product, FdFolio™, to perform risk analysis on hazmat shipments. Were the risk calculation methods implemented by this software appropriate for a monitoring and tracking system?
  - a. If not, what changes would you suggest to improve risk calculations and therefore enhance the visibility of potentially vulnerable shipments?
  - b. Is a more dynamic form of risk calculation appropriate?
  - c. What variables are most important for accurately estimating the level of risk associated with a hazmat shipment?

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7. The independent verification and validation contractor put forward 11 recommendations to build upon and improve the HTSP technology prototype. Which of these suggestions do you feel it would be most critical to implement during future phases of system development, and which would yield the most significant security benefits?
8. The HTSP technology prototype design did not explicitly cater to the Tier 1 HSSMs. Bearing in mind that future system development will exclusively target this class of hazardous materials, what changes should be made to the technology prototype to comply with current governmental regulations pertaining to their security.
9. Should e-manifests and electronic route preparation be more integral for the tracking and monitoring system?
10. What attributes would a successful truck tracking center possess (this applies to the performance of security specialists, software design, communication between stakeholders, or any other factor that you believe warrants particular scrutiny)?

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#### Appendix B

#### Hazardous Materials Transport Survey

Name (optional):

Title:

Organization:

#### Attack Modes:

Please examine the following attack scenarios involving commercial motor vehicles hazardous materials and rank each one from 1-5 according to likelihood (this is a modified Likert Scale). Here, a 1 indicates the scenario is extremely unlikely to occur, and a 5 indicates occurrence is very probable.

Attack Mode Description	Ranking
• Explosive device placed on a commercial motor vehicle (CMV)	
• Explosive device placed on highway infrastructure of a planned CMV route	
• Weapon launched at a CMV from a distance (e.g. high powered rifle, rocket propelled grenade)	
• Explosive device placed in a vehicle near a CMV (i.e. Vehicle Borne Improvised Explosive Device – VBIED)	
• A hijacker commandeers a CMV to immediately release hazardous materials or catalyze an explosion	
• A hijacker commandeers a CMV and drives it to a nearby location with the intent of releasing hazardous materials or catalyzing an explosion	
• An insider (e.g. trucking firm employee) commandeers a CMV to immediately release hazardous materials or catalyze and explosion	
• An insider (e.g. trucking firm employee) commandeers a CMB and drives it to a nearby location with the intent of releasing hazardous materials or catalyzing an explosion	
• Sabotage of TIH cargo tank motor vehicle (e.g. opening or damaging a valve)	
• External crash initiate (e.g. placing something on the roadway, collision with another vehicle)	
• An aircraft is used to attack a hazardous material shipment	
• Chemical, biological, radiological or nuclear	

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attack (CBRN)	
• A waterborne vessel carrying an IED explodes close to a CMV	
• Coordinated or sequential attacks (e.g. sabotage of a truck's braking system and subsequent use of a rocket-propelled grenade once the vehicle crashes)	
• Burglary or theft of hazmat materials (i.e. removing the materials from the vehicle)	
• Damage to hazardous materials (through vandalism or some other means) that does not produce a release or explosion	
• Cyber-attack causing theft/diversion (e.g. electronically changing a manifest so that hazmat are delivered to an improper destination)	
• Natural disasters (e.g. hurricane, tornado, earthquake)	

- Based on your professional experience, which of the preceding scenarios are in your opinion the most likely?
- Why do these particular scenarios merit extra scrutiny?

**Threat Analysis Questions**

- The following questions relate to threat analysis for highway motor carriers transporting hazardous materials.

Which of the following hazardous materials classes should be considered in dynamic threat calculations? (Dynamic meaning a threat value that would change as the location of the material changed both temporally and spatially).

<b>Hazardous Materials Class</b>	<b>Inclusion? (Yes/No)</b>
<b>Class 1: Explosives</b>	
<b>Class 2: Gasses</b>	
<b>Class 3: Flammable Liquid and Combustible Liquid</b>	
<b>Class 4: Flammable Solid, Spontaneously Combustible, and Dangerous When Wet</b>	
<b>Class 5: Oxidizer and Organic Peroxide</b>	
<b>Class 6: Poison (Toxic) and Poison Inhalation Hazard</b>	
<b>Class 7: Radioactive</b>	
<b>Class 8: Corrosive</b>	
<b>Class 9: Miscellaneous Materials – Chemical Weapons</b>	

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#### Trailer and Container Type

- Threat varies depending on the trailer and type of container holding hazardous materials. The list below is of trailer and container types. Please order them from 1-6 with respect to their vulnerability to potential terrorists attacks. “1” equals the *highest* threat, while “6” is the *lowest* vulnerability.

Trailer/Container Type	Vulnerability Ranking (1-6)
Van Trailer	
Cargo Tank	
Container	
Hopper	
Flatbed	
Other	

- The attractiveness of a CMV carrying hazardous materials is contingent on numerous factors, such as proximity of critical infrastructure, key resources, and population density. Which factors, based on your professional experience, do you believe contribute the most to elevating the dynamic threats a Tier 1 HSSM shipment encounters?

#### Vulnerability Analysis

- The CIA and other intelligence agencies use the Kent Scale to convert linguistic statements into quantitative probabilities in order to determine the likelihood that a scenario will play out. For example, in the table below, there are a series of descriptions about the challenges involved in executing an attack against a hazardous materials shipment. The first statement, “Attack is not challenging and simple to execute,” denotes a linguistic possibility of “Certain,” and a quantitative probability that the attack will *not fail* because of technical obstacles of 1.0 Please examine the following Kent Scale and answer the associated question:

- V is Vulnerability

-  $V_{\text{no failure (tech)}}$  = probability attackers do not fail due to the technical challenges of carrying out the attack

Kent Scale for $V_{\text{no failure (tech)}}$		
Description	Linguistic Probability	$V_{\text{no failure (tech)}}$ (0-1)
Attack is not challenging and simple to execute	Certain	1.0
Attack is somewhat challenging and relatively simple to execute	Nearly Certain	0.93
Attack is challenging and somewhat complex, requiring good logistics and coordination	Probable	0.75
Attack is challenging and complex, requiring substantial logistics and coordination	Chances even	0.5
Attack is very challenging and complex, requiring substantial logistics and coordination	Probably not	0.3
Attack is very challenging and very complex, requiring substantial logistics, coordination and resources	Highly Doubtful	0.07
Attack is very challenging and extremely complex requiring substantial logistics, sophisticated coordination and significant resources	Practically impossible	0.01
Attack is not possible	Not Possible	0.0

- Given your experience do the assigned probabilities seem reasonable?

