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Policy Responses to the Safety and Security Externality**

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# **Rail Transportation of Toxic Inhalation Hazards**

## **Policy Responses to the Safety and Security Externality**

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## **Abstract**

Toxic inhalation hazard (TIH) chemicals such as chlorine gas and anhydrous ammonia are among the most dangerous of hazardous materials. Rail transportation of TIH creates risk that is not adequately reflected in the costs, creating a TIH safety and security externality. This paper describes and evaluates policy alternatives that might effectively mitigate the dangers of TIH transportation by rail. After describing the nature of TIH risk and defining the TIH externality, general policy approaches to externalities from other arenas are examined. Potential risk reduction strategies and approaches for each segment of the supply chain are reviewed. The paper concludes by summarizing policy options and assessing some of the most promising means to reduce the risks of transportation of toxic inhalation hazards. Four policy approaches are recommended: internalizing external costs through creation of a fund for liability and claims, improving supply chain operations, enhancing emergency response and focusing regulatory authority. It is further suggested that the Department of Transportation convene a discussion among stakeholder representatives to evaluate policy alternatives.

## I. Introduction

Hazardous materials — industrial materials that are flammable, corrosive, toxic, explosive, or infectious — play a vital role in the U.S. economy. They are used by industries from farming and mining to manufacturing and pharmaceuticals, in the form of fertilizers, raw materials, fuels, and other essential inputs. Of all hazardous materials, toxic inhalation hazards (TIH) may be among the most dangerous.<sup>1</sup> Chlorine gas and anhydrous ammonia are the most common TIH chemicals; others include sulfur dioxide, ethylene oxide, and hydrogen fluoride, and a variety of other products that are important manufacturing inputs.<sup>2</sup>

After the terrorist attacks of September 11, 2001, the security of hazardous materials became increasingly salient in public concern and political debate. Release of toxic inhalation hazards, whether the result of attack or accident, could result in devastating consequences. Many hazardous chemicals are transported over long distances by rail, during which they are particularly vulnerable.<sup>3</sup>

Safety from accidents as well as security against attack are of concern. Toxic inhalation hazards were involved in a number of deadly rail accidents in the early part of this decade. They could have been far worse: all of the TIH accidents we describe in this paper occurred at night in areas of relatively sparse population, limiting the number of people exposed to the effects of the chemicals. A daylight TIH release in a densely populated area could have catastrophic consequences.

Movement of TIH materials through the supply chain creates risk for shippers, rail carriers, and the general public that is not quantified and is not adequately reflected in the costs, leaving a significant portion of the risk as an externality. Our focus, therefore, is on the TIH safety and security externality, that is, the consequences associated both with

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<sup>1</sup> Toxic inhalation hazards are also sometimes called poison inhalation hazards (PIH).

<sup>2</sup> “Six toxic-by-inhalation (TIH) chemicals (ammonia, chlorine, SO<sub>2</sub>, hydrogen fluoride, fuming nitric acid and sulfuric acid) account for more than 90% of the total TIH transportation related risk. Chlorine and ammonia account for 70% and 84 % of the transported TIH material.” Mark Hartong, Rajni Goel, and Duminda Wijesekera, “A Risk Assessment Framework for TIH Train Routing,” <volgenau.gmu.edu/~klaskey/OR680/MSSEORProjectsSpring08/RR\_Group\_09MAY2008/CIP\_TIH\_Submitted.pdf>, citing D.F. Brown; W.E. Dunn; and A.J. Policastro, “A National Risk Assessment for Selected Hazardous Materials in Transportation ANL/DIS-01-1,” Decision and Information Sciences Division (Argonne National Laboratory), U.S. Department of Energy, January 2001.

<sup>3</sup> The United States has over 140,000 miles of freight rail. Several hundred thousand workers handle over 1.2 million hazardous materials movements daily.

accidents and with deliberately perpetrated attacks. Improving “safety” means reducing the accident risk; improving “security” means reducing the terrorist risk. Accidents and deliberate attacks may result in similar consequences. Therefore many safety regulations and policies will also mitigate, to some degree, the consequences of a security breach. The domains of safety and security overlap with respect both to mitigation and to consequence.

This study focuses on potential means of reducing the risk of TIH rail transportation by developing a better understanding of the safety and security externality and proposing a more comprehensive approach to the way that TIH materials are handled. The risk mitigation actions of individual stakeholders, while positive, may not be enough. A focus on incorporating the safety and security externality into the entire TIH supply chain would allow the participants in that supply chain to assess risks more effectively and to make better plans for the safe transport, storage, and delivery of TIH.

### ***What is the TIH Risk? Framing the Problem***

TIH chemicals are among the most dangerous hazardous materials because they are very toxic and they can spread easily in the air if released. Nonetheless, TIH chemicals are economically essential. Over \$660 billion worth of hazardous materials were transported in the United States in 2002, the latest year for which comprehensive data are available, with each shipment moving an average of 136 miles.<sup>4</sup> Without the movement of these hazardous materials, gas stations would close, crop yields would diminish, potable water prices would rise, and many manufacturing activities would come to a halt.

We focus in this paper on two of the most extensively used TIH products, chlorine and anhydrous ammonia. Chlorine gas is used for purifying potable and waste water at treatment plants throughout the country and is also used as a chemical intermediary in various manufacturing processes, for products ranging from PVC pipes to shampoo.<sup>5</sup> Anhydrous ammonia is the nation’s dominant commercial fertilizer and is applied extensively throughout the country’s main agricultural regions, particularly the Midwest farm states.

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<sup>4</sup> U.S. Department of Transportation (DOT), Bureau of Transportation Statistics, “U.S. Hazardous Materials Shipments by Transportation Mode, 2002,”

<[www.bts.gov/publications/national\\_transportation\\_statistics/html/table\\_01\\_56.html](http://www.bts.gov/publications/national_transportation_statistics/html/table_01_56.html)>.

<sup>5</sup> American Chemistry Council, “The Chlorine Tree,” <[www.chlorinertree.org](http://www.chlorinertree.org)>. But see Global Security Newswire, “Clorox to Halt Use of Chlorine at Bleach Production Sites,” November 2, 2009,

<[gsn.nti.org/gsn/nw\\_20091102\\_6428.php](http://gsn.nti.org/gsn/nw_20091102_6428.php)>.

Most TIH chemicals are shipped from production locations to usage sites (although some are produced, stored, and used at a single site). Rail is generally preferred for long-distance transportation, since one rail tank car carries as much as four trucks. In 2007, almost two-thirds (64 percent) of TIH moved by rail, amounting to 105,000 rail-car shipments (TIH materials represent only a small portion of total hazardous materials transported by rail).<sup>6</sup> Rail transportation of TIH is generally believed to be safer than truck transportation, because a smaller number of shipments move along a fixed, dedicated network.

TIH rail transportation is not without risk. Deadly railway accidents involving TIH in Minot, North Dakota, in 2002, in Macdona, Texas, in 2004, and in Graniteville, South Carolina, in 2005 resulted in the evacuation of thousands of people, forced over 800 people to seek medical attention; and caused the deaths of 13 people.<sup>7</sup> The economic costs were staggering; the costs of the Graniteville accident were estimated at \$126 million.<sup>8</sup> These accidents took place when relatively few people were exposed; a terrorist attack on TIH tank cars could have far worse results. One worst-case estimate predicted up to 100,000 deaths should a chlorine gas tank car be attacked and breached on the rail line that passes the Capitol Mall in Washington, D.C. during a major outdoor public event.<sup>9</sup> Although there have been no incidents of terrorist use of TIH in the United States, in Iraq in 2007 there were several attacks on chlorine containers carried by trucks.<sup>10</sup>

Rail transportation providers, aware of the danger, have undertaken risk-mitigation activities. Railroads have worked with the Department of Transportation to review and

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<sup>6</sup> Testimony of Joseph H. Boardman, Administrator, Federal Railroad Administration (FRA), U.S. DOT, before the U.S. Senate Committee on Commerce, Science, and Transportation.

<sup>7</sup> See National Transportation Safety Board (NTSB) Railroad Accident Reports, <[www.nts.gov/Publictn/R\\_Acc.htm](http://www.nts.gov/Publictn/R_Acc.htm)>.

<sup>8</sup> FRA, "Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers" PHMSA-RSPA-2004-18730, April 2008, 7.

<sup>9</sup> Presentation of Dr. Jay Boris, U.S. Naval Research Laboratory, to City Council, Washington D.C., October 6, 2003. This is a worst-case estimate based on specific climate conditions and a large outdoor event with many people in proximity to the release point. A less extreme scenario can be found in Anthony M. Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense: Assessing Chlorine Truck Attack Consequence and Countermeasure Cost Effectiveness," PhD dissertation at Carnegie Mellon University, Department of Engineering and Public Policy, May 2009, discussed below.

<sup>10</sup> See Global Security Newswire, "U.S. Soldiers Exposed to Chlorine in Iraq," June 4, 2007, <[gsn.nti.org/gsn/GSN\\_20070604\\_51B827B8.php](http://gsn.nti.org/gsn/GSN_20070604_51B827B8.php)>.

improve tank car design standards. Special speed limits and increased inspections on corridors with high volumes of hazardous materials traffic are other ways that railroads are modifying their handling of hazardous materials. Partly thanks to these efforts, over 99.9 percent of rail HAZMAT shipments reach their destination without a release caused by an accident.<sup>11</sup> In addition, railroad carriers have sought to raise rates to attempt to cover their risk exposure and to encourage product substitution and shorter movements, although these efforts are complicated by common-carrier regulations. Indeed, railroad companies cannot, by themselves, solve the problem.

Reducing the risk of TIH transportation is complicated by the diversity of the actors and stakeholders involved. Chemical producers and users initiate and receive shipments. Railroads as the carriers may bear most of the liability in case of a release; many railroads, therefore, would prefer not to carry any TIH products, but their common-carrier obligations under federal law prevent them from refusing, and limit the extent to which they can raise rates.<sup>12</sup>

Trade associations representing the chemical companies and the railroads lobby Congress and the regulatory agencies on behalf of their respective industries. A variety of regulatory agencies at the federal level oversee TIH transportation. The Federal Railroad Administration (FRA) is part of the Department of Transportation (DOT). Railroads and their TIH cargoes are subject to regulations of the Pipeline and Hazardous Materials Safety Administration (PHMSA) and the Surface Transportation Board (STB), both of which are part of the Department of Transportation, as well as the regulations of the Transportation Safety Administration (TSA), which is part of the Department of Homeland Security (DHS).

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<sup>11</sup> Association of American Railroads, "Hazmat Transportation by Rail: An Unfair Liability," <<http://www.aar.org/InCongress/Safety%20and%20Security/~media/AAR/PositionPapers/Hazmat%20by%20Rail%20September%202009.ashx>>

<sup>12</sup> See, for example, the Surface Transportation Board (STB) decision affirming that Union Pacific (UP) was obligated to quote common-carrier rates and provide transportation service for chlorine to U.S. Magnesium LLC, although the railway argued that "the transfer would pose 'remote, but deadly, risks' as the material passed through high-population cities such as Chicago, Houston and Kansas City." Quoted in Global Security Newswire, "Rail Firm Opposes Some Chlorine Shipments," Wednesday, March 25, 2009, <[gsn.nti.org/gsn/nw\\_20090325\\_3045.php](http://gsn.nti.org/gsn/nw_20090325_3045.php)>. The railway argued that common-carrier requirements did not apply because U.S. Magnesium had solicited rates for an unreasonable move over long distances and that alternative sources of chlorine were available; but this argument was unsuccessful. STB Docket 35219, June 11, 2009.

State and local governments have some authority over the railroad lines that may carry TIH through their jurisdictions. Local emergency responders, including firefighters and police, will be on the frontlines of any incident.<sup>13</sup> A major stakeholder is the public, because the public at large would be endangered if there is a TIH release.

Many corporate participants in the TIH supply chain, for reasons both of corporate social responsibility and of prudent business-risk management, have looked for ways to mitigate TIH risks. Major producers of chlorine gas are exploring collocation of the facilities that produce and those that use chlorine, in order to minimize the need for transportation of chlorine. Clorox plans to begin phasing out use of chlorine at all seven of its U.S. bleach production facilities.<sup>14</sup> Dow Chemical, the Union Pacific railway, and the Union Tank Car Company are among the companies collaborating in the Next Generation Railroad Tank Car Project to design safer tank cars. Chemical producers, railroads, and public safety officials have combined their efforts to improve emergency response in the event of a TIH release. End users are looking for substitute products. In the past decade, a number of wastewater facilities and drinking water plants have switched from the use of chlorine gas and other toxic purification agents to less toxic alternatives, but as yet these represent a fairly small proportion of the number of facilities nationwide that still use hazardous chemicals.<sup>15</sup>

Industry efforts to improve safety have not yet allayed all public concerns. The District of Columbia City Council took action in 2005 to block TIH from moving through its jurisdiction. The Council sought to keep TIH off the main rail line that crosses the District and passes within one mile of the Capitol, the White House, the Pentagon, and National Airport. The ban was successfully challenged by CSX, the freight railroad involved, with support of the Department of Justice, which argued that a local-level regulation such as this one was preempted by federal regulation under the Commerce clause of the Constitution.<sup>16</sup> At the federal level, these security issues are under study. The regulator of railroad safety, the Federal Railroad Administration, issued new regulations in 2009 on tank car design, routing, and operational practices. The regulator

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<sup>13</sup> Any of over 1 million first responders nationwide could be involved in a TIH incident.

<sup>14</sup> Global Security Newswire, "Clorox to Halt Use of Chlorine at Bleach Production Sites," November 2, 2009, <[gsn.nti.org/gsn/nw\\_20091102\\_6428.php](http://gsn.nti.org/gsn/nw_20091102_6428.php)>.

<sup>15</sup> Paul Orum, *Preventing Toxic Terrorism: How Some Chemical Facilities are Removing Danger to American Communities*, Center for American Progress, April 2006.

<sup>16</sup> The U.S. Court of Appeals for the D.C. Circuit held that federal law preempted the city's effort to regulate the railroad. See *CSX Transportation, Inc. v. Williams*, United States Court of Appeals, D.C. Circuit, May 3, 2005, <[bulk.resource.org/courts.gov/c/F3/406/406.F3d.667.05-5131.html](http://bulk.resource.org/courts.gov/c/F3/406/406.F3d.667.05-5131.html)>.

of railroad economics, the Surface Transportation Board, has heard arguments over whether the common-carrier obligation requires railroads to carry TIH traffic.<sup>17</sup> The Transportation Security Administration, which coordinates threat assessments and security inspections, issued new rail transportation security regulations in November 2008. Effective government regulation requires cooperation and coordination among all of these agencies.

### ***Objectives and Outline***

The primary objective of this study is to describe and evaluate the policy alternatives that might effectively mitigate the dangers of transportation of toxic inhalation hazards, by internalizing the negative externalities of the TIH supply chain. In addition, this paper aims to be summary of information on the characteristics and risks of the TIH supply chain, providing a single source for stakeholders and policymakers. Section II describes the TIH risk by explaining the scientific basis of TIH danger, the complexity of the supply chain, and the risk features of accidents and terrorist attacks. Section III defines the TIH externality and shows why it is difficult to quantify the TIH risk; it examines general policy approaches to externalities from other arenas, and explores their applicability to TIH. Section IV details potential risk reduction strategies and approaches for each leg of the supply chain — production, transportation, and use. Section V concludes by summarizing policy options and assesses some of the most promising means to reduce the risks of transportation of toxic inhalation hazards.

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<sup>17</sup> See discussion below of the Union Pacific case brought before the STB by chlorine producer U.S. Magnesium. See Global Security Newswire, “Rail Firm Opposes Some Chlorine Shipments,” Wednesday, March 25, 2009, <[gsn.nti.org/gsn/nw\\_20090325\\_3045.php](http://gsn.nti.org/gsn/nw_20090325_3045.php)>.

## **II. Risks in Transportation of Toxic Inhalation Hazards**

Security concerns following 9/11 brought into focus the danger posed by the presence of hazardous materials near population centers. In this section, we describe the chemical properties of certain chemicals that make them particularly hazardous. Then, we outline the risks involved in transportation along the supply chain from manufacture to end-user. We describe a particular challenge to internalizing the risk externality: common-carrier regulations imposed on railways prevent them from refusing to carry TIH, which they might prefer due to the risk, and from imposing higher rates for carrying TIH to reflect that risk. The section then describes a number of railway accidents, including three TIH accidents that resulted in fatalities, and two other accidents involving hazardous (but not TIH) materials that further illustrate the potential dangers. The distinctions between accidents and potential terrorist attack are described and their implications for policy are explored.

### ***Chemical Properties of Toxic Inhalation Hazards***

To understand the danger posed by TIH chemicals, it is useful to have a basic understanding of their chemical properties. This brief overview centers on chlorine and anhydrous ammonia, the most widely used and most transported TIH products.

Chlorine is a greenish-yellow noncombustible gas at room temperature and atmospheric pressure.<sup>18</sup> It is transported as a pressurized liquid. Chlorine gas is heavier than air, meaning that the gas settles into low areas when released into the open. It is chemically unstable and breaks down quickly when in contact with sunlight or water. Chlorine is used as a disinfecting agent for drinking water and waste water, and plays an important role in many manufacturing processes.

When chlorine is released into the air, it becomes very dangerous. Small doses irritate the eyes, skin, and respiratory tract; large concentrations of chlorine gas can kill people within minutes. If inhaled at very high concentrations, chlorine breaks down in the lungs to form hydrochloric acid that burns lung tissue, causing pulmonary edema and essentially causing drowning as liquid floods the lungs. The extent of chlorine poisoning depends on the quantity of gas, setting, time of exposure, and other circumstances. As

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<sup>18</sup> For more information, see U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, "Draft Toxicological Profile for Chlorine," September 2007. < <http://www.atsdr.cdc.gov/toxprofiles/tp172.pdf>>

little as 3.5 parts per million (ppm) can be detected as an odor. The lowest lethal exposure is reported as 430 ppm for 30 minutes. Over shorter periods of time, exposure even to 15 ppm of chlorine causes throat irritation, while exposure to 50 ppm is dangerous, and exposure to 1000 ppm can be fatal after a few deep breaths. Frequent exposure to chlorine gas can degrade an individual's sense of smell; workers who have had occupational exposure to the gas are thus at greater risk of inhalational damage. The most effective countermeasure to exposure is to flush affected body parts with large quantities of water and move the victim to an unaffected area with clean air.