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- If not, how should the probabilities be adjusted?

- Please examine the following Kent Scale and answer the associated question:

- Here, V = Vulnerability, and

-  $V_{\text{no failure (secure)}}$  = probability attackers do not fail because of security measures

<b>Kent Scale for <math>V_{\text{no failure (secure)}}</math></b>		
<b>Description</b>	<b>Linguistic Probability</b>	<b><math>V_{\text{no failure (secure)}}</math> (0-1)</b>
<b>No security processes/procedures in place</b>	Certain	1.0
<b>Personnel security and access control in place with minimal effectiveness</b>	Nearly Certain	0.93
<b>Personnel security and access control in place with limited effectiveness</b>	Probable	0.75
<b>Personnel security, access control, and en-route security in place with moderate effectiveness</b>	Chances even	0.5
<b>Personnel security, access control and en route security in place with significant effectiveness</b>	Probably not	0.3
<b>Personnel security, access control, and en-route security in place with high effectiveness</b>	Highly Doubtful	0.07
<b>Personnel security, access control, and en-route security in place with maximum effectiveness</b>	Practically impossible	0.01
<b>Personnel security, access control, and en-route security in place with complete effectiveness</b>	Not Possible	0.0

- Given your experience do the assigned probabilities seem reasonable?
- If not, what alternatives do you suggest, or which probabilities would you change?

- Based upon your professional knowledge, judgment, and experience please assign  $V_{\text{no failure (tech)}}$  (0-1) and  $V_{\text{no failure (secure)}}$  (0-1) values to the following hypothetical scenarios table:

<b>Scenario</b>	<b>Attack Mode</b>	<b>Hazmat</b>	<b>Truck/Container Combination</b>	<b><math>V_{\text{no failure (tech)}}</math> (0-1)</b>	<b><math>V_{\text{no failure (secure)}}</math> (0-1)</b>
<b>1</b>	Explosive device on CMV	Class 1 Explosives	Van Trailer		
<b>2</b>	Explosive device on CMV	Class 1 Explosives	Container		
<b>3</b>	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Van Trailer		
<b>4</b>	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Cargo Tank		
<b>5</b>	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Container		
<b>6</b>	Explosive device on the highway infrastructure	Class 1 Explosives	Van Trailer		
<b>7</b>	Explosive device on the	Class 1 Explosives	Container		

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	highway infrastructure				
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- Are there other evaluation methods (i.e. other than the Kent Scale) that would be appropriate for estimating the vulnerability of a given shipment? If so, describe the method you have in mind, provide a 2-3-sentence description of how it works, and a brief statement of why it offers a superior manner of risk assessment.

**Consequence Analysis**

- Consequences are the effects that result from a terrorist attack and hazardous materials release. Four dimensions of consequences—human, economic, mission, and psychological—are often considered when assessing the potential outcomes of an attack. In some cases, factors such as environmental conditions may be important as well, and therefore figured into consequence assessments. Look at the following entities and categories, each of which may be impacted from a hazardous materials release. Using the scale provided, rank the impact each one would have on the aggregate consequences of an attack. **Here 1 is no impact, and 5 is a very high impact.**

Consequence	Ranking
<b>Population</b>	
<b>Critical Infrastructure</b>	
<b>Key Resources</b>	
<b>Environmentally Sensitive Areas</b>	
<b>Economic Impact</b>	
<b>Public Psychology/Fear</b>	
<b>International Politics</b>	
<b>Civil Liberties</b>	

**Concluding Questions**

1. What considerations do you think are frequently omitted from assessments that evaluate the level of risk associated with hazardous materials shipments?
2. Do you think that a real-time monitoring and tracking system for hazard materials shipments would lead to the improved security of hazardous materials while expediting response times in the case of an attack?
3. If yes, what kinds of hazardous materials should this system prioritize?
4. How vulnerable to attacks do you think the United States’ highway motor carrier hazardous materials supply chain is?
5. What are the most pressing security challenges that shippers, carriers and consignees face with respect to the hazardous materials transportation security landscape?
6. In your view, what steps can public (i.e. federal and state governments) and private stakeholders take to enhance the security of hazardous materials shipments?



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**Script for Telematics Providers Phone Interviews**

Hello, we are researching the features of different tractor-based telematics systems. The information we collect will be used to compare the attributes of different systems. We will be evaluating their capacity to perform various functions. Our focus is on the appropriateness of systems for security-based applications. Specifically, our interest is in hazardous materials. We are designing a system that can be used to dynamically track the location of hazardous materials shipments as they move across road networks. With that in mind, we have several questions we would like to ask you about the telematics systems and services your company provides. Most of these are of a technical nature and are concerned with the features of your products and can be answered with either a “yes” or “no.” We are using a survey-style questionnaire to keep the research as objective as possible. At the end of the interview, if you have anything you would like to add — for example, wanting to draw attention to a particular component of the system that we did not ask about but think is salient to this project — you are welcome to do so. However, we cannot make any guarantees as to whether this information will be included in our final report. Thank you for your time.