Anhydrous ammonia is a colorless gas characterized by a very sharp odor.<sup>19</sup> Anhydrous ammonia is lighter than air and invisible. It can be identified by its acrid odor, which is apparent even at very low concentrations. Ammonia is stored under pressure in rail tank as a liquid, but in the case of a rupture, the ammonia returns to a gaseous state and expands. Its primary use is as a fertilizer due to its high nitrogen content. It is applied directly and also used as a base for other fertilizer products.

Exposure to large quantities has severe health effects. Anhydrous means “without water,” and anhydrous ammonia seeks water from any source, with corrosive results: its main toxic effect is severe burns to the moist parts of the body, such as the eyes, throat and lungs. Ammonia is less toxic at a given concentration than chlorine: exposure to greater than 50 ppm of ammonia causes mild irritation to the nose or throat. Exposure to 700 ppm or more causes such effects as coughing and severe eye irritation. Exposure to larger quantities can cause blindness and other severe or fatal injuries. Ammonia at 5,000 to 10,000 ppm is rapidly fatal to humans. The recommended response to ammonia release is to flood the area, and any persons affected, continuously with large amounts of water.

For these and other gases posing toxic inhalation hazard, the consequences of a release depend on the source, the surrounding terrain and meteorological conditions. The source determines the quantity of material released and duration of gas release. Meteorological conditions and the morphology of the surroundings influence the dispersion of the gas and the duration of exposure. These conditions include the amount of moisture in the air, wind direction and speed, amount of sunlight, terrain, and temperature. If the released TIH enters enclosed indoor environments, it can concentrate to fatal levels.

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<sup>19</sup> For more information, see U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, “Toxicological Profile for Ammonia,” September 2004. < <http://www.atsdr.cdc.gov/toxprofiles/tp126.pdf>>

Given these variations in a TIH release, responders such as railway employees, firefighters, and police must be made aware of the nature of any release and of other local conditions so that they can deal effectively with it.

### ***TIH Supply Chain***

The complexity of the TIH supply chain poses challenges to chemical security and complicates any attempt at regulation, because stakeholders have divergent interests. The supply chains are different for each TIH chemical, involving diverse modes such as rail, truck, barge, and pipeline. In general, trucks carry the largest number of shipments, but rail moves more ton-miles.<sup>20</sup>

Producer-consumer geographical relations are also complicated. Chlorine, for example, is produced at chemical plants mostly concentrated in the southeast part of the country (see Figure 1) from which it is shipped to customer sites, such as water purification plants and other chemical plants. There are some cases in which chlorine is both produced and used at the same plant; this avoids exposure over long shipping times and distances. A chlorine user can sometimes also persuade a manufacturer to relocate nearby, in order to reduce transportation costs and risks.

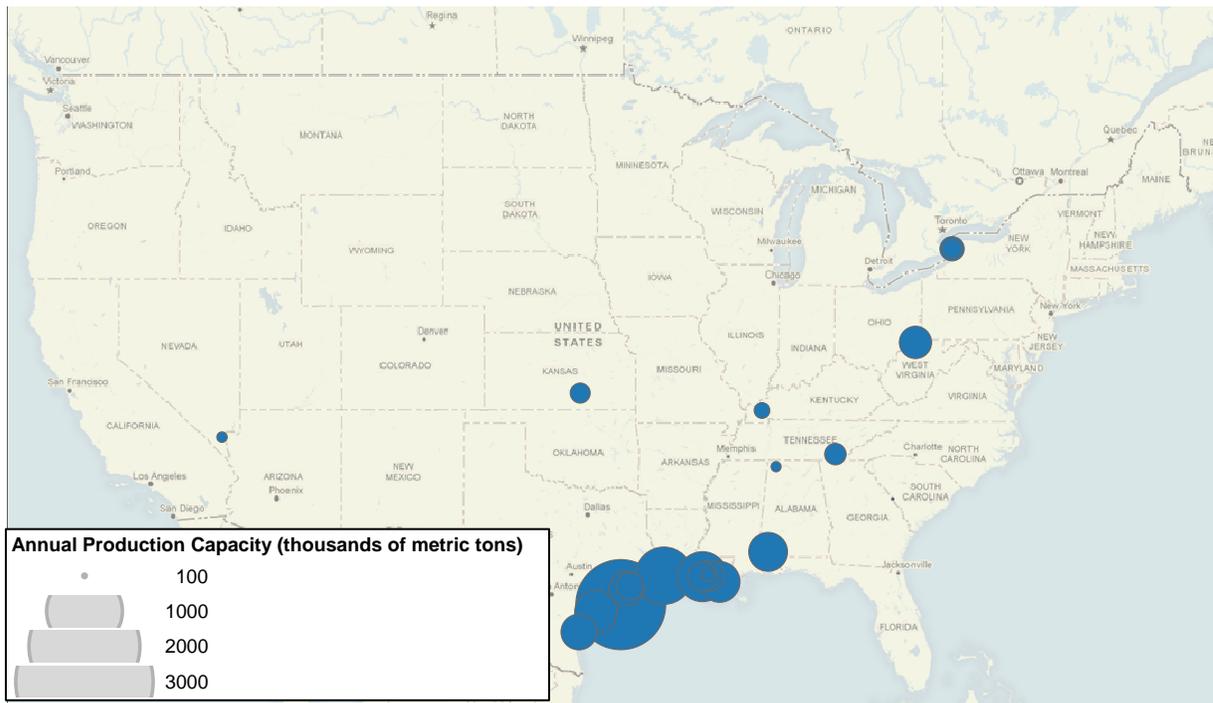
The use of chlorine in large chemical plants and at water treatment sites results in a limited number of nodes in the transportation network (in contrast to the dispersed usage patterns of ammonia-based fertilizers described below). Even so, chlorine tank cars must travel significant distances. A tank car typically carries 90 tons of liquid chlorine. As Figure 1 shows, chlorine production is concentrated along the Gulf Coast and in a few other locations, but it is used at water treatment facilities and manufacturing sites all over the country. Many of these facilities are located in or near large cities, requiring chlorine transport through populated areas. This creates the need for long-distance carriage and potential exposure of large populations.

The economics of transportation favor rail transportation and indeed the majority of chlorine shipments in the United States are shipped by rail. The other safe and practical mode for long-distance transportation of chlorine is by barge, which is indeed considered to be safer than rail but is less available. Trucking companies are reluctant to offer long-

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<sup>20</sup> Annual liquid chlorine transport by truck totals approximately 500,000 tons, but these shipments tend to travel shorter distances than chlorine transported by rail, and are often shipped in smaller quantities. See Barrett, "Mathematical Modeling and Decision Analysis for Terrorism Defense."

haul chlorine transportation services<sup>21</sup> and since, unlike railroads, motor carriers are not subject to common-carrier obligations, they are therefore free to accept or decline shipper requests to transport TIH products or to charge very high prices (but perhaps non-competitive) prices to do so. Due to these factors, an estimated 85 percent of long-distance chlorine movements occur by rail.<sup>22</sup>



**Figure 1: Major U.S. Chlorine Plants, by Annual Production Capacity.** (Source: ATSDR, “Draft Toxicological Profile for Chlorine,” September 2007)

Ammonia is widely used throughout the main U.S. agricultural areas and thus, like chlorine, must be transported from a limited number of production and import locations to a large number of users. As Figure 2 shows, thirty-two plants in 19 states produced ammonia, with most production concentrated in Texas, Louisiana and Oklahoma, near sources of natural gas (the primary chemical feed stock for ammonia production).<sup>23</sup> A

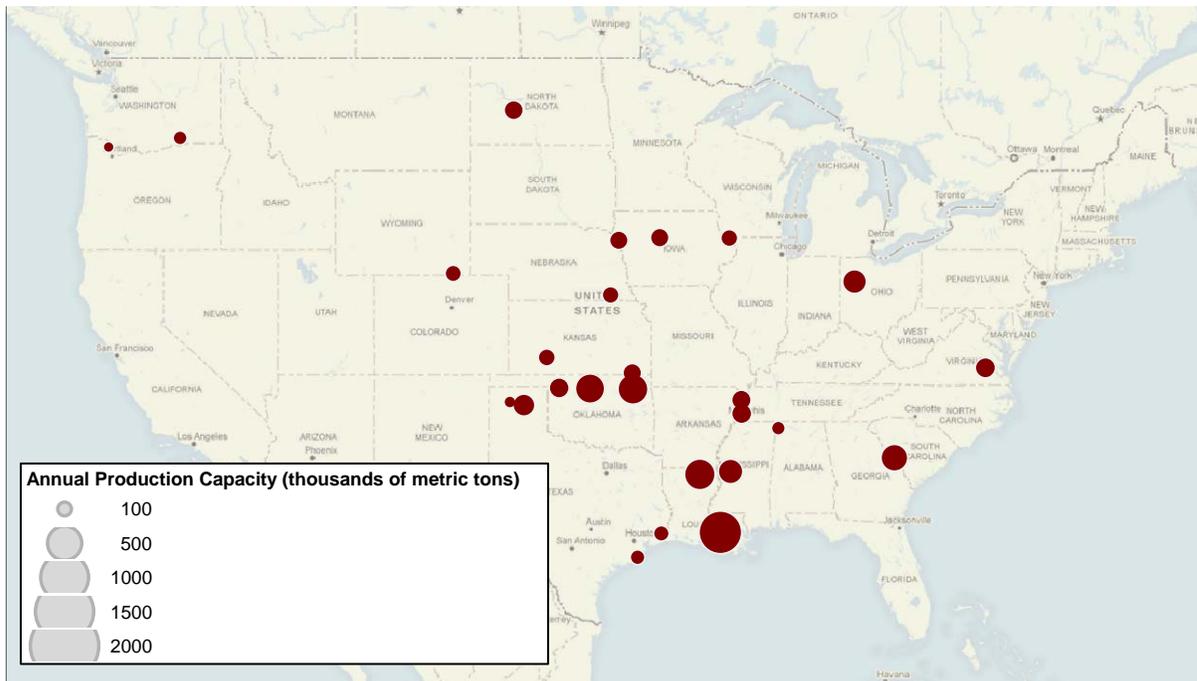
<sup>21</sup> Statement of Stephen J. Lube, CSX Transportation, STB Docket No. NOR 42100.

<sup>22</sup> Estimate by the Chlorine Institute, May 31, 2006,

<[www.americanchemistry.com/s\\_acc/bin.asp?CID=634&DID=2467&DOC=FILE.PDF](http://www.americanchemistry.com/s_acc/bin.asp?CID=634&DID=2467&DOC=FILE.PDF)> Also see E.I. DuPont de Nemours and Co., Complainant’s Opening Evidence, STB Docket No. 42100, February 11, 2008.

<sup>23</sup> Deborah A. Kramer, U.S. Geological Survey, Mineral Commodity Summaries, January 2005, p. 116, <[minerals.usgs.gov/minerals/pubs/commodity/nitrogen/nitromcs05.pdf](http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/nitromcs05.pdf)>.

large quantity of ammonia travels by pipeline and barge and most local distribution to farmers occurs by truck, but rail plays a vital long-haul transportation role.<sup>24</sup>



**Figure 2: Major U.S. Ammonia Plants, by Annual Production Capacity (Source: D. Kramer, “Nitrogen”, U.S. Geological Survey Minerals Yearbook, 2002)**

Since various supply chain participants share responsibility for TIH transportation, this creates legal and liability complexity. A shipment of TIH may be owned by the producer of the shipment or by the end user, depending on the contractual arrangements. A railroad’s contract for carriage may be with either the shipper or the receiver, or with an intermediary such as a broker. The railroad is almost never the legal owner of the product it is transporting, nor does the railroad typically own the tank car. Tank cars are mostly owned by the TIH shipper, or by a rail car leasing company.

Adding to these complexities, the shipment may be stored in a tank car for some time after delivery to the customer plant, waiting on a rail siding for unloading. There may be legal ambiguity over who is responsible for the contents of the tank car during this period. Seeking to resolve this ambiguity and ensure the continuous monitoring of hazardous materials involved, the Transportation Security Administration of the Department of Homeland Security set as a goal the establishment of a “secure chain of

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<sup>24</sup> See, for example, Stephen J. Lube Statement, STB Docket No. NOR 42100. Major import locations for ammonia include Tampa, FL and Pascagoula, MS for shipment inland via truck and rail.

custody” for all TIH shipments, addressing this issue in a Rail Transportation Security Rule issued in November 2008.<sup>25</sup>

### ***Rail Pricing Regulation***

If railroads could impose higher prices for transporting TIH than for transportation of other, less risky materials, TIH rates might reflect more accurately the potential costs of the risk of TIH accidents or other releases. Higher prices would, all else being equal, tend to decrease the number of rail TIH shipments and the ton-miles transported. In this section, we describe how this possibility is complicated by the current rail pricing regime.<sup>26</sup>

It is difficult to know exactly how expensive it is to ship TIH materials. In most cases, rail rates are set by contract between the shipper and the railroad and are not published. These contract rates, driven by supply and demand as well as the relationship between the negotiating parties, are not subject to regulation, because the railroad is deemed to be acting as a private or contract carrier. However, if shipper and railroad are unable to agree on a contract rate, the railroad is required to publish a “common carrier rate” for the movement in question, without discrimination as to the identity of the shipper or the material being shipped.

Although contract rates are not published, the published common carrier tariffs for TIH shipments are several times greater than those for comparable non-TIH chemicals. In 2008 rate case between a chemical company and a railroad, there was evidence that the railroad quoted a rate of \$9,173 (including fuel surcharge) for transporting a tank car of chlorine from Niagara Falls, NY to New Johnsonville, TN.<sup>27</sup> Common carrier prices posted on the railroad website for transporting one tank car of caustic soda (a frequently shipped material that is hazardous but is not a toxic inhalation hazard) reveals rates of \$3,707–4,634 per car (depending on the size of the shipment) for the same distance.<sup>28</sup> Analysis of public tariffs shows that the additional increments for longer distances

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<sup>25</sup> Rail Transportation Security Rule, Transportation Security Administration (TSA) of the U.S. Department of Homeland Security (DHS), 49 Code of Federal Regulation (CFR), Parts 1520 and 1580, Rail Transportation Security: Final Rule, November 26, 2008.

<sup>26</sup> The current rail pricing regulation regime is a result of the partial deregulation enacted under the Railroad Revitalization and Regulatory Reform Act of 1976 and the Staggers Act of 1980.

<sup>27</sup> DuPont Opening Evidence, STB Docket No. 42100.

<sup>28</sup> Movement of caustic soda from Niagara Falls, N.Y., to New Johnsonville, Tenn., <[www.Shipcsx.com](http://www.Shipcsx.com)>, consulted May 28, 2009.

increase more steeply for TIH shipments than for non-TIH shipments. The rate differential suggests that rail carriers may be trying to recoup part of the cost of the risk for TIH shipments, particularly over long hauls.

If a shipper wants to challenge a published rate, it brings a complaint before the Surface Transportation Board (STB), a three-member panel that is the economic regulator of the railroad industry.<sup>29</sup> Rate cases may be filed under one of several procedural methods. If the STB finds the carrier's rates to be excessive, the shipper is entitled to rate relief. However, calculations for STB adjudications are based on system-average costs that do not incorporate the unique handling and risk characteristics of TIH traffic.

Generally, the STB has shown itself to be more sympathetic to shippers than to rail carriers. In a recent chemical company complaint against a railroad concerning certain movements of chlorine, the STB ruled that the railroad's proposed rates were unreasonably high and ordered the railroad to establish lower rates and pay reparations to the shipper.<sup>30</sup> The railroad had failed to convince the STB to allow an adjustment for TIH chemicals that would more accurately have reflected the risks inherent in TIH transport. In a similar case in early 2009, a railroad refused to quote a rate for a shipment of chlorine on the grounds that this was not a reasonable movement request, given the availability of alternative chlorine manufacturers closer to the destination. When the case went before the STB as a common carrier case (rather than a rate case), the STB required the railroad to establish rates and to provide service for this shipment of chlorine.<sup>31</sup>

Thus, the current regulatory scheme means that the risks of carrying a product that could cause billions of dollars in damage and impose potentially huge liability on a railway in the event of a release are rarely reflected adequately in rail transportation rates. In other words, they remain externalities.

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<sup>29</sup> "The STB is an economic regulatory agency charged with resolving freight railroad rate and service disputes, reviewing proposed rail mergers, rail line purchases, constructions and abandonments. The Board also oversees Amtrak's on-time performance and has jurisdiction over other matters." <[www.stb.dot.gov](http://www.stb.dot.gov)>.

<sup>30</sup> STB Decision Docket No. 42100, June 27, 2008. Whether an entity like DuPont qualified as a "small shipper" under the rules was a contentious topic in the STB hearings.

<sup>31</sup> See STB Docket No. 35219; see also Global Security Newswire, "Rail Firm Opposes Some Chlorine Shipments," Wednesday, March 25, 2009, <[gsn.nti.org/gsn/nw\\_20090325\\_3045.php](http://gsn.nti.org/gsn/nw_20090325_3045.php)>. Note that a common carrier case is meant to establish whether the railroad can refuse to carry the traffic in question, while a rate case determines the tariffs the railroad may charge.

## *Accidents*

An essential step towards ensuring secure transportation of TIH products is minimizing the risk of accidental releases. Recent events highlight issues that must be addressed as part of the risk-reduction process. Three fatal accidents involving TIH product release have taken place in the past decade: at Minot, South Dakota, in 2002, at Macdona, Texas, in 2004, and at Graniteville, South Carolina, in 2005. In addition, a 2001 accident in a tunnel near downtown Baltimore, Maryland, although causing no fatalities, showed the potential danger of a HAZMAT accident in an urban setting. A 1987 New Orleans case suggests the vast potential exposure to liability claims in the event of an incident. These events are described in this section.

### *Minot, North Dakota, January 2002: Anhydrous Ammonia Release*

On January 18, 2002, at 1:37 AM (CST), a Canadian Pacific (CP) train derailed half a mile from the city limits of Minot, North Dakota. Of a total of 112 cars, 31 cars, numbers 4–34, derailed.<sup>32</sup> The train “consist” included 39 HAZMAT cars, including 15 tank cars of anhydrous ammonia that were positioned as cars 18 through 32. All of these cars derailed, and five of them ruptured catastrophically. Tank car fragments were propelled up to 1,200 feet from the track, and 146,700 gallons of anhydrous ammonia — almost the entire contents of the five tank cars — were released almost instantaneously. Ammonia vapor spread five miles downwind over an area where 11,600 people lived.

Within minutes of the accident, the conductor notified the Canadian Pacific dispatcher in Minneapolis, Minnesota, and called 911 on his cell phone. By 1:41 AM, less than five minutes after the accident, emergency service operators were telling residents who phoned seeking information to shelter-in-place, by staying in their homes, closing windows, running showers, and breathing through wet cloths. By 5:30 AM, the vapor cloud had begun to dissipate. Emergency responders then began to evacuate residents.

The National Transportation Safety Board, after an extensive investigation, blamed the accident primarily on an “ineffective Canadian Pacific Railway inspection and maintenance program that did not identify and replace cracked joint bars [on the rails]

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<sup>32</sup> All information for this section, unless otherwise cited, from National Transportation Safety Board, “Derailment of Canadian Pacific Railway Freight Train 292-16 and Subsequent Release of Anhydrous Ammonia Near Minot, North Dakota — January 18, 2002,” NTSB Railroad Accident Report NTSB/RAR-04/01, <[www.nts.gov/publicn/2004/RAR0401.pdf](http://www.nts.gov/publicn/2004/RAR0401.pdf)>, hereafter cited as “NTSB Report—Minot.”

before they completely fractured and led to the breaking of the rail at the joint.”<sup>33</sup> Tank car failure also contributed: the five cars that experienced catastrophic failure were constructed of non-normalized steel, which was more prone to cracking at the low temperatures found at the time of the accident.<sup>34</sup>

Public notification issues affected the consequences: many residents did not hear the city’s emergency broadcasts because of power outages, and did not hear warning sirens because they were too far away. Authorities were initially unable to communicate with local radio stations to request emergency broadcasts; the local television station had no staff on duty.

The accident caused one death, due to anhydrous ammonia inhalation; the victim had become disoriented while trying to flee the area immediately following the accident. Eleven residents suffered serious injuries; 322 train crew, residents, and first responders had minor injuries. Equipment damage reported to the NTSB totaled \$2.5 million and environmental cleanup costs were \$8 million. Valuation for property damage and casualties is not available.

Following the Minot accident, the NTSB made several recommendations to improve track inspections and maintenance. The NTSB also made recommendations for improved tank car safety, including a call for a comprehensive analysis to determine the impact resistance of the steels in the shells of tank cars constructed before 1989. Ultimately, the NTSB recommended development and implementation of tank car fracture toughness standards.

*Macdona, Texas, June 2004: Chlorine Gas*

At 5:03 AM (CDT) on June 28, 2004, near Macdona, Texas, a Union Pacific (UP) train traveling at 44 mph passed a stop signal and collided with the middle of a Burlington Northern Santa Fe (BNSF) train that was leaving the mainline and entering a siding.<sup>35</sup>

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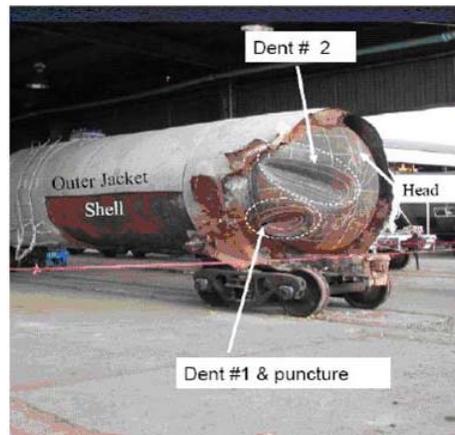
<sup>33</sup> Ibid., vi.

<sup>34</sup> Non-normalized steel was common in tank cars constructed before regulations were tightened in 1989. Normalization of steel is a metallurgic process by which the steel is heated to extreme temperatures and then air-cooled, increasing the metal’s toughness and resistance to cracking at low temperatures. The outdoor temperature at the time of the Minot accident was -6°F. The anhydrous ammonia had been loaded at 40°F and was insulated. It was calculated that by the time of the accident, the temperature of the shell was 36°F and was thus below the ductile-to-brittle transition temperature for non-normalized steel.

<sup>35</sup>All information for this section, unless otherwise cited, from National Transportation Safety Board,

The four UP locomotive units and first 19 cars of that train were derailed, as were 17 cars of the BNSF train. The 16th car of the UP train, carrying liquefied chlorine gas, was punctured by the side of a UP flatcar that had derailed four cars ahead of it. As a result, 9,400 gallons of chlorine gas were released and formed a 1400-foot-diameter cloud, which then began to drift. The BNSF train crew notified both BNSF and UP dispatchers. It was later estimated that the chlorine concentration was 400,000 ppm near the accident scene, far above lethal levels (even 1000 ppm can quickly kill).

Within minutes of the accident, at 5:06 AM, a 911 call was made from a residence near the accident. For several hours, first responders and HAZMAT specialists arrived at the site. However, in part because of the high concentration of chlorine gas and due to the wreckage, it was not until 9:45 AM that an “entry team” in HAZMAT gear could begin attempting to rescue people trapped within the chlorine cloud. The accident resulted in three deaths, including the UP train conductor and two elderly local residents. The UP engineer, six emergency responders, and 26 residents were treated for injuries. Railroad equipment damages reported to the NTSB totaled \$5.7 million; site cleanup costs were \$150,000. Again, property damage values and compensation for victims is not publicly available.



**Figure 3: Head Puncture in Macdona Accident (DOT, 2007)**

The NTSB concluded that neither the conductor nor the engineer of the UP train had fulfilled their duties. At the display of the “approach” signal, the engineer should have

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“Collision of Union Pacific Railroad Train MHOTU-23 With BNSF Railway Company Train MEAP-TUL-126-D With Subsequent Derailment and Hazardous Materials Release Macdona, Texas June 28, 2004,” Railroad Accident Report NTSB/RAR-06/03, <[www.nts.gov/publicctn/2006/RAR0603.pdf](http://www.nts.gov/publicctn/2006/RAR0603.pdf)>, hereafter cited as NTSB Report—Macdona.

slowed the train to 10 mph in preparation for stopping to allow the BNSF train to proceed onto the siding. Instead, the engineer increased speed from 44 mph to 46 mph and continued to operate as if under a “clear” signal.

The NTSB blamed the “UP engineer’s combination of sleep debt, disrupted circadian processes, limited sleep through the weekend, and long duty tours in the days before the accident,” which, it said, “likely caused him to start the accident trip with a reduced capacity to resist involuntary sleep.” The engineer (and other UP crew) likely experienced periods of sleep and were not sufficiently alert to respond correctly to the signals. The NTSB investigation also held that emergency responders had not reacted aggressively enough to rescue trapped residents: the road was blocked, but they had failed to consider alternatives.

The NTSB recommended that the Federal Railway Administration and the Union Pacific railroad study measures to limit crew fatigue. It also asked two unions — the Brotherhood of Locomotive Engineers and Trainmen, and the United Transportation Union — to raise awareness among their members regarding the importance of rest. The NTSB also suggested that the FRA consider revising certain operating measures; for example, the NTSB recommended positioning tank cars at the back of trains to minimize impact forces. It also reiterated recommendations made after the Minot accident to improve tank car design, although the tank cars involved at Macdona met the highest existing standards. The NTSB also noted that positive train control technology (discussed further below) could have prevented the Macdona accident.<sup>36</sup>

#### *Graniteville, South Carolina, January 2005: Chlorine Gas*

With nine deaths and over 500 injuries, the January 6, 2005, accident at Graniteville, South Carolina, was the most serious of the fatal railway releases of TIH.<sup>37</sup> Norfolk Southern (NS) train 192 collided with another NS train that was parked on a customer

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<sup>36</sup> Positive Train Control (PTC) is the term used in the United States to designate a collection of systems designed to increase railroad safety by overriding the engineer’s control of the train and automatically stopping the train in certain dangerous situations.

<sup>37</sup> All information for this section, unless otherwise cited, from National Transportation Safety Board, “Collision of Norfolk Southern Freight Train 192 With Standing Norfolk Southern Local Train P22 With Subsequent Hazardous Materials Release at Graniteville, South Carolina — January 6, 2005,” Railroad Accident Report NTSB/RAR05/04, <[www.nts.gov/publicctn/2005/RAR0504.pdf](http://www.nts.gov/publicctn/2005/RAR0504.pdf)>, hereafter cited as “NTSB Report—Graniteville.”

side track at 2:39 AM EST, derailing both locomotives and 16 cars of the moving train. Three tank cars containing chlorine derailed, one of which was punctured.

The side track on which the accident occurred served textile manufacturing facilities of Avondale Mills, Inc. Investigations showed that the crew of the parked train had completed their duties but had failed to realign the switch back to the mainline track from the industry side track. Track in this area is non-signaled, known as “dark” territory in the railroad industry. Authority to use track in this area is conveyed by the dispatcher in Greenville, South Carolina. Train 192, approaching at 48 mph, collided with the train parked on the side track. The punctured chlorine car released a chlorine vapor cloud that extended at least 2,500 feet to the north of the accident site, 1,000 feet to the east, 900 feet to the south, and 1,000 feet to the west.

Emergency responders were dispatched. A reverse 9-1-1 notification told nearby residents to shelter indoors until entry teams of emergency responders could evacuate people affected by the gas release.<sup>38</sup> An additional 5,400 people within a one-mile radius of the site were evacuated by law enforcement personnel. Over the next days, HAZMAT teams sealed the punctured car and removed hazardous materials from the site.

The accident caused nine deaths. Among the fatalities were the NS train engineer, six Avondale Mills employees, a truck driver, and a local resident. Approximately 554 people were taken to local hospitals, and 75 were admitted for treatment. All casualties were due to chlorine exposure; the NTSB concluded that the accident might have been non-fatal if not for the chlorine release. In addition, property damages reported to the NTSB totaled \$6.9 million; a later FRA analysis estimated that the total cost of the accident was \$126 million, including fatalities, injuries, evacuation costs, property damage, environmental cleanup, and track out of service.<sup>39</sup>

The NTSB investigation determined that the cause of the accident was the failure of the crew of the parked train to realign the switch after the crew completed its work. The crew, running up against its 12-hour duty limit, had rushed the completion of its tasks.

Following the accident, several railroads modified operating procedure to require that crews confirm the switch position to the dispatcher before signing off duty. The FRA

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<sup>38</sup> Reverse 9-1-1 is a notification system by which authorities can initiate automated recorded calls to citizens to notify them of an imminent hazard.

<sup>39</sup> FRA, “Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers” PHMSA-RSPA-2004-18730, April 2008.

issued a safety advisory asking railroads to review switch procedures. In the face of repeated accidents throughout 2005 caused by misaligned switches, the NTSB viewed these measures as insufficient. Upon conclusion of its investigation of the Graniteville accident, NTSB recommended establishing mechanisms to remind crews of their duty to realign switches, such as an electronic device or a strobe light. The NTSB was also concerned that although train 192 was traveling under the speed limit, its speed did not give it sufficient time to react to the banner displaying the status of the misaligned switch. Therefore the NTSB suggested that reduction of train speeds in non-signaled territory be considered, to give train crews more time to react to misaligned switches.

### *Baltimore, July 2001: Tunnel Fire*

The three accidents described above all occurred in areas of relatively sparse population and early in the morning. By contrast, a 2001 rail accident that involved hazardous materials (HAZMAT) but not toxic inhalation hazards (TIH) occurred in an urban setting in the middle of the afternoon. On July 18, 2001, eleven of sixty cars in a CSX freight train derailed while passing through the Howard Street Tunnel in downtown Baltimore, Maryland, at 3:08 PM EST.<sup>40</sup> The train included eight tank cars loaded with hazardous materials; four of these were among the cars that derailed. One of the derailed tank cars contained tripropylene, two cars hydrochloric acid, and one car di-phthalate. A leak in the car containing tripropylene resulted in a chemical fire. A break in a water main above the tunnel flooded both the tunnel and the streets above it. The tunnel collapsed. Damage and cleanup costs reported to the NTSB from this accident totaled \$12 million.

Although there were no serious injuries or casualties, this incident illustrates the risks of rail transportation of hazardous materials through urban areas. It also underlines the challenges of emergency response.<sup>41</sup> The city sounded emergency sirens, but many

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<sup>40</sup> See National Transportation Safety Board, "Railroad Accident Brief: CSX Freight Train Derailment and Subsequent Fire in the Howard Street Tunnel in Baltimore, Maryland, on July 18, 2001," <[www.nts.gov/publictn/2004/RAB0408.pdf](http://www.nts.gov/publictn/2004/RAB0408.pdf)>, hereafter cited as "NTSB Report—Baltimore." The NTSB's investigation was unable determine the cause of the accident. Further information and sources in report prepared for DOT, "Effects of Catastrophic Events on Transportation System Management and Operations," <[www.itsdocs.fhwa.dot.gov/jpodocs/repts\\_te/13754\\_files/13754.pdf](http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13754_files/13754.pdf)>. See also Arnold M. Howitt and Herman B. Leonard, *Managing Crises: Responses to Large Scale Emergencies* (Washington, D.C.: CQ Press, 2009), pp. 201–233.

<sup>41</sup> Stephanie Shapiro, "CSX train fire sparks debate of stay or go," *The Baltimore Sun* <[www.dailypress.com/features/arts/bal-to.disaster21jul21,0,4656728.story](http://www.dailypress.com/features/arts/bal-to.disaster21jul21,0,4656728.story)>. See also Howitt and Leonard, *Managing Crises*, pp. 201-233.

residents did not know that the sirens meant they were to return home to seek information from television and radio, which would have told them to shelter in place. Instead, many residents chose to evacuate the area.

“Human behavior has to be taken into consideration when managing an emergency or disaster,” said John Bryan, retired chairman of the department of fire protection at the University of Maryland's engineering school.<sup>42</sup> Announcements about the threat must, he said, be specific. Public education and establishment of public trust in police and other emergency responders are essential so that residents will follow directions from the authorities in case of a HAZMAT or TIH incident.

### *New Orleans, 1987: Rail Yard Fire*

A 1987 case illustrates the issues that arise when there are many players that might be blamed for a HAZMAT accident. In 1987, an unattended rail car in the CSX yard in New Orleans leaked butadiene, a petroleum product, causing a fire that prompted authorities to order road closings and large-scale evacuations.<sup>43</sup> There were no serious injuries or deaths, and minor injuries were not conclusively linked to the fire. Nevertheless in 1997, in a class action suit brought by nearby residents that charged negligence, a jury awarded plaintiffs compensatory damages of \$2 million for actual harm, and imposed additional punitive damages totaling \$3.4 billion. Named in the suit were CSX, which owned the track where the tank car was parked, the shipper, other railroads that had moved the tank car (including Alabama Great Southern Railway which had actually moved it to the CSX yard), and a previous owner of the tank car, Phillips Petroleum Company, which had improperly installed a gasket that was blamed for the leak (however, Phillips could not be found liable under certain terms of Louisiana HAZMAT law).

Most of the punitive damage award (\$2.5 billion of the total \$3.4 billion) was imposed on CSX, despite its argument that it did not make the problem tank car, did not own it, and did not install the faulty gasket. CSX had not loaded the butadiene, and did not even move the car after it was dropped off at CSX's interchange yard. CSX was the owner of the track where the tank car was parked, and was scheduled to move it later to Chattanooga, Tenn. Nonetheless, CSX faced a punitive damage claim of \$2.5 billion, and additional punitive damages were awarded against other defendants, including the

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<sup>42</sup> Shapiro, “CSX train fire sparks debate of stay or go.”

<sup>43</sup> Carol Marie Cropper, “Jury in CSX Case Sent Angry Message with a \$3.4 Billion Stamp,” *New York Times*, September 15, 1997, <[www.nytimes.com/1997/09/15/business/jury-in-csx-case-sent-angry-message-with-a-3.4-billion-stamp.html](http://www.nytimes.com/1997/09/15/business/jury-in-csx-case-sent-angry-message-with-a-3.4-billion-stamp.html)>.

railroads that had moved the tank car, the shipper, and the tank car company GATX. The damage awards were challenged successfully on appeal and reduced from \$2.5 billion to \$850 million. Nonetheless, this case illustrates the potentially enormous liability exposure of railways carrying hazardous substances.<sup>44</sup>

### ***Terrorism***

Secure transportation of TIH chemicals requires protection against terrorist attacks as well as accidents. To date, no hazardous materials release from a railroad in the United States has been caused by a terrorist attack. The Federal Bureau of Investigation has reported, however, that terrorists are specifically interested in “targeting hazardous material containers” by attacks on rail cars on U.S. soil.<sup>45</sup>

Richard Falkenrath, former Deputy Homeland Security Adviser to President Bush and current Deputy Commissioner of Police, New York City, made this assessment of the severity of the terrorist threat of TIH transport through urban areas by rail and truck:

Of all the various remaining civilian vulnerabilities, one stands alone as uniquely deadly, pervasive and susceptible to terrorist attack: industrial chemicals that are toxic when inhaled, such as chlorine, ammonia, phosgene, methyl bromide, and hydrochloric and various other acids. These chemicals, several of which are identical to those used as weapons on the Western Front during World War I, are routinely shipped through and stored near population centers in vast quantities, in many cases with no security whatsoever. A cleverly designed terrorist attack against such a chemical target would be no more difficult to perpetrate than were the September 11 attacks. The loss of life could easily equal that which occurred on September 11 — and might even exceed it. I am aware of no other category of potential terrorist targets that presents as great a danger as toxic industrial chemicals.<sup>46</sup>

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<sup>44</sup> See “CSX Says Court Reduced Damage Verdict,” *New York Times*, November 17, 1999, <[www.nytimes.com/1999/11/17/business/csx-says-court-reduced-damage-verdict.html](http://www.nytimes.com/1999/11/17/business/csx-says-court-reduced-damage-verdict.html)>.

<sup>45</sup> Richard Falkenrath, “We Could Breathe Easier: The Government Must Increase the Security of Toxic Chemicals in Transit,” <[www.washingtonpost.com](http://www.washingtonpost.com)>, March 29, 2005, p. A15.