Questions:

- Does your system have the capability of offering panic buttons?
- Does your system provide push to talk buttons that will automatically connect with a service center?
- Does your system provide gate-in and gate-out buttons?
- Does your system have text display?
- Does your system have a keypad that allows a driver to enter information?
- Does the onboard computer have a Bluetooth connection?
- Does the onboard computer link to both mobile devices and the in cab terminal?
- Does your system have a GPS Satellite Receiver?
- Does your system have GSM jamming detection capability?
- Does your system offer a hybrid satellite/cellular modem?
- Does the system have an impact/accident alert feature?
- Does the system have any equipment tampering detection available?



## Consent to Participate in a Research Study

### **Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

#### **WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

You are being invited to take part in a research study about the shipment of Tier 1 hazardous materials by highway motor carriers. The purpose of the study is to assess the need and technology available to design a truck tracking and risk management system. You are being invited to take part in this research study because of your subject matter expertise in relation to truck telematics. If you volunteer to take part in this study, you will be one of about five people to provide information on truck telematics systems available in North America.

#### **WHO IS DOING THE STUDY?**

The person in charge of this study is Steven Douglas (Doug) Kreis (*Principal Investigator, PI*) of University of Kentucky Department of Civil Engineering. Doug is a doctoral candidate in the Department of Civil Engineering, and he is being guided in his research by Dr. Tim Taylor (Advisor).

#### **WHAT IS THE PURPOSE OF THIS STUDY?**

By doing this study, we hope to learn about the range of telematics providers available to the trucking industry, and the range of services that those providers offer. The hope is to ascertain the current technology available, and the cost of this technology to the individual truck driver.

#### **ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?**

No.

#### **WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?**

The research procedures will be conducted at College of Engineering, in the University of Kentucky. The interview will be conducted over the phone, and it is estimated to take 45-60 minutes of your time. You will be contacted during regular business hours, at a time that is most convenient to you.

#### **WHAT WILL YOU BE ASKED TO DO?**

You will be asked questions about the telematics system that your company offers to the trucking industry. These questions will cover aspects such as cost of initial installation, monthly costs, system operations requirements and/or platforms, tracking capabilities and technology employed (e.g. GPS, or satellite) and any additional features or services offered as a part of your device.

## **WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

## **WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

You will not get any personal benefit from taking part in this study.

## **DO YOU HAVE TO TAKE PART IN THE STUDY?**

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

## **IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you do not want to be in the study, there are no other choices except not to take part in the study.

## **WHAT WILL IT COST YOU TO PARTICIPATE?**

There are no costs associated with taking part in the study.

## **WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.

## **WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep confidential all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. The data generated during the course of the study will be stored on the PI's desktop computer. This data will be password protected, and no one will have access to the desktop or the office except the PI. The data will be destroyed 6 years after completion of the project. PI generated notes pertaining to conversations will be kept in a locked file cabinet, inside the PI's locked office on the University of Kentucky campus. After the 6 years of holding the records has lapsed, the desktop hard drive will be wiped by the College of Engineering's computer technician. Additionally, no information or data generated during the course of the study will be sent to anyone via email.

We may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.

## **CAN YOUR TAKING PART IN THE STUDY END EARLY?**

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

#### **WHAT ELSE DO YOU NEED TO KNOW?**

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.

#### **WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Doug Kreis at 859-257-6898. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky between the business hours of 8am and 5pm EST, Mon-Fri. at 859-257-9428 or toll free at 1-866-400-9428.

## Consent to Participate in a Research Study

### **Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

#### **WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

You are being invited to take part in a research study about the shipment of Tier 1 hazardous materials by highway motor carriers. The purpose of the study is to assess the need and technology available to design a truck tracking and risk management system. You are being invited to take part in this research study because of your subject matter expertise in relation to the Hazmat Truck Security Pilot (HTSP) conducted beginning October 2005. If you volunteer to take part in this study, you will be one of about four people to provide information on the HTSP.

#### **WHO IS DOING THE STUDY?**

The person in charge of this study is Steven Douglas (Doug) Kreis (*Principal Investigator, PI*) of University of Kentucky Department of Civil Engineering. Doug is a doctoral candidate in the Department of Civil Engineering, and he is being guided in his research by Dr. Tim Taylor (Advisor).

#### **WHAT IS THE PURPOSE OF THIS STUDY?**

By doing this study, we hope to evaluate the HTSP, and develop a list of lessons learned during the initial pilot study. These lessons learned will be used to inform our system architecture for a truck tracking and risk management system that would serve the shippers, carriers and consignees involved in the hazardous material supply chain.

#### **ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?**

No.

#### **WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?**

The research procedures will be conducted at College of Engineering, in the University of Kentucky. The interview will be conducted over the phone, and it is estimated to take 45-60 minutes of your time. You will be contacted during regular business hours, at a time that is most convenient to you.

## **WHAT WILL YOU BE ASKED TO DO?**

You will be asked questions about your involvement in the HTSP. You will be asked to give your opinion on both the successes and failures of the original project. You will also be asked your opinion on the original study methods.

## **WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

## **WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

You will not get any personal benefit from taking part in this study.

## **DO YOU HAVE TO TAKE PART IN THE STUDY?**

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

## **IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you do not want to be in the study, there are no other choices except not to take part in the study.

## **WHAT WILL IT COST YOU TO PARTICIPATE?**

There are no costs associated with taking part in the study.

## **WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.

## **WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep confidential all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. The data generated during the course of the study will be stored on the PI's desktop computer. This data will be password protected, and no one will have access to the desktop or the office except the PI. The data will be destroyed 6 years after completion of the project. PI generated notes pertaining to conversations will be kept in a locked file cabinet, inside the PI's locked office on the University of Kentucky campus. After the 6 years of holding the records has lapsed, the desktop hard drive will be wiped by the College of Engineering's computer technician. Additionally, no information or data generated during the course of the study will be sent to anyone via email.

We may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Kentucky.

### **CAN YOUR TAKING PART IN THE STUDY END EARLY?**

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

### **WHAT ELSE DO YOU NEED TO KNOW?**

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.

### **WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Doug Kreis at 859-257-6898. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky between the business hours of 8am and 5pm EST, Mon-Fri. at 859-257-9428 or toll free at 1-866-400-9428.

## Kreis Survey Cover Letter

To XXXXX:

You are being invited to participate in an online survey for a project titled “Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain”. This survey is being completed as a part of a doctoral dissertation that seeks to develop a risk analysis and management protocol for Tier 1 highway security sensitive materials that will improve both the safety and security of highway based freight. This survey is being sent to subject matter experts in the field of highway security sensitive materials nationwide, including representatives from government agencies, private industry and academia. The purpose of the survey is to request your feedback and based upon your expertise rank a number of fields that will assist the PI Steven Kreis in developing a semi-quantitative risk equation. This equation will be used to analyze the risk of a particular shipment of hazardous material in both space and time. That is to assist in determining how the risk profile of a shipment will change as it moves across the country (rural as opposed to urban locations) and in time (daytime or rush hour as opposed to nighttime).

Although you will not get personal benefit from taking part in this research study, your responses may help us understand more about these shipments and the biggest risks associated with them, as perceived by our Nation’s leading experts and practitioners in this field.

We hope to receive completed questionnaires from about 200 people, so your answers are important to us. Of course, you have a choice about whether or not to complete the survey/questionnaire, but if you do participate, you are free to skip any questions or discontinue at any time.

The survey/questionnaire will take about 30 minutes to complete.

There are no known risks to participating in this study.

Although we have tried to minimize this, some questions may be beyond your area of expertise or you may feel uncomfortable providing a response. If this is the case you have the option to quit the survey, or preferably skip the question and continue with the questions you do feel comfortable answering.

Your response to the survey will be kept confidential to the extent allowed by law. When we write about the study you will not be identified.

Please be aware, while we make every effort to safeguard your data once received from the online survey/data gathering company, given the nature of online surveys, as with anything involving the Internet, we can never guarantee the confidentiality of the data while still on the survey/data gathering company’s servers, or while en route to either them or us. It is also possible the raw data collected for research purposes may be used for marketing or reporting purposes by the survey/data gathering company after the research is concluded, depending on the company’s Terms of Service and Privacy policies.

If you have questions about the study, please feel free to ask; my contact information is given below. I am a PhD candidate at the University of Kentucky, and this research will be used as a part of my doctoral degree. Study questions can also be directed to my faculty advisor Dr. Timothy Taylor, who can be contacted at the University of Kentucky [tim.taylor@uky.edu](mailto:tim.taylor@uky.edu) or 859 323 3680. If you have complaints, suggestions, or questions about your rights as a research volunteer, contact the staff in the University of Kentucky Office of Research Integrity at 859-257-9428 or toll-free at 1-866-400-9428.

Thank you in advance for your assistance with this important project. I would appreciate if you could respond at any time in the coming two weeks.

Sincerely,

Steven Douglas Kreis  
*College of Engineering,*  
University of Kentucky  
PHONE: 859-257-6898  
E-MAIL: [douglas.kreis@uky.edu](mailto:douglas.kreis@uky.edu)



<b>Principal Investigator: Steven Douglas Kreis</b>	<b>Date: 09/21/15</b>
<b>Study Title: Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain</b>	

**Form F  
Include in IRB Application to  
Waive Requirement for Documentation of Informed Consent**

**Check the box next to the option below that best fits your study, and explain in the space provided how your study meets the criteria for the selected regulatory option.**

Note: The IRB cannot waive the requirement for documentation or alter the consent form for FDA-regulated research unless it meets Option #2 below. FDA does not accept Option #1.

Note: Even if a waiver of the requirement for documentation is approved by the IRB, participants must still be provided oral or written (e.g., cover letter) information including all required and appropriate elements of consent.

<input type="checkbox"/>	<b>Option 1</b>
	a) The only record linking the participant and the research would be the consent document.
	b) The principal risk would be potential harm resulting from a breach of confidentiality (i.e., a study that involves participants who use illegal drugs).
	Under these conditions, each participant must be asked whether (s)he wants to sign a consent form; if the participant agrees to sign a consent form, only an IRB approved version should be used.

<input checked="" type="checkbox"/>	<b>Option 2</b>
	a) The research presents no more than minimal risk to the participant.
	b) The research involves no procedures for which written consent is normally required outside of the research context (i.e. a cover letter on a survey, or a phone script).
	The interviews will be conducted over the phone, and will have an accompanying email provided to the interviewees beforehand that covers all the necessary information involved in informed consent. This email will be tailored to each of the interviewees, and should reduce the burden on the individuals taking part in the phone interviews. The informed consent email will be tailored for a) the Telematics Providers and b) General Dynamics employees. The online survey will include a cover letter that explains the purpose of the study, and follows the template provided by IRB.

Form M Survey and Interview Questions  
Tier 1 hazardous materials shipment security – Addressing critical research gaps to  
secure the United States supply chain

**Interview Questions for General Dynamics**

In October 2005, General Dynamics began work on a Hazmat Truck Security Pilot (HTSP). The purpose of this program was to demonstrate whether “smart truck” technology could be incorporated into an effective and efficient system for tracking hazmat shipments. While this study verified a tracking system could be implemented, there were many shortcomings with the system design that would have prevented the General Dynamics system from being implemented on a nationwide scale. Some of these issues were related to system architecture, while others stemmed from the system malfunctioning during testing. This set of interview questions will be administered during conversations with General Dynamics personnel, the U.S. Transportation Security Administration’s independent verification and validation contractor – which evaluated the prototype for the federal government, – U.S. Department of Homeland Security staff, and private sector stakeholders to identify a set of lessons learned from the HTSP. In cataloguing lessons learned, future iterations of Fedtrak can be refined, and the appropriate systems engineering principles used, to improve system performance and meet the needs of multiple stakeholders. While these questions are concerned with understanding how engineering principles are used in an applied context, this knowledge is of academic value in that it can inform literature focused on the design and implementation of complex systems. Interviews will use a semi-structured format. That is, all participants, regardless of background, will be asked the questions listed below; however, when a participant brings up a point that requires further exploration because it promises to deepen our conceptual knowledge, I will pursue those lines of inquiry in a more unstructured manner. Follow-up questions that depart from the list below will be recorded in interview notes.