<sup>46</sup> Falkenrath, “We Could Breathe Easier.” However, railroad industry officials point out that it would be difficult for terrorists to coordinate an attack against a moving freight train, although perhaps less difficult against a stationary target.

Chlorine has been used as a weapon; it was used extensively in chemical warfare in World War I. In Iraq, insurgents have exploded small canisters of chlorine in trucks filled with explosives.<sup>47</sup>

An important distinction from accidental release is that a terrorist attack involving TIH could be deliberately targeted in such a way as to cause a high number of casualties. A worst-case scenario simulation performed at the Naval Research Laboratory concluded that if such an attack occurred during a celebration or political event in a setting similar to the National Mall, over 100 people per second might die, and up to 100,000 people could be killed within 30 minutes.<sup>48</sup> A July 2004 study by the Homeland Security Council (a White House office) estimated that even under less crowded conditions, a TIH attack in an urban area could result in as many as 17,500 deaths, 10,000 severe injuries, and 100,000 hospitalizations.<sup>49</sup>

A study by the National Research Council addressed a more conservative scenario: a terror attack on stored toxic chemicals in an industrial city, with a release of TIH materials in large (but unspecified) quantities.<sup>50</sup> The release was assumed to occur at midnight under mild meteorological conditions, resulting in a predicted 1,000 deaths and 22,000 injuries. The study also addresses release from a TIH rail car under similar circumstances, but it concludes that: “because of the quantity of chemical involved, multiple attacks at multiple sites would be required to produce numbers of casualties that would be considered catastrophic by the standards indicated in U.S. Department of

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<sup>47</sup> In the attacks in Iraq, fewer people were killed by the chlorine than by the explosives. The deadliness of the released chlorine gas is thought to have been reduced by chemical reactions resulting from the high temperatures of the explosions. The Iraq explosions were not “chlorine bombs,” said Steven Kornguth, director of the biological and chemical defense program at the University of Texas in Austin. “They are putting canisters of chlorine on trucks with bombs, which then puncture the canisters and release the chemical,” Kornguth said. “But it hasn’t been very effective because the high temperature created by the bombs oxidizes the chemical, making it less dangerous.”

<sup>48</sup> Boris presentation to D.C. City Council; see also Jay Boris, “The Threat of Chemical and Biological Terrorism: Roles for HPC in Preparing a Response,” *Computing in Science and Engineering*, Vol. 4, No. 2 (March/April 2002), pp. 22–32.

<sup>49</sup> “Planning Scenarios: Executive Summaries Created for Use in National, Federal, State and Local Homeland Security Preparedness Initiatives,” The Homeland Security Council, July 2004, Scenario 8.

<sup>50</sup> National Research Council, Committee on Assessing Vulnerabilities Related to the Nation’s Chemical Infrastructure, *Terrorism and the Chemical Infrastructure: Protecting People and Reducing Vulnerabilities* (Washington, D.C.: National Academies Press, 2006), also available online at <[www.nap.edu/catalog/11597.html](http://www.nap.edu/catalog/11597.html)>.

Homeland Security (DHS) National Response Plan.”<sup>51</sup> However, this conclusion seems implausible, as it assumes that terrorists would choose to attack at midnight; it is more likely that terrorists would choose to attack when streets are crowded. If so, this scenario would have predicted far more than 1,000 deaths.

The scale of potential fatalities is confirmed by the sophisticated and comprehensive analysis in a recent dissertation that examined the consequences of a 17 ton chlorine terror attack on a tanker truck.<sup>52</sup> The study takes as its base case the rupture of a tanker truck carrying 17 tons of liquid chlorine in a generic urban area during daylight. While the analysis of the effect of structures on the three-dimensional propagation of the chlorine plume is less detailed than the Boris study and is, unlike that study, not specific to a particular city, the behavioral model is more detailed, and accounts for both the rate at which people can escape from open spaces and the extent to which sheltering in place saves (or sometimes may cost) lives. In the absence of a fast and effective defense response and with 2.5 meters/second wind speed, and a specified wind stability, approximately 4,000 fatalities are estimated, half within 10 minutes, and up to 30,000 fatalities, half within 20 minutes, depending on the dose response model. Fatality consequences are found to be roughly proportional to the amount of chlorine released, so a ruptured 90 ton rail car would, under a reasonable range of conditions, kill approximately 5 times as many people as would release of 17 tons from a truck. Assumptions for this range of estimates (4,000 to 30,000 fatalities depending on dose-response assumptions) is based on an outdoor population density in the target area of only 7 percent of the total daytime population density, it suggests that the Boris estimate of up to 100,000 deaths from a successful rail car attack is not as excessive or unsubstantiated as some critics have claimed.

Intelligence about terrorist intentions and capabilities is highly uncertain, which makes it quite difficult to estimate the likelihood of a terrorist attempt to rupture a TIH tank car in a crowded urban area. Several scenarios are conceivable for terrorist attacks on TIH-carrying trains. An implanted explosive weapon might detonate a rail car, perhaps when the car is motionless and is not in a protected environment. Current procedures provide for inspection by railroad personnel to guard against this type of attack.

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<sup>51</sup> According to the National Response Framework, “A catastrophic incident is defined as any natural or manmade incident, including terrorism, that results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, and/or government functions.” U.S. Department of Homeland Security, “National Response Framework,” January 2008, < <http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf>>, p. 42.

<sup>52</sup> Barrett, “Mathematical Modeling and Decision Analysis for Terrorism Defense.”

In another scenario, a projectile weapon might puncture a storage tank or a tank car. If someone attempted to do so with a rifle, release from the resulting small punctures would not be rapid; instead, a relatively slow release and dissipation of the product would limit the effect. More worrisome is the potential use of a heavier weapon, perhaps one delivering a shoulder-launched shaped-charge projectile from a great distance, which could create a large rupture.

Terrorists might attack infrastructure such as rails, bridges, or tunnels in order to derail TIH tank cars. The consequences are hard to predict; they would depend in part on whether the cars meet the current government standards for robustness, and on their location in the train. The effects of such an attack might be similar to the effects of an accidental derailment. It might be worse if terrorists chose time and place deliberately to expose a large population of potential victims to gas release. Planning for such an attack is not so easy, however, because of the uncertain schedule of most trains and the additional uncertainty of the presence or absence of a TIH tank car.

For terrorists to have high confidence that such an attack would be devastatingly successful, they would need access to tools comparable the computational meteorology tools used by the government to estimate consequences and plan responses. The attacker would need to know train loading, schedules, and routing information, and would have to find a time when one or more tank cars of TIH materials would pass up-wind of a large population, and when wind and moisture conditions were appropriate. Having confidence of optimizing such an attack would require a complex operation.

One means of discouraging such a terrorist attack is to deny the possibility of a lucrative target, by ensuring that rail cars transporting TIH never pass through highly populated areas, at least not when those populations are likely to be out of doors. Shipping TIH only at night, or rerouting around exposed populations, would greatly reduce the attractiveness of targets.<sup>53</sup>

Denial of an attractive target could also be enhanced by assuring a more effective response to attack, in order to mitigate death and injury. Key components of effective response include a very fast situational assessment, combined with means to warn people in exposed places and to give them appropriate directions for protective action (such as sheltering in place or evacuating in the safest direction). This would require a much better program of public education in disaster response behavior than is in place today in U.S. cities.

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<sup>53</sup> This would, however, introduce significant operational complications for the railroads, discussed below in Section IV.

Currently the plan for responding to a TIH release assumes that emergency operations officials would have about 15 minutes to understand the nature of the threat, including meteorological and other information, and that first responders would therefore have 15 minutes to arrive on the scene prepared with appropriate equipment and information to mitigate the consequences.<sup>54</sup> However, this is not fast enough. There are simulation models that could provide essential information more quickly. The Office of Naval Research (ONR), for example, has constructed a simulation model called FAST3D-CT which can rapidly predict, with accurate details, the intensity and movements of a contaminant cloud, taking into account the specific morphology of the surrounding city streets and buildings.<sup>55</sup> However, it requires very fast computing facilities that are unavailable to most cities. The ONR team has found they can overcome this difficulty and greatly reduce the time to compute by running scenarios in advance for many cities, computing the consequences of a range of threats and meteorological situations. Then the detailed local conditions can be entered into a more modest computer to make the local corrections very rapidly. However the ONR model is not yet widely implemented.

Increasing the security of TIH transportation requires cooperation of the railways, the chemical industry, federal and state regulators, a challenge that is compounded by the ambiguity and uncertainty surrounding the magnitude of the risk, as the next section explores.

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<sup>54</sup> Private communication to Lewis Branscomb from Jay Boris, Naval Research Laboratory, Washington DC, Spring 2009.

<sup>55</sup> Boris, "The Threat of Chemical and Biological Terrorism," Boris presentation to D.C. City Council.

### III. Policies for Dealing with Externalities

The full societal cost of TIH transportation — including the risks of potential damage from accident or attack — is not reflected in the market prices for TIH products. A calculation of the full social cost of TIH transportation would include both the probabilistic costs of the consequences of TIH releases and the costs of countermeasures implemented to reduce the frequency and potential effects of a release. Economists described such costs as negative externalities. The discrepancy between the market price and social cost is the TIH safety and security externality.

The extent of the externalities — the degree of this misalignment of costs and benefits — is disputed among shippers and railroads. Railroads argue that rates for TIH, although they are already higher than those for other commodities, are not high enough to fully cover the probabilistic costs of an unintended release. Therefore, the railroads argue, they bear disproportionate risks while being forced to carry TIH by their common-carrier obligations.<sup>56</sup> Many shippers counter that shippers should not be responsible for the consequences if a release were to occur due to actions by railroad employees, such as at Graniteville, or is exacerbated by railroad equipment conditions, such as at Minot.

The public at large is endangered by transportation of TIH. As the accidents in Minot, Macdona, and Graniteville demonstrate, the potentially fatal consequences of TIH releases during rail transportation may fall upon the general public and, in this sense, external costs of TIH materials are borne by the public. The government and thus, ultimately, the tax-paying public also bears a portion of the costs of preparing for a possible TIH incident, including public education, emergency preparedness and specialized equipment and training, as well as the costs of emergency response and cleanup after a TIH release.

A sense of the risk from TIH transportation accidents can be drawn from the actual TIH release events described above. The damage valuations reported to the NTSB relating to train equipment range from \$2.5 million in the case of the Minot accident to \$12 million in the Baltimore case, with additional environmental cleanup costs ranging from \$150,000 (Macdona) to \$8 million (Minot). However these figures exclude casualties, private property damage, and interruption of business, which are necessary to evaluate the total value of all losses to the society from the accidents in question. In the case of the

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<sup>56</sup> The railroads view TIH transportation as a “bet-the-company” risk, which they are unwilling to take on at any price. In this, the railroads demonstrate significant risk aversion.

Graniteville accident, the FRA estimated that the total cost of the accident, including loss of life, injuries, and evacuation costs, was \$126 million.<sup>57</sup> This figure gives a more accurate sense of the magnitude of TIH costs. Indeed, total costs in all of the cited cases could -- under different circumstances -- have been far higher. The Graniteville accident, for example, took place in a rural setting, at an early morning hour. If a similar accident had occurred in an urban area in the daytime, there might be many casualties and severe economic disruptions, while a successfully targeted terrorist attack could have even more catastrophic effect.

If the TIH risk could be quantified and incorporated into the price of TIH products and their transportation, this would allow stakeholders to make economically rational decisions concerning production, use, and shipping of TIH chemicals. Better understanding of the sources of the risk would facilitate setting rational priorities for various risk-reduction strategies.

However, quantification of the TIH risk presents formidable challenges that hinder the development of comprehensive policies to deal with the externality. The challenges of quantification stem in part from the high degree of uncertainty surrounding possible TIH rail accidents, and the even greater unpredictability of a potential terrorist attack. Fatal TIH releases are generally considered to be low-probability high-consequence events, which difficult to predict but produce potentially devastating effects if they do occur.

Acknowledging these difficulties, in this paper we define the risk as the product of:

1. the probability of an accident or terrorist attack that results in a TIH release; and,
2. the probable consequences of a release, if one occurs.

This is the definition used by the U.S. Department of Transportation in its 1989 HAZMAT transportation guidelines (revised in 1994) and it is generally accepted as the starting point for risk calculation.<sup>58</sup>

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<sup>57</sup> FRA, "Regulatory Assessment; Regulatory Flexibility Analysis – Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shippers" PHMSA-RSPA-2004-18730, April 2008. This analysis values fatalities at \$27 million, injuries at \$35 million, evacuation costs at \$10.5 million, property damage costs at \$6.9 million, environmental cleanup costs at \$150,000, and track out of service time at \$46 million.

<sup>58</sup> U.S. Department of Transportation, Federal Highway Administration, Office of Highway Safety, "Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials," FHWA-SA-94-083, September 1994.

The first component of risk, the probability of an incident of TIH release, is based on a number of factors. This discussion will focus on the risk stemming from accident, because the risk of terrorism is nearly impossible to quantify and will be discussed separately. The presence or absence of TIH cars in a train is not a major factor in the probability of an accident.<sup>59</sup> The probability of an accidental release is a function of the time and distance of exposure to risk, the quality of track and its signaling system, operating conditions (such as speed, single or double track, train routing, train control, train consist), quality of the rolling stock, and other factors. Human factors also play a role in many train accidents. Human errors exacerbated by excessive fatigue can be minimized by regulating working hours. At grade crossings where highway traffic intersects with rail tracks, many accidents are caused by motorists; such accidents are outside the railroads' control, and would be very difficult to quantify.

In the event of an accident, the second factor, the severity of the consequences, depends on various elements. The impact of a release will be influenced by the quantity of product released and the nature and toxicity of the specific chemical involved. The dispersion of the gas will be affected by the atmospheric conditions at the time of release, including the temperature, moisture in the air, and wind direction and speed. The spread of gas from the release site is also affected by the morphology of the terrain, the density of buildings, and the shape and direction of streets. Injuries and deaths caused by the release will depend on the number of persons and the duration of their exposure to the plume, which is a function of density of persons within the area, the size of the plume at toxic levels, and the speed at which persons affected can escape toxic levels. These factors are a function of time of day, the distance of that population from the release, the effectiveness of public response to emergency instructions, the rate at which people can move to safety, and the effectiveness of shelter-in-place.

The above elements of risk are relevant to a particular place and circumstance. To quantify risks for accidents in a network of rail links connecting many sources and delivery points of rail traffic, one must sum over the entire transit of a TIH train from loading point to product delivery. On the other hand, one could imagine dividing each link of a route into segments, each of which represents a different level of probability of accidents and the level of consequences based on the probabilistic analysis of a typical set of circumstances within each segment. The lowest risk segments could be analyzed by more simplistic assumptions, and the risk of the entire link could then be combined,

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<sup>59</sup> Human errors exacerbated by excessive fatigue can be minimized by regulating working hours. At grade crossings where highway traffic intersects with rail tracks, many accidents are caused by motorists; such accidents are outside the railroads' control, and would be very difficult to quantify.

based on length of the link and duration of exposure to accident. Conceptually, this allows a calculation of risk in terms of possible casualties. Practically, such a calculation would require gathering a broad range of information. As a practical matter, the result would be dominated by the higher risk segments on each link, and in urban areas at least one could expect a more complete risk analysis to be done by the local emergency operations authorities in the urban area in question. Perhaps more important, such an analysis would be used to compare the sensitivity of estimated risk and consequences to each of the analytical elements, thus supporting decisions on strategies to reduce risk.

### ***Policy Experience from Externalities Other Than Shipping Hazardous Materials.***

Lessons for dealing with the transportation of TIH and its safety and security externalities can be sought in policies that have addressed other externalities in the past. A variety of regulatory instruments seek to internalize external costs and protect the public. These include taxes such as the gasoline tax, emissions standards and market-based controls including cap-and-trade regimes (such as the Acid Rain Program), and limitations on liability and insurance schemes employed for nuclear reactors, oil spills, or bank deposits.

Perhaps the simplest way of addressing a situation in which private actors do not take into account the public consequence of their actions is to tax an offending activity or subsidize a beneficial activity. Taxes designed to change behavior (in contrast to taxes designed to raise revenue) are known as “Pigouvian” taxes, after the early twentieth century English economist Arthur Cecil Pigou. Pigouvian taxes work when an increase in the price of any existing good, service, or input into a production process leads to a decrease in its use. The magnitude of the change in usage generated by a Pigouvian tax depends on the availability of good substitutes, as well as the overall cost share of the input. As a consequence, while policy can predictably affect behavior through a Pigouvian tax, the magnitude of the impact will depend on the particulars of the situation. The better the available substitutes, the more effective the Pigouvian tax. An example might be the tax deductions granted owners of buildings installing green energy facilities during the Carter administration.

If the externality has the potential to be mitigated by new technology, policy could support research and development. The difference between this sort of subsidy and a Pigouvian subsidy is that an R&D subsidy is provided in an entirely different market from the one in which the external effect is present. In a technology-based approach for TIH, for example, a government-funded R&D program would subsidize firms that seek new approaches to accomplish industrial tasks while using smaller quantities of TIH chemicals. This type of policy strategy faces at least four obstacles. The first is the inherently uncertain nature of research, given that technical solutions cannot be counted

on to materialize when they are needed. Second, and related, long time horizons may be necessary to research new technical options and put them into practice. Such timeframes put outcomes outside of the scope of accountability for corporate leaders, directors of federal agencies, or elected officials. Third, systems integration challenges confront industry supply chains. Modification of such large, complex technical systems can result in unintended consequences. The generic challenge of transitioning an invention into a market-ready innovation is exacerbated here by the difficulty of embedding an innovation into these complex systems. Fourth, absent regulatory restrictions or Pigouvian taxes on the existing technology, the incentive to adopt a new technology may be insufficient to induce its creation and adoption.

Taxes (sticks) and research subsidies (carrots) may be supplemented by other policy instruments. The arena of environmental regulation provides several examples. The government might simply limit the use of a toxic substance. For example, the Clean Air Act Extension of 1970 empowered the EPA to set binding emissions limits on new sources of specified common air pollutants. The EPA was required to base standards on the “best technological system of continuous emission reduction,” that is, the state of the art in pollution control.

It can be a major challenge for the owner of an industrial facility to satisfy a complex set of federal environmental requirements imposed by different regulators with little or no coordination. While an inherent logic supported the notion that firms should utilize the “best available technology,” the unintended consequence of such an approach was to create an incentive for regulated industries to oppose the development of new and improved anti-pollution technologies.