**Questions**

1. Describe your involvement in the HTSP (e.g. designer, engineer, evaluator).
2. From your perspective, did this program adequately demonstrate that “smart truck” technology could be used to track and monitor hazardous materials shipments?
3. A key component of HTSP development was the Transportation Event Analysis and Management System (TEAMS), an event-based system that stored and displayed information relating to potential transportation security incidents. What were the major shortcomings TEAMS and HTSP technology prototypes more generally?
  - a. How did these defects impact overall system performance?
  - b. Were any components of the system particularly vulnerable to failure?
  - c. During prototype testing, what were the most significant problems?
    - i. Would any of these problems inhibit the implementation of a truck-tracking system? If so, which ones?
4. Did the HTSP technology prototype meet the needs of a wide range of users (e.g. security specialists, private sector entities, state and federal governments)? If not, what design changes would be necessary to make the system more accommodating?
5. TEAMS used several geo-fencing algorithms to identify when and where a potential transportation security incident was underway. Were the assumptions underpinning geo-fencing conceptually and empirically sound? If not, what changes would be necessary to implement a more robust tracking and monitoring system?
  - a. Should geographic information systems (GIS) be used more extensively when refining geo-fencing solutions?
6. The HTSP technology prototype used an already-existing commercial product, FdFolio™, to perform risk analysis on hazmat shipments. Were the risk calculation methods implemented by this software appropriate for a monitoring and tracking system?
  - a. If not, what changes would you suggest to improve risk calculations and therefore enhance the visibility of potentially vulnerable shipments?
  - b. Is a more dynamic form of risk calculation appropriate?
  - c. What variables are most important for accurately estimating the level of risk associated with a hazmat shipment?
7. The independent verification and validation contractor put forward 11 recommendations to build upon and improve the HTSP technology prototype. Which of these suggestions do you feel it

- would be most critical to implement during future phases of system development, and which would yield the most significant security benefits?
8. The HTSP technology prototype design did not explicitly cater to the Tier 1 HSSMs. Bearing in mind that future system development will exclusively target this class of hazardous materials, what changes should be made to the technology prototype to comply with current governmental regulations pertaining to their security.
  9. Should e-manifests and electronic route preparation be more integral for the tracking and monitoring system?
  10. What attributes would a successful truck tracking center possess (this applies to the performance of security specialists, software design, communication between stakeholders, or any other factor that you believe warrants particular scrutiny)?

## Hazardous Materials Transport Survey for Subject Matter Experts

Organization:

### Attack Modes:

Please examine the following attack scenarios involving commercial motor vehicles hazardous materials and rank each one from 1-5 according to likelihood (this is a modified Likert Scale). Here, a 1 indicates the scenario is extremely unlikely to occur, and a 5 indicates occurrence is very probable.

Attack Mode Description	Ranking
• Explosive device placed on a commercial motor vehicle (CMV)	
• Explosive device placed on highway infrastructure of a planned CMV route	
• Weapon launched at a CMV from a distance (e.g. high powered rifle, rocket propelled grenade)	
• Explosive device placed in a vehicle near a CMV (i.e. Vehicle Borne Improvised Explosive Device – VBIED)	
• A hijacker commandeers a CMV to immediately release hazardous materials or catalyze an explosion	
• A hijacker commandeers a CMV and drives it to a nearby location with the intent of releasing hazardous materials or catalyzing an explosion	
• An insider (e.g. trucking firm employee) commandeers a CMV to immediately release hazardous materials or catalyze and explosion	
• An insider (e.g. trucking firm employee) commandeers a CMB and drives it to a nearby location with the intent of releasing hazardous materials or catalyzing an explosion	
• Sabotage of TIH cargo tank motor vehicle (e.g. opening or damaging a valve)	
• External crash initiate (e.g. placing something on the roadway, collision with another vehicle)	
• An aircraft is used to attack a hazardous material shipment	
• Chemical, biological, radiological or nuclear attack (CBRN)	
• A waterborne vessel carrying an IED explodes close to a CMV	
• Coordinated or sequential attacks (e.g. sabotage of a truck's braking system and subsequent use of a rocket-propelled grenade once the vehicle crashes)	

• <b>Burglary or theft of hazmat materials (i.e. removing the materials from the vehicle)</b>	
• <b>Damage to hazardous materials (through vandalism or some other means) that does not produce a release or explosion</b>	
• <b>Cyber-attack causing theft/diversion (e.g. electronically changing a manifest so that hazmat are delivered to an improper destination)</b>	
• <b>Natural disasters (e.g. hurricane, tornado, earthquake)</b>	

- Based on your professional experience, which of the preceding scenarios are in your opinion the most likely?
- Why do these particular scenarios merit extra scrutiny?

**Threat Analysis Questions**

- The following questions relate to threat analysis for highway motor carriers transporting hazardous materials.

Which of the following hazardous materials classes should be considered in dynamic threat calculations? (Dynamic meaning a threat value that would change as the location of the material changed both temporally and spatially)

<b>Hazardous Materials Class</b>	<b>Inclusion? (Yes/No)</b>
<b>Class 1: Explosives</b>	
<b>Class 2: Gasses</b>	
<b>Class 3: Flammable Liquid and Combustible Liquid</b>	
<b>Class 4: Flammable Solid, Spontaneously Combustible, and Dangerous When Wet</b>	
<b>Class 5: Oxidizer and Organic Peroxide</b>	
<b>Class 6: Poison (Toxic) and Poison Inhalation Hazard</b>	
<b>Class 7: Radioactive</b>	
<b>Class 8: Corrosive</b>	
<b>Class 9: Miscellaneous Materials – Chemical Weapons</b>	

**Trailer and Container Type**

- Threat varies depending on the trailer and type of container holding hazardous materials. The list below is of trailer and container types. Please order them from 1-6 with respect to their vulnerability to potential terrorists attacks. “1” equals the *highest* threat, while “6” is the *lowest* vulnerability.

<b>Trailer/Container Type</b>	<b>Vulnerability Ranking (1-6)</b>
<b>Van Trailer</b>	
<b>Cargo Tank</b>	
<b>Container</b>	
<b>Hopper</b>	
<b>Flatbed</b>	
<b>Other</b>	

- The attractiveness of a CMV carrying hazardous materials is contingent on numerous factors, such as proximity of critical infrastructure, key resources, and population density. Which factors, based on your professional experience, do you believe contribute the most to elevating the dynamic threats a Tier 1 HSSM shipment encounters?

### **Vulnerability Analysis**

- The CIA and other intelligence agencies use the Kent Scale to convert linguistic statements into quantitative probabilities in order to determine the likelihood that a scenario will play out. For example, in the table below, there are a series of descriptions about the challenges involved in executing an attack against a hazardous materials shipment. The first statement, “Attack is not challenging and simple to execute,” denotes a linguistic possibility of “Certain,” and a quantitative probability that the attack will *not fail* because of technical obstacles of 1.0 Please examine the following Kent Scale and answer the associated question:

- V is Vulnerability

-  $V_{\text{no failure (tech)}}$  = probability attackers do not fail due to the technical challenges of carrying out the attack

<b>Kent Scale for <math>V_{\text{no failure (tech)}}</math></b>		
<b>Description</b>	<b>Linguistic Probability</b>	<b><math>V_{\text{no failure (tech)}}</math> (0-1)</b>
<b>Attack is not challenging and simple to execute</b>	Certain	1.0
<b>Attack is somewhat challenging and relatively simple to execute</b>	Nearly Certain	0.93
<b>Attack is challenging and somewhat complex, requiring good logistics and coordination</b>	Probable	0.75
<b>Attack is challenging and complex, requiring substantial logistics and coordination</b>	Chances even	0.5
<b>Attack is very challenging and complex, requiring substantial logistics and coordination</b>	Probably not	0.3
<b>Attack is very challenging and very complex, requiring substantial logistics, coordination and resources</b>	Highly Doubtful	0.07
<b>Attack is very challenging and extremely complex requiring substantial logistics, sophisticated coordination and significant resources</b>	Practically impossible	0.01
<b>Attack is not possible</b>	Not Possible	0.0

- Given your experience do the assigned probabilities seem reasonable?
- If not, how should the probabilities be adjusted?

- Please examine the following Kent Scale and answer the associated question:

- Here, V = Vulnerability, and

-  $V_{\text{no failure (secure)}}$  = probability attackers do not fail because of security measures

<b>Kent Scale for <math>V_{\text{no failure (secure)}}</math></b>		
<b>Description</b>	<b>Linguistic Probability</b>	<b><math>V_{\text{no failure (secure)}}</math> (0-1)</b>
<b>No security processes/procedures in place</b>	Certain	1.0
<b>Personnel security and access control in place with minimal effectiveness</b>	Nearly Certain	0.93
<b>Personnel security and access control in place with limited effectiveness</b>	Probable	0.75
<b>Personnel security, access control, and en-route security in place with moderate effectiveness</b>	Chances even	0.5
<b>Personnel security, access control and en route security in place with significant effectiveness</b>	Probably not	0.3
<b>Personnel security, access control, and en-route security in place</b>	Highly	0.07

with high effectiveness	Doubtful	
Personnel security, access control, and en-route security in place with maximum effectiveness	Practically impossible	0.01
Personnel security, access control, and en-route security in place with complete effectiveness	Not Possible	0.0

- Given your experience do the assigned probabilities seem reasonable?
- If not, what alternatives do you suggest, or which probabilities would you change?

- Based upon your professional knowledge, judgment, and experience please assign  $V_{\text{no failure (tech)}}$  (0-1) and  $V_{\text{no failure (secure)}}$  (0-1) values to the following hypothetical scenarios table:

Scenario	Attack Mode	Hazmat	Truck/Container Combination	$V_{\text{no failure (tech)}}$ (0-1)	$V_{\text{no failure (secure)}}$ (0-1)
1	Explosive device on CMV	Class 1 Explosives	Van Trailer		
2	Explosive device on CMV	Class 1 Explosives	Container		
3	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Van Trailer		
4	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Cargo Tank		
5	Explosive device on CMV	Class 2 Gases (non-flammable and toxic)	Container		
6	Explosive device on the highway infrastructure	Class 1 Explosives	Van Trailer		
7	Explosive device on the highway infrastructure	Class 1 Explosives	Container		

- Are there other evaluation methods (i.e. other than the Kent Scale) that would be appropriate for estimating the vulnerability of a given shipment? If so, describe the method you have in mind, provide a 2-3-sentence description of how it works, and a brief statement of why it offers a superior manner of risk assessment.