The challenge, therefore, was to achieve the desired aim of reducing the overall quantity of pollutants emitted into the environment while providing firms with incentives to achieve those reductions at the lowest cost. The approach to regulation that eventually resulted was the model of emissions trading, also known as cap-and-trade. In these programs, a mandatory emissions cap is set. Each emissions source, such as a power plant, must choose its own preferred avenue of compliance with standards. Each is permitted to trade its emissions allowances, which are priced by the market. This is coupled with a strict monitoring and inspection regime. This type of market-based solution creates incentives for companies to search for efficient solutions.

Perhaps the most successful experience with emissions trading programs have been the cap and trade programs for Sulfur dioxide (SO<sub>2</sub>) and Nitrogen oxides (NO<sub>x</sub>), both administered by the EPA. SO<sub>2</sub> trading under the Acid Rain Program began in 1995, and initially targeted a subset of coal-burning power plants, later expanding to include more

power plants.<sup>60</sup> Each year, a set number of allowances for permitted tons of SO<sub>2</sub> are distributed by the EPA, which makes a limited number of further allowances available at auction. These allowances may then be bought, sold, or saved for future use. In 2007, the total value of the SO<sub>2</sub> allowance market was approximately \$5.1 billion, with an average nominal price of \$325 per ton and 4,700 transactions moving 16.9 million allowances.<sup>61</sup> The goal of the Acid Rain Program is to reduce SO<sub>2</sub> emissions to 8.95 million tons, or 50 percent of 1980 levels, in 2010 (the cap as of 2000 was 9.5 million tons). Meanwhile, the NO<sub>x</sub> cap-and-trade program successfully reduced emissions to 60 percent below 1990 levels by 2002.<sup>62</sup> However there is a fundamental difference between these pollutants and TIH in that whereas risk is evenly distributed across the population in the former case, only a fraction of the population is exposed to TIH release.

In situations where a dangerous good is also important to the public interest, a liability or insurance scheme can distribute the risk. For example, the Price-Anderson Act was enacted in 1957 to facilitate the development of the nuclear power industry.<sup>63</sup> The Act, which required reactor licenses involving technical and operational requirements, created a federal pool of funds to compensate victims of a nuclear accident that might take place at any point in the supply chain, including transportation, storage, or reactor operation. To fund the Act, reactor licensees are required to have \$300 million in private insurance; that sum is periodically revised based on the available amount of insurance.<sup>64</sup> In addition, in case of an incident with a cost exceeding \$300 million, licensees would be obliged to contribute further at a rate of up to \$10 million per year for each reactor, up to a maximum of \$95.8 million. This creates a virtual secondary insurance pool of over \$10 billion. If damages from a nuclear accident were to exceed the primary and secondary insurance coverage thus created, the government would, under the Price-Anderson Act have to propose a compensation scheme, which would require Congressional approval. The fund, administered by the Nuclear Regulatory Commission, has disbursed more than \$200 million since 1957, \$71 million of this related to the 1979 Three Mile Island accident.

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<sup>60</sup> U.S. Environmental Protection Agency (EPA), <[www.epa.gov/captrade/documents/arbasics.pdf](http://www.epa.gov/captrade/documents/arbasics.pdf)>.

<sup>61</sup> EPA, <[www.epa.gov/captrade/allowance-trading.html](http://www.epa.gov/captrade/allowance-trading.html)>.

<sup>62</sup> Established in 1999 among a group of northeastern and mid-Atlantic states, the NO<sub>x</sub> program regulates emissions of power-generating facilities and industrial boilers during ozone season. See EPA, <[www.epa.gov/captrade/documents/nox.pdf](http://www.epa.gov/captrade/documents/nox.pdf)>.

<sup>63</sup> For background on the Price-Anderson Act, see GAO, “Nuclear Regulation: NRC’s Liability Insurance Requirements for Nuclear Power Plants Owned by Limited Liability Companies,” GAO-04-654, May 2004.

<sup>64</sup> All nuclear liability policies are written by American Nuclear Insurers [see note above.].

Oil spills have also been tackled by federal regulation through a liability mechanism. The 1989 Exxon Valdez oil spill was a catalyst for the Oil Pollution Act of 1990. It authorized the creation of the Oil Spill Liability Trust Fund, managed by the National Pollution Funds Center. The OSLTF is financed by industry via a tax of \$0.05 per barrel of imported oil, interest on the Fund principal, assessed penalties, and cost recovery from responsible parties. The fund totaled a maximum of \$2.7 billion as of 2005.<sup>65</sup> The OSLTF can be used for federal cleanup costs and to meet damage claims by government entities, corporations, or individuals.<sup>66</sup> If an accident occurs, the responsible party must cover cleanup and claims up to its liability limit (except that liability for a spill due to gross negligence is not capped).<sup>67</sup> Liability limits for accidents vary by vessel size; for example, the liability limit for a tank vessel of more than 3,000 gross tons is the greater of \$3,000 per gross ton or \$22 million.<sup>68</sup> Beyond the liability limit, responsible parties may present claims to the OSLTF for additional funding. However, the funds available from the OSLTF are limited to \$1 billion per incident. The Oil Pollution Act also set operational mandates relating to vessel construction, crew licensing and manning, and contingency planning in order to reduce the risk of future accidents. This is similar in concept to the licenses required of reactors by the Price-Anderson act, combining technical and operational requirements with a financial liability scheme.

Other models may be found in the financial arena. An example of an insurance scheme is the Federal Deposit Insurance Corporation (FDIC), an independent government agency created in 1933 during the Great Depression to insure private accounts in commercial banks against bank failures.<sup>69</sup> Individual deposits are insured up to \$100,000 (in late

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<sup>65</sup> The Oil Spill Liability Trust Fund (OSLTF) is described at [http://www.uscg.mil/npfc/About\\_NPFC/osltf.asp](http://www.uscg.mil/npfc/About_NPFC/osltf.asp).

<sup>66</sup> U.S. Department of Homeland Security, U.S. Coast Guard, "Oil Spill Liability Trust Fund (OSLTF) Funding for Oil Spills," January 2006.

<sup>67</sup> Other exceptions to the liability cap include failure to report the incident and violation of federal regulations: see U.S. Code Title 33, Chapter 40, Subchapter 1, Section 2704 "Limits on liability," [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse\\_usc&docid=Cite:+33USC2704](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+33USC2704). However the responsible party is not liable for costs and damages if the spill is caused by an act of God, an act of war, government negligence, or act or omission of a third party: see U.S. Code Title 33, Chapter 40, Subchapter 1, Section 1321, "Oil and hazardous substance liability," [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse\\_usc&docid=Cite:+33USC1321](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+33USC1321)

<sup>68</sup> See the National Pollution Funds Center, "Oil Pollution Act (OPA) Frequently Asked Questions," November 6, 2009, [www.uscg.mil/npfc/About\\_NPFC/opa\\_faqs.asp#faq1](http://www.uscg.mil/npfc/About_NPFC/opa_faqs.asp#faq1).

<sup>69</sup> See FDIC website, [www.fdic.gov/about/learn/symbol/index.html](http://www.fdic.gov/about/learn/symbol/index.html); see also "Deposit Insurance: An Annotated Bibliography," [www.fdic.gov/deposit/deposits/international/bibliography/index.html](http://www.fdic.gov/deposit/deposits/international/bibliography/index.html).

2008, this limit was temporarily raised to \$250,000). Funding for the FDIC derives from fees banks are required to pay based on the volume of deposits they hold. FDIC funds are invested in U.S. Treasury securities. As of 2009, the FDIC insurance fund totaled over \$17.3 billion and insured more than \$4 trillion of deposits.<sup>70</sup> The FDIC is charged with monitoring member banks to ensure that they are meeting liquidity requirements. If a bank fails, the FDIC pays out for depositor losses, and also oversees the sale of the failed bank's assets and the settlement of its liabilities.

Another example of insurance, the Terrorism Risk Insurance Act (TRIA) of November 2002 (reauthorized in December 2006), was designed to solve a specific problem. After the events of September 11, 2001, the insurance industry was newly appreciative that terrorist attacks might occur and involve enormous potential liabilities. Thus they became reluctant to provide insurance coverage against terrorism for new commercial construction while, particularly in New York City, builders were unwilling to move forward with construction projects without such terrorism protections. Congress therefore agreed to underwrite terrorism risk insurance. Much like the Price-Anderson Act, TRIA pledged the resources of the federal government in order to encourage economic activity in an environment of pervasive risk. However, this step did not reduce those risks.

These various policy instruments all provide models for the TIH issue, and their potential applicability is evaluated below. First, however, we examine risk-reduction strategies that are applicable to TIH; these are comparable to policies such as the OSLTF and the Price-Anderson Act that impose operational requirements designed to enhance the safety of the underlying supply chain and reduce the risk of a catastrophic accident.

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<sup>70</sup> See FDIC website, <[www.fdic.gov/about/learn/symbol/index.html](http://www.fdic.gov/about/learn/symbol/index.html)>.

## **IV. Risk Reduction Strategies**

Several broad areas of TIH transportation offer the potential for risk reduction, including changes in rail operations, improvements in tank car design, more effective emergency response, product substitution by TIH users, and relocation of TIH sources or users. Improvements can be achieved through a combination of voluntary initiatives by the railroads and their unions, together with government regulation. This section lays out the various options, and examines progress to date and potential for future action.

First, changes to rail operations may diminish the chances of a catastrophic accident, and may also reduce the opportunities for a terrorist attack. Rail safety improvement is an ongoing process that is in the interest of all stakeholders. Initiatives that have already been undertaken include modifications of rail equipment, such as tank car design enhancements, and development and installation of positive train control following a legislative mandate. Other risk-reduction measures might include changes to rail operations, such as rerouting, improved yard management, or repositioning the tank car within the train composition or “consist.”

A second broad area for improvements is emergency response, to mitigate the effects of any incident. Better training for emergency responders that is specific to dealing with hazardous materials and TIH, appropriate equipment for such incidents, management of response infrastructure, information and training of the public and improved coordination among parties are critical, particularly in the case of an intentional or terrorist attack.

Another category of risk-reduction strategies involves product substitution and management of the supply chain (including modifying production and use locations) so as to minimize the need to transport TIH materials over long distances. This approach attacks the source of the risk directly, and would be the best long term risk reduction strategy, but could be the most difficult to achieve comprehensively because existing patterns of use and location of sources and users of TIH chemicals would be hardest to change.

### ***Tank Car Design and Safety Improvements***

One area offering clear potential for risk reduction is tank car design. Recent accidents have underlined the need to develop better safety standards for tank cars and spurred both private industry and government regulators to address the design issue. However, stakeholders in the chemical and rail industry may have conflicting interests; together

with uncertainty as to regulatory roles, this creates contentious issues relating to the quantification and assignment of costs and risks borne by each player.

The modern pressurized railroad tank car is designed to transport liquids in bulk, such as petroleum products, liquid chemicals, or liquefied gases. Tank car shells made after 1989 are constructed from rolled plates of TC-128 normalized steel. The shell is surrounded by insulation and enclosed in an outer jacket of steel, which keeps the insulation in place but adds little protection. A stub sill, which is the structural member for the couplers and draft gear and is also the attachment point for the wheel sets, is attached to the underside of the tank at each end. Brakes and other features are welded to pads, which are welded to the tank shell to improve stress distribution. The average cost of a tank car in 2008 was around \$120,000.<sup>71</sup>

As of 2006, there were 275,000 such tank cars in use in the United States, representing 17 percent of the total railcar fleet.<sup>72</sup> Of these, 74 percent were owned by rail car leasing companies, 26 percent by shippers, and less than 1 percent by the railroads.<sup>73</sup> Tank cars vary considerably in design to make them appropriate for carriage of specific chemicals; only about one-fourth of the tank car fleet is approved for use with TIH chemicals.<sup>74</sup>

The accident record of rail tank cars is very good overall, despite the recent TIH rail accidents described above. However, these incidents highlighted the need to strengthen TIH tank cars. The National Transportation Safety Board found that deficiencies in the breached tank cars were a major cause of the 2002 accident in Minot, ND.<sup>75</sup> The ruptured tank cars were constructed before the 1989 rule change that required normalized steel in tank car construction; because they were made of non-normalized steel, they were therefore less resistant to puncture than newer cars.

Many recent efforts to improve tank car design were initiated in the private sector, prompted by the desire to preempt government regulation, to gain advantage over competitors, as well as ethical consideration, public relations benefits, and a focus on enterprise risk management.

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<sup>71</sup> See Comments by Olin Corporation, PHMSA Docket FRA-2006-25169, June 2, 2008, p. 1.

<sup>72</sup> D. Samples, “2008 and Beyond — Building for the Future,” Union Tank Car Co., October 4, 2007.

<sup>73</sup> D. Samples, “2008 and Beyond — Building for the Future.” The three largest tank-car leasing companies are the GATX Corporation, the Union Tank Car Company, and GE Rail.

<sup>74</sup> Patrick J. Krick, “Security, Capacity and Risk Management — The Case of TIH Products and Pressure Tank Car,” 2006, (consulting company white paper), <[www.thomasgroup.com/eLibrary/White-Papers/Security-Capacity-and-Risk-Management-The-Caseof-.aspx](http://www.thomasgroup.com/eLibrary/White-Papers/Security-Capacity-and-Risk-Management-The-Caseof-.aspx)>.

<sup>75</sup> NTSB Report — Minot.

The Association of American Railroads Tank Car Committee (AAR-TCC) began to study the design of a safer tank car following TIH accidents of 2002-2005. Its goal was to develop a TIH tank car that would reduce the conditional probability (CPR) of TIH release upon impact by 65 percent.<sup>76</sup> In March 2008, the AAR set new standards for shell, tank-head, and top fittings.<sup>77</sup> These industry rules applied a higher DOT standard to various base types of tank car used for TIH carriage.<sup>78</sup> However these rules were later preempted by a January 2009 federal rule, described below.

Meanwhile, shippers, carriers, rail car builders, and government joined in an effort designated the Next Generation Rail Tank Car Project (NGRTC). The project included participation by Dow Chemical, Union Pacific Railroad, and the Union Tank Car Company (UTLX), as well as the Transportation Security Administration (TSA) of the Department of Homeland Security, the Federal Railway Administration (FRA), and its Canadian counterpart, Transport Canada.<sup>79</sup> The goal of the project was to design a tank car that would perform five to ten times better in a standardized test that measures the energy required to cause failure in a current tank car approved for carrying chlorine.<sup>80</sup> The NGRTC declared the “end of [the] evolutionary path for [a] ‘thicker is better’ approach,” and instead considered options to modify the structural design of the current tank cars to increase impact resistance or shock absorption.<sup>81</sup> Added head protection measures, for example, would include either stronger head shields or deformable head shields to create “crumple zones” that would absorb more impact before the impact force could reach the TIH container. The non-structural outer layer of steel could be strengthened to provide additional crash protection, with incorporation of energy-

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<sup>76</sup> Conditional probability of release (CPR), the metric used by the AAR, is the estimated probability of release from a given tank car in the event of an accident.

<sup>77</sup> Ibid. For example, chlorine cars meeting minimum DOT specification for 105J500W cars with no head shield, head thickness of 0.787 inches, and shell thickness of 0.787 inches, would, according to the industry’s new standard, have to comply with minimum specification 105J600W, with a full-height head shield and increased head and shell thickness (to 1.1360 inches and 0.9810 inches respectively). According to the AAR, the new requirements could be met using upgraded versions of the current tank cars.

<sup>78</sup> Association of American Railroads, “Docket No. FRA-2006-25169: Hazardous Materials: Improving the safety of railroad tank car transportation of hazardous materials: Comments of the Association of American Railroads.” June 2, 2008, p. 8.

<sup>79</sup> See NGRTC Project, “Next Generation Rail Tank Car,” presentation to Transportation Research Board (TRB), 87th Annual Meeting, January 16, 2008; and David Noland, “Safer Train Tank Car Tech Rolling Down the Line,” *Popular Mechanics*, February 6, 2007.

<sup>80</sup> NGRTC Project, “Next Generation Rail Tank Car.”

<sup>81</sup> NGRTC Project, “Next Generation Rail Tank Car.”

absorbing layers. Within the shell, the tank support system could be modified to allow the tank to move more freely in case of impact, isolating it from crash forces. One the most promising and easiest design modifications would be improvement of fittings and valves. Reducing their profile or creating removable valves would decrease vulnerability in case of accident. The installation of real-time monitors on TIH cars to transmit information to control centers was studied, and shippers have begun to implement this measure.<sup>82</sup>

In August 2005, after the TIH rail accidents described above, Congress added a section of hazmat law to the SAFETEA-LU federal transportation authorization statute.<sup>83</sup> It required the FRA to develop and validate a predictive model for tank car accidents and to begin the rulemaking process for improved tank car standards.<sup>84</sup> These efforts resulted in new FRA regulations in early 2009 that raised standards for tank cars.<sup>85</sup>

FRA research has focused on evaluating accident survivability of tank cars through a modeling and testing process. The Volpe National Transportation Systems Center conducted a program of testing and modeling that eventually developed a concept design for a new type of tank car. The Volpe conceptual design is based on the use of sandwich panels of two sheets of steel, separated by an interior structure such as a honeycomb. Such panels can “support loads in the plane of the panel while offering effective energy-absorbing capability in the normal (out-of-plane) direction, as well as a high bending resistance.”<sup>86</sup> Significant work remains to be done before a prototype car using this technology could be constructed.

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<sup>82</sup> RFTTrax of Sugarland, Texas, is developing an Asset Command Unit for the NGRTC that uses GPS to track the tank car's position and sensors to detect the level of chemical product in the tank car; it transmits this information to shippers. Dow Chemical has installed GPS tracking on its TIH tank cars.

<sup>83</sup> See SAFETEA-LU, “Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users,” text at <frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109\_cong\_bills&docid=f:h3enr.txt.pdf>.

<sup>84</sup> HAZMAT is addressed in Title VII of SAFETEA-LU.

<sup>85</sup> U.S. DoT, Pipeline and Hazardous Materials Safety Administration (PHMSA), 49 CFR Parts 171, 172, 173, 174 and 179. “Hazardous Materials: Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials; Final Rule,” January 13, 2009.