### Consequence Analysis

- Consequences are the effects that result from a terrorist attack and hazardous materials release. Four dimensions of consequences—human, economic, mission, and psychological—are often considered when assessing the potential outcomes of an attack. In some cases, factors such as environmental conditions may be important as well, and therefore figured into consequence assessments. Look at the following entities and categories, each of which may be impacted from a hazardous materials release. Using the scale provided, rank the impact each one would have on the aggregate consequences of an attack. **Here 1 is no impact, and 5 is a very high impact.**

Consequence	Ranking
Population	
Critical Infrastructure	
Key Resources	
Environmentally Sensitive Areas	
Economic Impact	
Public Psychology/Fear	
International Politics	

**Concluding Questions**

1. What considerations do you think are frequently omitted from assessments that evaluate the level of risk associated with hazardous materials shipments?
2. Do you think that a real-time monitoring and tracking system for hazard materials shipments would lead to the improved security of hazardous materials while expediting response times in the case of an attack?
3. If yes, what kinds of hazardous materials should this system prioritize?
4. How vulnerable to attacks do you think the United States' highway motor carrier hazardous materials supply chain is?
5. What are the most pressing security challenges that shippers, carriers and consignees face with respect to the hazardous materials transportation security landscape?
6. In your view, what steps can public (i.e. federal and state governments) and private stakeholders take to enhance the security of hazardous materials shipments?



### Script for Telematics Providers Phone Interviews

Hello, we are researching the features of different tractor-based telematics systems. The information we collect will be used to compare the attributes of different systems. We will be evaluating their capacity to perform various functions. Our focus is on the appropriateness of systems for security-based applications. Specifically, our interest is in hazardous materials. We are designing a system that can be used to dynamically track the location of hazardous materials shipments as they move across road networks. With that in mind, we have several questions we would like to ask you about the telematics systems and services your company provides. Most of these are of a technical nature and are concerned with the features of your products and can be answered with either a “yes” or “no.” We are using a survey-style questionnaire to keep the research as objective as possible. At the end of the interview, if you have anything you would like to add — for example, wanting to draw attention to a particular component of the system that we did not ask about but think is salient to this project — you are welcome to do so. However, we cannot make any guarantees as to whether this information will be included in our final report. Thank you for your time.

#### Questions:

- Does your system have the capability of offering panic buttons?
- Does your system provide push to talk buttons that will automatically connect with a service center?
- Does your system provide gate-in and gate-out buttons?
- Does your system have text display?
- Does your system have a keypad that allows a driver to enter information?
- Does the onboard computer have a Bluetooth connection?
- Does the onboard computer link to both mobile devices and the in cab terminal?
- Does your system have a GPS Satellite Receiver?
- Does your system have GSM jamming detection capability?
- Does your system offer a hybrid satellite/cellular modem?
- Does the system have an impact/accident alert feature?
- Does the system have any equipment tampering detection available?



FORM Z  
SIGNATURE ASSURANCE SHEET

**Study Title: Tier 1 hazardous materials shipment security – Addressing critical research gaps to secure the United States supply chain**

---

**Principal Investigator’s Assurance Statement:**

I understand the University of Kentucky's policies concerning research involving human subjects and I agree:

1. to comply with all IRB policies, decisions, conditions, and requirements;
2. to accept responsibility for the scientific and ethical conduct of this research study;
3. to obtain prior approval from the Institutional Review Board before amending or altering the research protocol or implementing changes in the approved consent/assent form;
4. to report to the IRB in accord with IRB/IBC policy, any adverse event(s) and/or unanticipated problem(s) involving risks to subjects;
5. to complete, on request by the IRB, the Continuation/Final Review Forms;
6. to notify the Office of Sponsored Projects Administration (OSPA) and/or the IRB (when applicable) of the development of any financial interest not already disclosed;
7. each individual listed as study personnel in this application has received the mandatory human research protections education (e.g., Dunn & Chadwick, CITI);
8. each individual listed as study personnel in this application possesses the necessary experience for conducting research activities in the role described for this research study.

Furthermore, by signing below, I also attest that I have appropriate facilities and resources for conducting the study.

SIGNATURE \_\_\_\_\_ DATE \_\_\_\_\_

NAME TYPED Steven Douglas Kreis\_\_\_\_\_

**\*Department Chairperson’s Assurance Statement:**

This is to certify that I have reviewed this research protocol and that I attest to the scientific validity and importance of this study; to the qualifications of the investigator(s) to conduct the project and their time available for the project; that facilities, equipment, and personnel are adequate to conduct the research; and that continued guidance will be provided as appropriate. When the principal investigator assumes a sponsor function, the investigator is knowledgeable of the additional regulatory requirements of the sponsor and can comply with them.

SIGNATURE \_\_\_\_\_ DATE \_\_\_\_\_

NAME TYPED \_Reginald R. Souleyrette \_\_\_\_\_

**\*If the Principal Investigator is also the Chairperson of the department, the Vice Chairperson or equivalent should sign the Signature Assurance Sheet.**

**\*\*Faculty Advisor’s Assurance Statement:**

This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of this study; to the qualifications of the investigator(s) to conduct the project; that facilities, equipment, and personnel are adequate to conduct the research; and that continued guidance will be provided as appropriate.

SIGNATURE \_\_\_\_\_ DATE \_\_\_\_\_

NAME TYPED \_Timothy R.B. Taylor\_\_\_\_\_

**\*\*If the Principal Investigator is completing this project to meet the requirements of a University of Kentucky academic program, the student’s faculty advisor, in addition to the Department Chairperson, should sign the Signature Assurance Sheet. The student’s faculty advisor is accepting a supervisory role in guiding the**

**student in conducting regulatory compliant research and therefore must be certified in human research protection training throughout the life of the protocol.**

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Zhang, J., Hodgson, J., & Erkut, E. (2000). Using GIS to assess the risks of hazardous materials transport in networks. *European Journal of Operational Research*, 121(2), 316-329.

## VITA

### Steven Douglas Kreis, PE, MBA, PMP

#### **EDUCATION**

- MPS in Supply Chain Management, Penn State University, 2013
- MA in Education, University of Kentucky, 1998
- MBA, University of Kentucky, 1996
- Graduate Certificate in Transportation Planning, University of Kentucky, 1996
- BS in Mining Engineering, University of Kentucky, 1995

#### **PROFESSIONAL DESIGNATIONS AND AWARDS**

- Geographical Information Systems Professional, GIS Certification Institute, Des Plaines, IL, 2014
- Professional Designation in Logistics and Supply Chain Management, American Society of Transportation and Logistics, Warrenton, VA, 2012
- Project Management Professional (PMP) Certification, Project Management Institute, New York, NY, 2000
- Facilitation Certification, Institute of Cultural Affairs, Phoenix, AZ, 2000
- Kentucky Professional Engineer (PE) Certification, State of Kentucky, 1999
- Certificate in Environmental Issues, University of Kentucky, 1995

#### **PROFESSIONAL EXPERIENCE**

- Associate Director, Kentucky Transportation Center, April 2014 - present
  - Manages several key areas including Traffic and Safety, Economics Finance and Multimodal, Intelligent Transportation Systems, Project Development, Technology Transfer, Special Projects and Initiatives, Information Technology, and Marketing.
- Program Manager/Transportation Research Engineer, Kentucky Transportation Center, May 1995 – March 2014
  - Oversaw the Freight and Logistics Program
- Owner, President, and CEO of SDKCE, January 2000 – present
  - Administrative management of a construction engineering consulting company
- Associate Staff Engineer, Traffic Engineering, Lexington Fayette Urban County Government, January 1998 – January 1999

## **RESEARCH INTERESTS AND SELECTED PROJECTS**

- North American Transportation Security Center. Funded by the National Institute for Hometown Security, Department of Homeland Security and Transportation Security Administration. PI. June 2007 – June 2013.
- Port Sustainability Audit Content/Processes. Funded by the Research and Innovative Technology Administration. PI with Co-PI Sarah McCormack. January 2012 – December 2013. \$142,755.
- Inland Waterway Shipment Management System. Funded by the Research and Innovative Technology Administration. PI with Co-PI Sarah McCormack. January 2012 – December 2013. \$254,590.
- Green Infrastructure. Funded by the Kentucky Transportation Center. KYSPR 12-477. Co-PI with PI Sarah McCormack. July 2011 – June 2013. \$130,000.
- Temporary Flood Barriers. Funded by the Kentucky Transportation Center. KYSPR-12-466. Co-PI with PI Sarah McCormack. July 2011– June 2012. \$65,000.
- Temporary Flood Barriers Implementation Study. Funded by the Kentucky Transportation Center. KYSPR 12-448. Co-PI with PI Sarah McCormack. July 2012 – June 2013. \$25,000.
- Jurisdictional Roadside Ditch Replacement. Funded by the Kentucky Transportation Center. KYSPR 13-458. Co-PI with PI Sarah McCormack. July 2012 – June 2015. \$195,000.
- Expanded CVISN 2008 – RFID, Virtual Weigh Station, Electronic Permitting for OSOW.
- Real ID – Management for Implementing the Requirements of Real ID in Kentucky.
- NATSC – Fedtrak Specifications and Release Plan, Marketing Initiative, Database Design, Development of Shipper and Carrier Portals, Routing Release 1 Multimodal.
- Transportation Infrastructure Consortium (MTIC) Management, Predictive Model Analysis for Inland Waterway, Port Sustainability Initiatives, Certain Dangerous Cargo Analysis, Finance Mechanism for Inland Waterways.

## **SELECTED PUBLICATIONS AND PUBLISHED REPORTS**

- Denison, D., B. Gibson, C. Wallace, C. Jepsen, and D. Kreis. 2013. Assessment of the Sufficiency of Kentucky's Road Fund. Kentucky Transportation Center, KTC-13-02/SPR449-12-1F.
- Denison, D., C. Jepsen, B. Gibson, C. Wallace, and D. Kreis. 2012. Development of Performance Measures and Revenue Projections for State Highway Transportation Systems. Kentucky transportation Center, KTC-12-19/TA-12-1F.
- Kreis, D. 2011. Deliverable 18- Fedtrak Field Pilot Participant Recruitment Plan. Kentucky Transportation Center. (Security Sensitive).
- Kreis, D. and M. Barclay. 2010. Deliverable 7.1- Fedtrak Business Rules Engine Integration. Kentucky Transportation Center. (Security Sensitive).



- Kreis, D. and M, Barclay. 2010. Deliverable 8.1-Fedtrak Connect. Kentucky Transportation Center. (Security Sensitive).
- Kreis, D. and M. Barclay. 2010. Deliverable 9.1- Fedtrak Customer Relationship Management Desktop. Transportation Center. (Security Sensitive).
- Kreis, D. 2010. Deliverable 10.1- Fedtrak Pilot Program Regulatory Plan. Kentucky Transportation Center. (Security Sensitive).
- Crabtree, J., D. Kreis and M. Barclay. 2010. Deliverable-12- Fedtrak Stakeholder Plan. Kentucky Transportation Center. (Security Sensitive).
- Kreis, D. 2010. Deliverable 15- Fedtrak Risk Plan. Kentucky Transportation Center. (Security Sensitive).
- Kreis, D. 2010. "Deliverable 17.1- Fedtrak Portals Release 4 Plan. Kentucky Transportation Center. (Security Sensitive).
- Crabtree, J., D. Kreis and M. Barclay. 2009. Deliverable 1.1- SERRT Analysis Update. Kentucky Transportation Center. (Security Sensitive).
- Crabtree, J., D. Kreis and M. Barclay. 2009. Deliverable 1.2- Technology Prototype gap Analysis. Kentucky Transportation Center. (Security Sensitive).
- Crabtree, J., D. Kreis and M. Barclay. 2009. Deliverable 3.1- Fedtrak Specifications and Release Plan. Kentucky Transportation Center. (Security Sensitive).
- Crabtree. J and D. Kreis. 2009. Fedtrak Tier 1 HSSM Tracking System (FY 2009 Transportation Security Grant Program). Kentucky Transportation Center. (Security Sensitive).
- Crabtree, J., D. Kreis and M. Barclay. 2009. Deliverable 5.a.1- Fedtrak Database Design. Kentucky Transportation Center. (Security Sensitive).