<sup>86</sup> M. Carolan, B. Talamini, and D. Tyrell, “Update on ongoing tank car crashworthiness research: predicted performance and fabrication approach,” Proceedings of 2008 Joint Rail Conference, Institute of Electrical and Electronics Engineers (IEEE) and American Society of Mechanical Engineers (ASME), April 22–23, 2008, p. 2.

The DOT nevertheless drew upon the Volpe research during the regulatory process that culminated in a Final Rule published in January 2009.<sup>87</sup> The rule requires better puncture resistance for TIH tank cars in either the inner shell or outer jacket, installation of full head shields, and enhanced protection for valves and fittings. It also set a 50 mph speed limit for loaded TIH cars and imposed a requirement to prioritize replacement of all tank cars built from non-normalized steel. The rule specified that these standards should be considered interim tank car standards, applying to all cars built after March 16, 2009. Even if later research and testing results in different standards, the rule specified that tank cars complying with the interim standards would be continue to be acceptable for 20 years under a “grandfather” clause. These federal standards explicitly preempt the AAR standards described above.

There was a long process of dialogue and debate among stakeholders before the terms of the final rule were settled. For example, a performance standard that would have required TIH tank cars to resist shell puncture at 25 mph and tank-head puncture at 30 mph was abandoned.<sup>88</sup> Since this had been based on the calculation that secondary car-to-car impact speed was approximately half that of the train speed, the 50 mph limit set in the final rule was expected to be adequate instead.<sup>89</sup> Ultimately, the final rule based standards on a chemical industry petition that proposed a commodity-specific scale-up in tank car specifications: each commodity, ranked by degree of TIH hazard, would require the next-strongest tank car, with thicker steel.

Another important point of debate involved speed limits. The FRA had found that a “disproportionate” number of accidents occurred in non-signaled or “dark” territory. The Proposed Rule therefore required a limit of 30 mph for TIH tank cars in dark territory, unless the tank cars conformed to the new, enhanced standards. However, the railroads argued successfully for dropping this standard, arguing that it would hinder service to the non-TIH customers that comprised the vast majority of traffic.

As of mid-2009, the FRA tank car regulation had not spurred demand for new cars.<sup>90</sup> American Railcar Industries blamed the economic slowdown: “We haven’t seen much of

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<sup>87</sup> U.S. DoT, Pipeline and Hazardous Materials Safety Administration (PHMSA), 49 CFR Parts 171, 172, 173, 174 and 179. “Hazardous Materials: Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials; Final Rule,” January 13, 2009. Hereafter DOT Tank Car Final Rule.

<sup>88</sup> Based on the calculation that secondary car-to-car impact speed was approximately half of the train speed, this standard had been proposed in conjunction with the 50 mph speed limit.

<sup>89</sup> See Discussion in DOT Tank Car Final Rule, p. 1779.

<sup>90</sup> Argus Rail Business, “FRA tank car replacement rules fail to spur demand,” June 22, 2009.

an impact from the FRA rule. Orders are pretty soft.... With the economy slowing down, shipments have slowed down.”<sup>91</sup>

The final rule represented an incremental approach that was more palatable to railroad and chemical industry stakeholders. The rulemaking process highlighted the difficulty of resolving the competing interests of different stakeholders. Instead, cooperative programs such as the NGRTC could provide a valuable model for performing the research necessary to allocate long-term investments towards the more radical tank car enhancements that might do more to reduce the risk of a TIH release.

### ***TIH Train Re-routing and Re-scheduling***

The potential consequences of a TIH release depend on the severity of the accident and also on the location and time of the accident. One widely-discussed risk-mitigation proposal involves re-routing trains containing TIH tank car loads, for example, by choosing a route with less population exposure.

This risk-reduction strategy came to the fore in the midst of concern over rail security after the 9/11 attacks. TIH tank cars passing through major population centers were recognized as potential chemical weapons. Proponents of mandatory rerouting of TIH products argued that diverting trains around cities would place fewer people at risk of a terrorist attack, and would also decrease risks due to accident.

On the basis of this reasoning, in February 2005 the Washington, D.C., City Council enacted an emergency measure that banned transportation of hazardous materials within a specified “Capitol Exclusion Zone” with a radius of 2.2 miles from the U.S. Capitol.<sup>92</sup> D.C. Councilmember Kathy Patterson argued that, given D.C.’s high profile as a target, and a lack of appropriate federal action, it was imperative for local authorities to act. In highly publicized testimony, Dr. Jay Boris of the U.S. Naval Research Laboratory suggested a potential for enormous casualty rates if TIH were released in Washington during a daytime event that had attracted huge crowds to the Mall. Under this worst case, he estimated, there could be as many as 100,000 deaths within thirty minutes of a chlorine release near the Capitol.<sup>93</sup> The D.C. Council asserted that the ban would not impose an unreasonable burden on the railroad. Baltimore, Cleveland, Boston and other

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<sup>91</sup> Ibid.

<sup>92</sup> Walt Bogdanich and James Dao, “Legislators Move to Toughen Federal Rail Oversight,” *New York Times*, February 2, 2005, <[www.nytimes.com/2005/02/02/national/02rail.html](http://www.nytimes.com/2005/02/02/national/02rail.html)>.

<sup>93</sup> Boris presentation to D.C. City Council.

cities considered implementing similar bans, but little effort was made to identify where the rerouted shipments would go instead.

CSX Transportation, Inc., owner of the rail line passing through the District, immediately filed a motion in federal court seeking suspension of the ban. CSX argued that the city's action violated the Commerce Clause of the U.S. Constitution and was preempted by existing federal law. CSX feared that if D.C.'s ban were upheld and other cities and counties followed, it would complicate railway operations and add significant extra costs especially to HAZMAT transportation.

CSX's initial challenge was at first denied in D.C. District Court in April 2005; the judge ruled that the D.C. ban did not conflict with federal law.<sup>94</sup> In early May 2005, however, the U.S. Court of Appeals for D.C. reversed that decision; ruling in favor of CSX, it held that an injunction to block the D.C. ban would be permitted.<sup>95</sup> There was public criticism of the decision on appeal, with calls for Congress to legislate mandatory HAZMAT re-routing to keep dangerous TIH chemicals away from government targets and population centers.<sup>96</sup>

The goal of any re-routing strategy should be to minimize both the risk and the impact of a TIH release. There are, however, many possible means to evaluate the route. Risk could be evaluated according to parameters that include least population exposed to TIH risk, shortest route by distance, shortest route by time, or safest track quality. Complicating the issue is that these criteria may be contradictory: for example, the shortest route might expose more people to a possible TIH release, or the route that puts the fewest people at risk might be a rural track of lower quality without signals, thus increasing the potential for an accident. Therefore, choice of re-routing criteria must involve careful evaluation to determine whether new routes actually represent a significant reduction of overall risk.

Rerouting is also complicated by the nature of the rail network itself, which is far less extensive than the highway network and therefore offers fewer route options.<sup>97</sup> Each individual rail carrier operates mostly over its own network, which is unlikely to have

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<sup>94</sup> Terrence Nguyen, "Judge rules in favor of DC HAZMAT ban," *Fleetowner.Com*, April 19, 2005, <fleetowner.com/news/dc\_hazmat\_ban\_washington\_041905/index.html>.

<sup>95</sup> CSX Transportation, Inc. v. Williams, United States Court of Appeals, D.C. Circuit, May 3, 2005, <bulk.resource.org/courts.gov/c/F3/406/406.F3d.667.05-5131.html>.

<sup>96</sup> "Washington's Deadly Bridge," *New York Times*, July 5, 2005, <www.nytimes.com/2005/07/05/opinion/05tue1.html>.

<sup>97</sup> Glickman, Erkut, and Zschocke, "The cost and risk impacts of rerouting railroad shipments of hazardous materials," p. 1016.

multiple efficient routing options. Cooperation with other rail companies would provide more rerouting options; however, it would also require interchanges among carriers. Interchanges involve switching, with greater risk of accidents, and they also impose administrative costs and loss of revenue for the railroad originating the shipment. In addition to the cost and complexity, and questions about which routing choice gives the greatest safety and security for the least cost, there will remain essential industries that can only be served by using track that lead through large cities.

Rail industry opponents of rerouting proposals have argued that moving TIH cars out of cities would not necessarily reduce overall risk of an accident.<sup>98</sup> Most tracks running through cities are of the highest quality, and are equipped with the best signaling systems. Moving TIH cars through cities often represents the most direct route, thus minimizing the distance the TIH must be shipped. The nature of the rail network makes it very difficult for most shipments to avoid cities; shifting TIH traffic to a more rural route might require carriage over less-safe track over greater distances, and for longer time in transit. Thus, seeking to decrease the likelihood of a terrorist attack by rerouting might, paradoxically, increase the likelihood that an accident might take place (although perhaps in an area where it would have consequences for fewer people). Thus whether overall risk would be reduced would depend on the relative balance between likelihood of an accident, which might be increased by rerouting, and the likelihood that a substantially smaller population would be exposed.

Several studies have attempted to assess the opportunities for improving safety by rerouting hazardous materials (HAZMAT). The Oak Ridge National Laboratory of the U.S. Department of Energy produced a framework and a Web/GIS tool for routing HAZMAT shipments.<sup>99</sup> This tool, designated “THREAT” (Tool for HAZMAT Rerouting Evaluation and Alternative Transportation), searches for routes to optimize specified objectives and calculates performance measures for those routes.<sup>100</sup> The routing engine incorporates GIS (global information system) data illustrating rail networks, HAZMAT data on commodity movement and characteristics, population data from the census, risk functions, and other parameters to generate routing solutions and route assessments.

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<sup>98</sup> AAR, “Mandatory HAZMAT Rerouting,”

<[www.aar.org/GovernmentAffairs/~media/AAR/PositionPapers/833.ashx](http://www.aar.org/GovernmentAffairs/~media/AAR/PositionPapers/833.ashx)>.

<sup>99</sup> Han, L.D., S. Chin, H. Hwang, and B.E. Peterson, “A Tool for Railroad Hazmat Routing under Shipment Bans in Major Cities,” Proceedings of the 85th TRB Annual Meetings CD, Paper 06-1790, Washington, DC, 2006.

<sup>100</sup> Han, Chin, Hwang, and Peterson, “A Tool for Railroad HAZMAT Routing.”

A 2006 case study applying this tool to various scenarios demonstrated the tradeoffs involved in re-routing and the possibility of unintended consequences of mandatory re-routing.<sup>101</sup> For example, a “Least Population” scenario reduced the number of people at risk, but did so with a route about twice as long in distance and time. Thus, although the population exposed in case of an accident might be diminished, the probability of an accident occurring was evidently worse. Since overall risk depends on both the probability of a release and the probable consequences of a release, the effect of such a - routing strategy on overall risk may be, at best, ambiguous.

Another rerouting analysis, conducted by Glickman, Erkut, and Zschocke, concluded however that in some cases, risk could be reduced without substantially increasing route length of shipments.<sup>102</sup> The authors studied alternate routes for a random selection of origin-destination (O-D) pairs, and assessed the expected number of residents exposed to the impacts of a HAZMAT release from an accident.<sup>103</sup> Some O-D pairs, such as the Birmingham-Providence route, offered an opportunity for risk reduction without increasing route length. Others did not. On the New York-Charlotte route, for example, an alternate route resulted in a risk reduction of 91 percent, but at the cost of a 25 percent increase in distance. The results of the study suggest that rerouting opportunities may indeed exist, but must be studied on a case-by-case basis.

The railroad industry has undertaken several TIH routing initiatives. For example, specified “key trains” carrying hazardous materials must travel on routes that are inspected at least twice per year.<sup>104</sup> Any track used for meeting and passing “key trains” is required to be at least Class 2.<sup>105</sup> Railroads prefer to route trains with TIH tank cars on

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<sup>101</sup> Han, Chin, Hwang, and Peterson, “A Tool for Railroad HAZMAT Routing.”

<sup>102</sup> T. Glickman, Erkut, E., and Zschocke, M.S., “The cost and risk impacts of rerouting railroad shipments of hazardous materials.” *Accident Analysis and Prevention*, Vol. 35, Issue 5, September 2007, pp. 1015-1025.

<sup>103</sup> Number of residents exposed was calculated as the product of the accident rate, link length, conditional release probability, impact area, and population density.

<sup>104</sup> AAR Circular OT-55-I. A “key train” is defined as having: “five tank car loads of Poison or Toxic Inhalation Hazard (PIH or TIH) (Hazard Zone A, B, C, or D) or anhydrous ammonia, or; 20 car loads or intermodal portable tank loads of a combination of PIH or TIH (Hazard Zone A, B, C or D), anhydrous ammonia, flammable gas, Class 1.1 or 1.2 explosives, and environmentally sensitive chemicals, or; one or more car loads of Spent Nuclear Fuel (SNF), High Level Radioactive Waste (HLRW).”

<sup>105</sup> The FRA classifies track based on safety in classes 1–9. The higher the class number, the higher quality the track and the faster trains are allowed to run on that track. Most freight operates on class 4 track or lower; no freight operates on tracks rated higher than class 5.

higher-quality track with better signaling systems, because this reduces risk. The dominant routing priority, however, is operational efficiency, generally determined by the shortest route. Railroads may be reluctant to shift TIH traffic away from the shortest route because such changes create both operational challenges and higher costs.

New federal regulations have signaled an increased government attention to routing. In general, the DOT has opted for a flexible approach that allows railroads considerable freedom in selecting TIH shipment routes. In a rule issued November 26, 2008, DOT explicitly declined to ban TIH movement through urban areas, acknowledging that such mandatory re-routing could potentially increase risks.<sup>106</sup> Instead, DOT emphasized mandatory route analyses. The new rule requires rail carriers to compile annual data on movements of explosives, TIH, and radioactive materials.<sup>107</sup> They must then use these data in a comprehensive assessment of safety and security risks for each route on which hazardous materials are transported, as well as possible alternate routes.<sup>108</sup> The rule directs that railroads use 27 specified factors as the basis for their analyses.<sup>109</sup> These factors include volume of HAZMAT transported, trip length for route, track type, class, and maintenance schedule, single vs. double track, proximity to iconic targets, presence of passenger traffic along route, and past incidents.<sup>110</sup> The rule directs that for each primary route currently used, “commercially practicable” alternatives must be identified and analyzed.<sup>111</sup> A practicable route is defined as “one that may be utilized by the railroad within the limits of the railroad’s particular operating constraints and, further, is economically viable given the economics of the commodity, route, and customer relationship.”<sup>112</sup> If a change in route would considerably raise costs, the rail carrier is to

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<sup>106</sup> DoT, PHMSA, 49 CFR Parts 172, 174 and 209, “Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments; Railroad Safety Enforcement Procedures; Enforcement, Appeal and Hearing Procedures for Rail Routing Decisions; Final Rules.” November 26, 2008. Hereafter referred to as PHMSA, Rail Routing Final Rule, November 2008.

<sup>107</sup> PHMSA, Rail Routing Final Rule, November 2008.

<sup>108</sup> Note that the regulation appears to focus more on accident risk than on the possibility of terrorism, since a targeted terrorist act would be designed to cause maximum casualties in an urban area; routing might therefore be expected to have a greater impact on reduction of risk from terrorism.

<sup>109</sup> These factors are specified in Appendix D to 49 CFR Part 172.

<sup>110</sup> Note, however, that the volume of population exposed along a route varies with time of day: at night, with a few exceptions such as nighttime athletic events, the majority of urban populations are already “sheltering in place” at nighttime, which is a common protection strategy for a public exposed to a TIH gas.

<sup>111</sup> PHMSA, Rail Routing Final Rule, November 2008, 72186.

<sup>112</sup> For definition, see Interim Final Rule of April 2008: DoT, PHMSA, 49 CFR Parts 172, 174 and 209, “Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials

document the supporting data for such a conclusion. Carriers must consider the use of interchange arrangements. Based on the route analyses, carriers must select routes for HAZMAT that pose the least risk, balancing all relevant factors.

### *Chain of Custody*

In a complex supply chain, TIH products are passed from producer to railroad carrier to end-user or consumer. The railroad carrier may switch the product from one train to another or to a different rail carrier (referred to as interchange). These handoffs create vulnerabilities: unattended tank cars could be attacked; accidental leaks might not be immediately detected.

Because of these potential vulnerabilities, securing the TIH chain of custody was a focus in a TSA rule on Rail Transportation Security in November 2008.<sup>113</sup> The new regulations ordered shippers and carriers to undertake physical inspections to check for signs of tampering and to require documentation of all transfers. In high-threat urban areas (HTUAs) designated by the TSA, delivered cars must be kept within secure areas. The regulation specified the authority of TSA officials to inspect facilities and records relevant to rail security. Railroads, shippers, and receivers must designate rail security coordinators to serve as the primary contact with TSA, to coordinate security activities, and to report any incidents or concerns. Time limits are set within which rail carriers must provide TIH tank-car locations and shipping information to TSA.

Railroad companies instituted new measures to comply with these new documentation and control requirements for TIH rail cars. For example, Union Pacific notified customers that billing information for tank cars must be in UP's system before cars could be accepted by UP employees.<sup>114</sup> CSX notified customers that they would be responsible for designating secure areas at their shipping and receiving facilities.<sup>115</sup> CSX specified that in

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Shipments; Railroad Safety Enforcement Procedures; Interim Final Rule and Proposed Rule." April 16, 2008, p. 20760. Under the Final Rule of November 2008, route selection procedures were to be implemented by September 1, 2009, if six months of data were analyzed, or by March 31, 2010, if data for all of 2008 were analyzed.

<sup>113</sup> Department of Homeland Security, Transportation Security Administration, 48 CFR Parts 1520 and 1580, "Rail Transportation Security; Final Rule" November 26, 2008.

<sup>114</sup> Union Pacific, "Chemical Transportation Safety Update," April 1, 2008.

<<http://www.uprr.com/she/cts/prevent.shtml>>

<sup>115</sup> CSX, Letter to HAZMAT Shippers and Receivers, December 19, 2008.

<<http://www.csx.com/share/customers/ch/docs/TSAREgsLetter-REF24822.pdf>>

HTUAs, consignees must have personnel present for hand-offs and must document all transfers.

### ***Positive Train Control***

Positive Train Control (PTC) is a collection of systems designed to increase railroad safety by overriding the engineer's control of the train in dangerous situations and automatically stopping the train. The American Association of Railroads describes the purpose of PTC as "systems designed to help prevent collisions among two or more trains, to enforce speed limits and to protect employees engaged in track maintenance."<sup>116</sup> A PTC system uses sensors on the locomotive and along the tracks, and then makes calculations involving the train composition (or "consist") and the terrain over which the track runs to determine when and whether to stop the train.<sup>117</sup>

Similar collision-avoidance train protection or control systems are already in use around the world, especially in high-speed passenger operations. However, nowhere in the world is such a system in place on a network comparable in extent and complexity to the North American rail network: its freight volumes exceed those of any other rail network in the world. Recognizing the potential safety benefits, however, Class I U.S. freight railroads (the largest by operating revenues as defined by the FRA) have been developing and testing PTC prototype systems, especially since the early 1990s.<sup>118</sup> In the U.S. Northeast Corridor between Washington DC and Boston, Amtrak uses a version of positive train control.<sup>119</sup> However, the high cost of implementing such a system over the entire U.S. rail network, combined with the technical challenges, have delayed PTC implementation in the United States.

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<sup>116</sup> AAR, "Positive Train Control: Frequently Asked Questions,"  
<[www.aar.org/Initiatives/PositiveTrainControl/PTC\\_FAQ.aspx](http://www.aar.org/Initiatives/PositiveTrainControl/PTC_FAQ.aspx)>.

<sup>117</sup> Positive Train Control could be complemented by electronically-controlled pneumatic (ECP) brakes, which are simultaneously activated along the entire length of the train by an electric signal. This would allow the train to stop much faster: between 40 percent and 60 percent more quickly for a long train. ECP brake systems are also considered to be more reliable and less subject to failure. However ECP brakes are incompatible with conventional brakes; an FRA official has estimated that it would cost around \$6 billion to retrofit the entire North American freight car fleet for ECP brake operations. See U.S. DOT, 49 CFR Part 232, "Electronically Controlled Pneumatic Brake Systems; Final Rule," October 16, 2008, p. 61513.

<sup>118</sup> Peter A. Hansen, "6 high-tech advances," *Trains*, November 2008, p. 29.

<sup>119</sup> See description of ACSES (Advanced Civil Speed Enforcement System), the Positive Train Control system installed on Amtrak's Northeast corridor, at  
<[www.alstomsignalingolutions.com/OurProducts/PositiveTrainControl/ACSES/](http://www.alstomsignalingolutions.com/OurProducts/PositiveTrainControl/ACSES/)>.

The recent catalyst for PTC was the collision of a Metrolink commuter train with a Union Pacific freight train on September 12, 2008, in Los Angeles, California, which resulted in 25 deaths and over 130 injured. The accident appears to have been caused by the Metrolink engineer's failure to respond to a stop signal, resulting in collision with the incoming freight train which had not yet entered a siding to let the commuter train pass by.<sup>120</sup> This accident prompted legislation that was signed into law on October 16, 2008.<sup>121</sup> The Rail Safety Improvement Act of 2008 (RSIA) required all Class I railroads (the largest) and all intercity passenger and commuter railroads to implement a PTC system by December 31, 2015, on main line track carrying either passengers or TIH materials.<sup>122</sup>

The implementation of PTC in the United States involves significant practical challenges. First, effective PTC requires interoperability among all major railroads, since locomotives from one railroad often operate over the tracks of another railroad. The four U.S. Class I freight railroads promptly agreed on interoperability standards in October 2008.<sup>123</sup> Second, PTC is not an "off-the-shelf system": significant components of the technology must be designed, tested, and adapted for the specific operating environments of the rail lines on which they are installed. The final major obstacle is cost, including a large investment in new technology. The FRA estimated that industry-wide costs might range from \$2.3 to \$5 billion,<sup>124</sup> with most of this cost borne by the private Class I railroads.

While PTC will not eliminate rail accidents, it should represent a safety improvement that could help reduce the risk of all rail accidents, including those involving TIH.

### ***Hours of Service Regulations***

TIH accidents at Graniteville and Macdonald raised questions about the hours-of-service regulations that govern rail labor. At Graniteville, a crew running up against a time limit

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<sup>120</sup> Jennifer Steinhauer and Michael Cieply, "Rail Line Says Train Ran Signal; Death Toll at 25," *New York Times*, September 13, 2008, <[www.nytimes.com/2008/09/14/us/14crash.html](http://www.nytimes.com/2008/09/14/us/14crash.html)>.

<sup>121</sup> Rail Safety Improvement Act of 2008 (RSIA), full text and bill summary, <[www.govtrack.us/congress/bill.xpd?bill=h110-2095](http://www.govtrack.us/congress/bill.xpd?bill=h110-2095)>.

<sup>122</sup> Main line track is track over which 5,000,000 gross tons or more of annual traffic is transported. These requirements are defined in the legislation and are subject to further specification by the FRA.

<sup>123</sup> AAR press release, "Four Biggest U.S. Railroads Committed To PTC Interoperability," <[www.aar.org/Initiatives/PositiveTrainControl/PTC\\_Interop/PTC\\_Interop1.aspx](http://www.aar.org/Initiatives/PositiveTrainControl/PTC_Interop/PTC_Interop1.aspx)>. The four largest U.S. railroads are: Union Pacific, Burlington Northern Santa Fe, Norfolk Southern Corporation, and CSX.

<sup>124</sup> AAR, "Positive Train Control: Frequently Asked Questions."

failed to perform its duties adequately, creating the conditions that led to the accident. At Macdona, the NTSB concluded, fatigue impaired a crew's ability to operate its train safely, and the crew missed stop signals, which led to the collision. The circumstances were very different, but both demonstrate the importance of designing hours-of-service regulations that create the right incentives for safety. Hours of service rules are the product of lengthy negotiations between rail management and labor, and are subject to stringent regulation by the government.<sup>125</sup>

Hours-of-service regulations were among the main focuses of the Rail Safety Improvement Act (RSIA) of 2008. According to the new requirements, an employee cannot be required to be on duty:

1. Where the employee has spent in any calendar month a total of 276 hours on duty ... or in another mandatory service for the carrier;
2. for more than 12 consecutive hours; or
3. unless the employee has had at least 10 consecutive hours off duty during the previous 24 hours.<sup>126</sup>

An employee may not be required to remain or go on duty without specific regular periods of extended rest at his or her home terminal. The employee may not spend more than 15 hours on duty and waiting for transportation, except in case of an accident or equipment failure. Hours of service regulations are also implemented for signal employees, contractors, and subcontractors.<sup>127</sup>

### ***Tank Car Position in Consist***

Train cars in an accident are subjected to complex and dynamic forces, which are affected by a car's position in relation to the point of impact, collision, or derailment. It would clearly be desirable to position cargoes that have the highest potential danger at the point where crash forces are weakest, but there is no consensus over what the safest position in a train consist is for hazardous materials.

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<sup>125</sup> The original Hours of Service Act was enacted by Congress in 1907 and has been modified many times.

<sup>126</sup> "H.R. 2095: Rail Safety Improvement Act of 2008 — Congressional Research Service Summary," <[www.govtrack.us/congress/bill.xpd?bill=h110-2095&tab=summary](http://www.govtrack.us/congress/bill.xpd?bill=h110-2095&tab=summary)>.

<sup>127</sup> Railroads and their employees are allowed to submit alternate hours-of-service regimes to the FRA for approval.

The NTSB has argued that TIH tank cars should be positioned at the rear of trains, based on a 1992 FRA report, “Hazardous Materials Car Placement in a Train Consist,” which concluded that the rear quarter of the train had a lower probability of damage in an accident.<sup>128</sup> The NTSB accident report on Graniteville concluded that, “Had the chlorine cars been placed behind the other loaded cars in the train, the reduction in the trailing tonnage would have reduced the impact forces on the tank cars.”<sup>129</sup>

The railroads, however, do not accept the argument that the rear quarter of the train is safer. They argue that regulations on placement of TIH cars within the consist would have the effect of increasing the amount of train handling and car coupling and decoupling, which present risk. The railroads emphasize procedures that minimize TIH tank car handling. Given the lack of agreement, there is little momentum for activity by regulators on this front.

### ***Emergency Response***

The consequences of accidents or of deliberate attacks involving shipments of TIH materials depend in part on the effectiveness of efforts by first responders such as emergency medical services (EMS), fire, police and others local officials, as well as railroad personnel on the scene. A well informed, adequately equipped, and effectively executed response can limit the scope of property damage and the loss of life. Response strategies might include containing exposure through patching, flooding the area with water, leading evacuation efforts, or encouraging shelter in place. The presence of an effective response capacity might also deter terrorist attacks, by making it clear that the amount of harm that could be achieved is limited.<sup>130</sup> In some instances, ineffective emergency response can actually make things worse; calling for sheltering in place or evacuation when the opposite strategy would be the best course of action can needlessly place populations at risk. Developing capacities for effective emergency response to TIH release is a form of resilience and risk mitigation that could help to reduce the overall scope of the externality associated with the transportation of TIH materials.

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<sup>128</sup> R.E. Thompson, E. R. Zamejc, and D. R. Ahlbeck, *Hazardous Materials Car Placement in a Train Consist*, Vol. 1: *Review and Analysis*, Report DOT/FRA/ORD/18.I (Washington, D.C.: Federal Railroad Administration, U.S. DOT, 1992).

<sup>129</sup> NTSB Report—Graniteville.

<sup>130</sup> Research and Special Projects Administration, Office of Hazardous Materials Safety, Department of Transportation, and John A. Volpe National Transportation System Center, *The Role of Hazardous Materials Placards in Transportation Safety and Security* (2003), p. iii.

The challenges of responding to a TIH incident have been on the public agenda since at least the early 1900s. A number of serious rail accidents involving the transportation of dangerous materials during this period spurred wide-spread concern and led the railways to create, in 1907, the bureau of explosives (BOE); federal controls were established a year later under the authority of the Interstate Commerce Commission (ICC).<sup>131</sup> Since the terrorist attacks of September 11, 2001, railroads, chemical manufacturers, and government renewed efforts to help ensure that local communities can quickly and effectively respond to a TIH incident. These efforts have expanded the abilities of emergency responders and helped to reduce the risk associated with the transportation of TIH materials, but there are still areas where public policy could do more to improve emergency response.

The transportation of shipments across a freight rail network comprising 140,000 miles of track creates difficult challenges for emergency response and planning.<sup>132</sup> TIH shipments travel across jurisdictions throughout the nation, along routes that are not usually specified ahead of time.<sup>133</sup> An unanticipated release could happen in many unexpected locations along the transportation route. Even communities without chemical facilities must be prepared to respond to a TIH incident. Thus, while rail security and safety is a national issue, initial response is a local activity.

The federal government, the chemical industry, and the railroads support local first responders through regulations, support for training, funding, and quick-response networks. Generally, federal law preempts local and state statutes governing the transportation of hazardous materials.<sup>134</sup> Federal law directs levels of training and response planning at the local and state level. It also requires clear markings on shipments of hazardous materials.<sup>135</sup> Federal legislation in 1986 directed the creation of local emergency planning committees (LEPCs) and state emergency planning committees (SEPCs) to develop plans and provide coordination for response to emergencies.<sup>136</sup>

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<sup>131</sup> Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation: Defining the Need, Converging on Solutions* (Washington, D.C.: National Academies Press, 2005), p. 24.

<sup>132</sup> Transportation Security Administration, *Freight Rail Modal Annex*, 2007, <[www.tsa.gov/assets/pdf/modal\\_annex\\_freight\\_rail.pdf](http://www.tsa.gov/assets/pdf/modal_annex_freight_rail.pdf)>, p. 2.

<sup>133</sup> Association of American Railroads, "HAZMAT Transport by Rail," 2008 p. 4.

<sup>134</sup> Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, p. 34.

<sup>135</sup> Marking hazardous shipments could increase the vulnerability to intentional disruptions or acts of terrorism, an issue discussed below.

<sup>136</sup> Title III of the Superfund Amendment and Reauthorization Act of 1986 (SARA), also known as the Emergency Planning and Community Right-to-Know Act. See Linda-Jo Schierow, "The Emergency

Labor Department regulations in conjunction with professional organization guidelines spell out obligations of first responders and mandate minimum levels of training.<sup>137</sup> Within the Department of Labor, Occupational Safety and Health Administration (OSHA) regulations define the minimum levels of training for first responders that may deal with hazardous materials. Recently, the National Fire Protection Organization (NFPA), a professional organization representing a significant portion of the first responder community, revised its guidelines interpreting the applicability of OSHA regulations in order to incorporate HAZMAT/WMD planning.<sup>138</sup> This revision responded to the suggestion that current interpretations of the baseline levels of competency were set too low to address the possible threat of terrorism and did not assure adequate first response capabilities.<sup>139</sup> NFPA guidelines now recommend that all fire, EMS, and other individuals who may be called to respond to a toxic incident are trained at the “operations” level, as defined by OSHA regulations. Previously, NFPA guidelines recommended that first responders be trained at the more basic “awareness” level in order to satisfy OSHA regulations. This revision in the interpretation of the applicability of OSHA regulations is a potentially significant change that supports a higher level of training and readiness for all first responders.<sup>140</sup>

The federal government, and the chemical and railroad industries, support and provide training programs for first responders and their own personnel.<sup>141</sup> Examples include CHEMTREC, the Chemical Transportation Emergency Center, which is supported and founded by the American Chemistry Council; the Transportation Technology Center (TTC), which is operated by the Association of American Railroads; and TRANSCAER (Transportation Community Awareness and Emergency Response), which is supported by the chemical and transportation industries and the emergency response community.

A variety of federal grants and programs help offset some of the costs of specialized training and equipment devoted to hazardous materials. Since 1990, DOT’s Hazardous

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Planning and Community Right-to-Know Act (EPCRA): A Summary,” Congressional Research Service (CRS) Report RL32683, 2007.

<sup>137</sup> See 29 CFR 1910.120(q)(6); National Fire Protection Association (NFPA), *NFPA 472: Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*, 2008.

<sup>138</sup> NFPA 472.

<sup>139</sup> See Steven Bell, “Current Issues in Transportation of Hazardous Materials,” Hearing before the U.S. House of Representatives, Subcommittee on Railroads of the Committee on Transportation and Infrastructure, June 13 2006.

<sup>140</sup> See Gregory Noll, “NFPA 472,” *NFPA Journal*, March/April 2008.

<sup>141</sup> See <[www.phmsa.dot.gov/HAZMAT](http://www.phmsa.dot.gov/HAZMAT)>.

Materials Emergency Preparedness Grant Program provided \$182 million in HMEP grants to states and territories for the development of response plans, training, and purchase of specialized equipment.<sup>142</sup> Additionally, FEMA distributed over \$2.4 billion through the Assistance to Firefighters Grant (AFG) program since the inception of the program in 2001.<sup>143</sup> These grants are offered annually to support firefighters and EMS first-responder activities, with highest priority on those activities that support response to chemical, biological, radiological, nuclear, and explosive (CBRNE) threats.<sup>144</sup> Yet despite ongoing support, as of April 2008 only 16.4 percent of U.S. fire departments had specialized HAZMAT teams.<sup>145</sup>

DOT regulations also support first responders. DOT regulations<sup>146</sup> require that shippers of hazardous materials provide accompanying information (in the form of both external placards and markings, as well as on shipping papers) about the type of material transported, the quantity, and a 24-hour emergency contact number that connects to a person informed about the hazardous material being transported and appropriate emergency response measures.<sup>147</sup> These regulations are critical to first responders. First responders are often initially alerted to the presence of a dangerous material through color-coded placards or other labels that are required by DOT regulations. Additionally, 24-hour hotlines operated by CHEMTREC and TRANSCAER supply first responders with emergency contact information and technical support. At the federal level, the National Response Center (NRC) coordinates between federal entities in the event of an accident involving hazardous materials and supplies support to on-site authorities.<sup>148</sup> The

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<sup>142</sup> HMEP grants are paid for by fees collected from shippers and carriers of hazardous materials. PHMSA, Hazardous Materials Emergency Preparedness (HMEP) Grants Program Fact Sheet.

<sup>143</sup> DHS. "America's Firefighters to Receive \$485 Million in Grants." October 6, 2006. <[http://firegrantsupport.com/docs/media06\\_061006.pdf](http://firegrantsupport.com/docs/media06_061006.pdf)>.

<sup>144</sup> Department of Homeland Security, Notice of Guidelines, *Federal Register*, Vol. 73, No. 50, March 13, 2008, p. 13555.

<sup>145</sup> See U.S. Fire Administration website, <[www.usfa.dhs.gov/applications/census/summary.cfm#table1](http://www.usfa.dhs.gov/applications/census/summary.cfm#table1)>. See also National Research Council, *Terrorism and the Chemical Infrastructure*, p. 53.

<sup>146</sup> 49 CFR 172.

<sup>147</sup> Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, pp. 67–68.

<sup>148</sup> The National Response Center (NRC) is the federal point of contact for reporting oil, chemical, radiological, biological, and etiological discharges. The NRC coordinates response activities between multiple federal entities and on-scene authorities. <[www.nrc.uscg.mil/](http://www.nrc.uscg.mil/)>.

chemical industry, through CHEMNET, and many railroads also field rapid-response teams to support on-site activities by responders at the local, state, and national levels.<sup>149</sup>

The efforts just described largely focus on the unique demands of hazardous material incidents, but effective emergency response also requires more general health and safety capabilities. Neglecting the broader challenges facing this infrastructure while focusing narrowly on ways in which HAZMAT response is novel could hamper the ability of local officials to respond to a TIH release. In addition, there is a potential for reducing overall safety and security if steps taken to counter the threat of terrorism raise the risk of accident, or vice versa.

The threat of terrorism creates responsibilities and burdens for first responders. The redesignation of first responders at the “operations” level, for example requires a greater commitment to specialized training and equipment.<sup>150</sup> This creates new burdens at a time when funding for many basic fire and EMS services is lacking. Devoting resources to preparing for low-probability events such as TIH incidents and terrorism diverts resources from challenges that may be more pressing. Federal programs and industry support offset some of these costs, but significant budgetary constraints at the local level mean that preparations for unlikely scenarios may be difficult to sustain and justify when support for the general operations of first responders is lacking or inadequate.<sup>151</sup> Without support for general operations, first responders will be under pressure to divert funds that are earmarked for specialized requirements, and to neglect those requirements. Providing general support for first responders, then, is an important component of addressing the unique challenges of transporting TIH materials.

Responding to the unexpected and fast-moving challenge of a TIH release involves special demands. A key challenge for first responders is to determine whether and how to direct nearby residents to shelter in place or to evacuate.<sup>152</sup> Determining which option is best requires expertise and simulation tools to synthesize a raft of data, including

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<sup>149</sup> Transportation Research Board, *Cooperative Research for Hazardous Materials Transportation*, p. 69.

<sup>150</sup> Equipment may be relatively cheap and simple, such as a drum handling tool, or expensive and sophisticated, such as advanced robotics. USFA, *Hazardous Materials Response Technology Assessment*. HAZMAT imposes specialized response conditions; for example, sometimes response must be delayed so that environmental conditions can be assessed remotely before first responders arrive on the scene. Bell, “Current Issues in Transportation of Hazardous Materials.”

<sup>151</sup> Budgetary constraints are a perennial challenge for local fire services, sometimes forcing cuts or reductions in basic services. USFA, “Introduction,” *Funding Alternatives for Fire and Emergency Services*, 2000, <[www.usfa.dhs.gov/downloads/pdf/publications/fa-141.pdf](http://www.usfa.dhs.gov/downloads/pdf/publications/fa-141.pdf)>.

<sup>152</sup> National Institute for Chemical Studies, “Sheltering in Place as a Public Protective Action,” 2001.

information about the material released, current meteorological conditions, and the topography of the exposed area. Advances in dispersion modeling, such as recent work undertaken by the U.S. Naval Research Laboratory, suggest that it may soon become possible to provide emergency responders with near-real-time predictions for the spread of a release of TIH through a complex urban environment.<sup>153</sup> The availability of such information could help emergency responders assess the rapidly evolving conditions of a TIH incident and advise the public accordingly. Such services might also speed up response time by providing essential meteorological data much faster.

Such technologies, to be effective, require “dual-use” tools applicable to a much broader range of circumstances, including effective public channels of communication and an extensive and continuing program of public education. Working and accessible emergency communication systems, including reverse 9-1-1 systems, sirens such as those used in tornado warning and civil defense, and the federal Emergency Alert System (EAS) are indispensable to ensuring that essential directions are received by the public. The Emergency Alert System, which relies on broadcasters and cable outlets, among others, to distribute instructions, failed during the derailment and ammonia release in Minot, ND in 2002, which hampered response efforts.<sup>154</sup> Developing and implementing sophisticated real-time simulation technologies is inadequate without devoting resources to maintaining other tools, such as channels of communication, and assuring that hospital staffs and facilities can handle the surge in patients and “worried well” that may result in the wake of TIH incident.<sup>155</sup>

The general challenges of emergency response thus intersect in many ways with the specific needs of HAZMAT response. Efforts to create an emergency response capacity for the unique features of a TIH incident also require a robust general response infrastructure.

In addition to new simulation tools, pre-notification and educational efforts directed toward at-risk populations can also reduce response times.<sup>156</sup> Pre-notification can reduce

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<sup>153</sup> Describing recent advances in simulation technology and how it can be usefully applied to unexpected releases of TIH is Boris, “The Threat of Chemical and Biological Terrorism.”

<sup>154</sup> Jack Shafer, “What Really Happened in Minot, N.D.?” *Slate*, January 10, 2007 <[www.slate.com/id/2157395/](http://www.slate.com/id/2157395/)>.

<sup>155</sup> National Research Council, Committee on Science and Technology for Countering Terrorism, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (Washington, DC: National Academies Press, 2002), pp. 127-131.

<sup>156</sup> On the importance of pre-notification and education in the context of a large-scale release within a densely populated area, Transportation Security Administration, “Proceedings of the May 28, 2008

the lag between initial notification and response through the coordination of TIH information with local emergency services. Local emergency responders and 9-1-1 services should be knowledgeable about the frequent types and locations of TIH shipments in their community before an incident occurs.<sup>157</sup> They should also have quick access to specific information concerning the presence of TIH shipments within a community that can be accessed as fragmentary reports are first coming into 9-1-1 operators. Doing so will allow emergency responders to quickly identify a possible TIH incident before arriving on scene and shorten the window for identifying which TIH material has been released.<sup>158</sup> During a release in a densely packed area, however, those in the immediate vicinity will have to take action before professional responders arrive on the scene. Educational outreach efforts targeting communities near chemical plants and rail yards that serve as hubs for TIH material describing how to properly shelter in place can be instrumental in mitigating the damage from a release.<sup>159</sup>

Wide distribution of information concerning the movement of TIH materials supports safety measures that are designed to limit the number of accidents and ensure effective response. Yet there are concerns that the availability of such data potentially undermines security, by providing terrorists with information that could be used to launch an attack. The tension between safety and security is evident in recent debates concerning the appropriate identification of hazardous materials.

Placards to identify hazardous materials are communication tools that are easy to understand and are recognizable by the first responders and workers that handle over 1.2 million hazardous materials movements daily.<sup>160</sup> However, the same qualities that makes such placards useful — their simplicity and accessibility to observers — may also facilitate attacks, by assisting terrorists in identifying TIH tank cars.<sup>161</sup> DOT and DHS recently examined alternative measures, such as radio frequency identification tags (RFIT), or operational alternatives such as armed escorts. However, the high cost of new

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Chicago-Area TIH Materials Emergency Response & Preparedness Roundtable,” Version 1.1, Sept. 14, 2009.

<sup>157</sup> Ibid.

<sup>158</sup> Ibid.

<sup>159</sup> Ibid.

<sup>160</sup> DOT and Volpe Center, *The Role of Hazardous Materials Placards*, p. 8.

<sup>161</sup> A DOT study concluded that placards would not supply enough information to terrorists to facilitate a significant attack. Ibid. p. iii.

investments in technology and training were judged to offer only marginal benefits, and these alternatives were dismissed.<sup>162</sup>

***Product Substitution and Supply Chain Management: “Inherently Safer Technologies”***

The most desirable solution in preventing chemical releases is to reduce or eliminate the hazard where possible, not to control it. This can be achieved by modifying processes where possible to minimize the amount of hazardous material used, replace a hazardous substance with a less hazardous substitute, or minimize transportation by co-locating production and use.<sup>163</sup> Product substitution and supply chain reorganization address the risk associated with the use and transportation of toxic chemicals at the source. These strategies are often grouped together under the rubric of “inherently safer technologies” (ISTs).<sup>164</sup> However, product substitution and supply chain reorganization are contentious issues that present significant political, economic, and technical barriers to implementation.

There have been many recent calls on the federal government to support the development and adoption of ISTs. In addition to the recommendation of the National Research Council, environmental groups such as Greenpeace and the Environmental Defense Fund have publicly declared their support for an active federal role mandating the use of ISTs in certain cases.<sup>165</sup> Security experts note that there is a need for government to provide incentives to encourage businesses to develop and adopt ISTs that would otherwise be economically unfeasible.<sup>166</sup> The railroad industry supports the promotion of ISTs as a

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<sup>162</sup> Ibid. See also “Department of Homeland Security Announces Support for Rail HAZMAT Placards.” April 8, 2005, <[www.dhs.gov/xnews/releases/press\\_release\\_0655.shtm](http://www.dhs.gov/xnews/releases/press_release_0655.shtm)>.

<sup>163</sup> National Research Council, *Terrorism and the Chemical Infrastructure*, p. 106.

<sup>164</sup> “Inherently safer technologies” may include a broad range of strategies, including product substitution and supply chain redesign. Senate Bill 1602, introduced in the 107<sup>th</sup> Congress, for example, defined ISTs broadly to include processes that limit or reduce the use, storage, and transportation of toxic chemicals through process redesign and simplification, product reformulation, or input substitution.

<sup>165</sup> Rick Hind (Greenpeace), Testimony before Committee on Homeland Security, Subcommittee on Transportation Security and Infrastructure Protection, December 12, 2007. Carol Adress (Environmental Defense Fund), Testimony before Senate Committee on Homeland Security and Government Affairs, July 13, 2007.

<sup>166</sup> Report 109-332, “Report to Accompany Chemical Facility Anti-Terrorism Act (S. 2145),” U.S. Senate Committee on Homeland Security and Governmental Affairs, 2006, p. 9.

way of solving its problems with transporting dangerous TIH materials.<sup>167</sup> At the Congressional level, proposed legislation would provide some support for ISTs, ranging from making their use mandatory, to requiring review of the possibilities of their use.<sup>168</sup> At the state and local level, a number of efforts have been undertaken to support the use of ISTs.<sup>169</sup>

However, the chemical industry opposes legislation that would lead to greater implementation of ISTs.<sup>170</sup> Chemical industry critics object to any federal role in promoting ISTs to achieve safety and security.<sup>171</sup> A related objection questions whether regulations should be considered within the sphere of environmental law or of national security.<sup>172</sup> John Chamberlin, Corporate Security Manager, Asset Protection for Shell and a representative of the American Petroleum Institute, testified that he was: “strongly oppose[d] to any environmental mandates for inherently safer technology pursued under the guise of security.”<sup>173</sup> This argument fails to acknowledge that the government has responsibility both for national security as a military matter, and for homeland security, assuring the well-being of the public.

The success of regulatory support for “inherently safer technologies” is uncertain and remains mired in ongoing disputes between advocates and opponents of ISTs.<sup>174</sup> However, the argument about the merits of specific ISTs is separate from question of

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<sup>167</sup> American Association of Railroads, Statement for the Record to the U.S. House of Representatives Committee on Homeland Security, Subcommittee on Transportation Security and Infrastructure Protection, December 12, 2007.

<sup>168</sup> Senate Bill 1602, the Chemical Security Act of 2001, and Senate Bill 2486, the Chemical Safety and Security Act of 2006, both supported the adoption of ISTs.

<sup>169</sup> Dana Shea and Todd Tatelman, “Chemical Facility Security: Regulation and Issues for Congress,” Congressional Research Service, Report RL 33847, 2008, p. 8.

<sup>170</sup> Jacob Schlesinger and Thaddeus Herrick, “Delayed Reaction: Chemical Manufacturers Elude Crackdown on Toxic Materials,” *Wall Street Journal*, May 21, 2003; Shea and Tatelman, “Chemical Facility Security.”

<sup>171</sup> Report 109-332, “Report to Accompany Chemical Facility Anti-Terrorism Act.”

<sup>172</sup> Paul Rosenzweig, “The Chemical Security Act: Using Terrorism as an Excuse to Criminalize Productive Economic Activity,” Heritage Foundation Executive Memorandum no. 833, September 12, 2002, <<http://www.heritage.org/Research/HomelandSecurity/em833.cfm>>.

<sup>173</sup> Report 109-332, “Report to Accompany Chemical Facility Anti-Terrorism Act,” p. 16.

<sup>174</sup> Bruce Alpert, “Chemical Security Bill Wins Nod from House: Industry May Press Battle in Senate,” *The Times-Picayune*, November 7, 2009, <<http://www.nola.com/news/t-p/capital/index.ssf?/base/news-7/1257576020228640.xml&coll=1>>.

what kinds of policies should be established that will induce firms to use them. All things begin equal, it is usually preferable to establish incentives to develop and use ISTs rather than creating a mandate to use specific technologies, because with incentives, research investments may discover ISTs that are both more effective and lower in cost than those now in use.

Critics and proponents of federal support for ISTs agree that, at present, significant technological and economic barriers prevent the large-scale elimination of the use of toxic chemicals. In some cases, alternatives simply do not yet exist, while in other instances, the costs of substitution are judged to be prohibitive.<sup>175</sup> For example, there are a number of alternatives to the use of chlorine gas in water treatment, such as processes that use ultraviolet light and sodium hypochlorite. However, as the chemical industry points out, there are far fewer alternatives to the use of chlorine in the production of plastics.<sup>176</sup>

The cases of chlorine and ammonia illustrate the possibilities and limitations of substitution and supply chain reorganization. The two chemicals present different challenges based on the nature of the products and the industries within which each is used, the alternatives available, and the costs of conversion. The case of chlorine reveals some conditions under which substitution or changes in the supply chain are both feasible and desirable. For example, swimming pools can be equipped with chlorine generators that electrify salt into chlorine, eliminating the need for chemicals that are typically manufactured regionally from long haul shipments of chlorine gas. Although the volumes involved may be relatively small, this kind of initiative illustrates the potential for incremental steps to reduce transportation of TIH. Usage and distribution of ammonia, by contrast, illustrates some of the challenges, as detailed below.

One of the most common uses for chlorine gas has been in purification of drinking water and wastewater.<sup>177</sup> In comparison with other industrial processes using chlorine gas, purification offers significant scope for potential substitution. Over the past decade, some

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<sup>175</sup> National Research Council, *Terrorism and the Chemical Infrastructure*, p. 7.

<sup>176</sup> Benjamin Brodsky, "Industrial Chemicals as Weapons: Chlorine," Nuclear Threat Initiative Issue Brief, 2007, < [http://www.nti.org/e\\_research/e3\\_89.html](http://www.nti.org/e_research/e3_89.html)>. See, however, "Clorox to Halt Use of Chlorine at Bleach Production Sites."

<sup>177</sup> Since 1999, all facilities using over 2,500 lbs of chlorine are subject to the Environmental Protection Agency's Risk Management Program (RMP) guidelines. The 2002 Bioterrorism Preparedness Act imposed additional security and safety obligations on all drinking water facilities (but not wastewater), requiring that all drinking water facilities serving over 3,300 people must prepare vulnerability assessments.

water facilities have begun to employ less-toxic methods of operation.<sup>178</sup> Sodium hypochlorite (NaOCl, a form of liquid bleach), ultraviolet light, ozone, and bleach generated on-site are some of the alternatives to chlorine gas.<sup>179</sup> Since 1999, at least 114 wastewater plants and 93 drinking water facilities have adopted less acutely toxic chemicals.<sup>180</sup> A 2006 survey of over 200 of the nation's largest wastewater utilities, serving roughly 25 percent of the U.S. population, found that less than half currently use chlorine gas, and an additional 10 percent plan to convert to a less toxic process in the near term.<sup>181</sup> A survey of facilities that recently converted from chlorine to an alternative found that initial conversion costs ranged from slightly over \$600,000 to \$13 million, depending on what new form of disinfection is used, the size of the facility, and building costs.<sup>182</sup> Liquid bleach generally costs the least, in terms of conversion and annual supply costs, compared to other alternate forms of disinfection. Switching to an alternative method in some instances actually projected to be cost-neutral or even produced a net savings in the long term.<sup>183</sup> The regulatory and reporting costs associated with handling large amounts of chlorine gas, for example, can be eliminated by switching to an inherently safer technology. Nonetheless, over 2,800 water facilities still use quantities of toxic chemicals that require reporting under the risk-management planning requirements of the Clean Air Act.<sup>184</sup>

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<sup>178</sup> Claudia Copeland, "Terrorism and Security Issues Facing the Water Infrastructure Sector," CRS Report RL32189, 2008, p. 5.

<sup>179</sup> Orum, *Preventing Toxic Terrorism*, pp. 10–11; Government Accountability Office (GAO), "Securing Wastewater Facilities: Costs of Vulnerability Assessments, Risk Management Plans, and Alternative Disinfection Methods Vary Widely," March 2007, pp. 5-6.

<sup>180</sup> Orum, *Preventing Toxic Terrorism*, p. 10. "Despite these improvements, approximately 1,150 wastewater facilities and 1,700 drinking water plants [still use] extremely hazardous chemicals, primarily chlorine gas." *Ibid.*

<sup>181</sup> GAO, "Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints," March 2006, pp. 2-5, 15-16.

<sup>182</sup> GAO, "Securing Wastewater Facilities: Costs of Vulnerability Assessments, Risk Management Plans, and Alternative Disinfection Methods Vary Widely," p. 13.

<sup>183</sup> *Ibid.*

<sup>184</sup> Copeland, "Terrorism and Security Issues Facing the Water Infrastructure Sector," p. 5. Any facility that stores over 2,500 lbs of chlorine gas must submit risk management plans to the EPA. GAO, "Securing Wastewater Facilities: Utilities Have Made Important Upgrades but Further Improvements to Key System Components May Be Limited by Costs and Other Constraints," March 2006, p. 9.

Anhydrous ammonia, which is used in fertilizer and other applications, presents a different set of challenges. Because there are many forms of fertilizer, there are numerous potential alternatives to direct application of anhydrous ammonia, including other nitrogen-based fertilizers, phosphorous-based fertilizers, and potassium-based fertilizers.

However there are numerous economic and logistical challenges to replacing anhydrous ammonia. It has a much higher nitrogen content than other fertilizers, so it is a more cost-effective option for farmers. Ammonia is also an input for other nitrogen-based fertilizers, such as nitrogen solutions or urea, as well as phosphate fertilizers. Agriculture industry advocates assert that, “the current level of crop production in the U.S. could not economically be sustained without the use of ammonia.”<sup>185</sup> Anhydrous ammonia is the only commercial fertilizer that can be effectively applied to crops in the fall.<sup>186</sup> Thus, it is argued, any fertilizer substitutes for anhydrous ammonia would be required in greater volumes, at greater cost, and with a high impact to farmers. Substitution of ammonia in industrial processes would likely be even more complicated.<sup>187</sup>

If external costs due to transportation hazards are not incorporated into the price, the feasibility of substitution of other fertilizers for anhydrous ammonia will depend on trade-offs between the resulting safety improvements and the potential loss of convenience and additional costs of alternatives to ammonia. The two sides in the debate over the potential for substitutions for ammonia appear to be very far apart. A federal push to reduce ammonia consumption might only be successful if significant subsidies to alternative products are offered. It may be more efficient to focus efforts on extending the pipeline network and promoting pipeline transportation of ammonia in order to decrease shipments by rail and truck.

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<sup>185</sup> “Statement on Behalf of Fertilizer Institute by Joe Giesler, Terra Industries, before PHMSA and FRA, Public Meeting on Safe Transportation of Hazardous Materials to Address the Safe Transportation of Hazardous Materials in Railroad Tank Cars,” p. 181.

<sup>186</sup> “Testimony of Robert Felgenhauer and Supplemental Written Submission on behalf of the Fertilizer Institute, Before the STB, EP 677, Common Carrier Obligation of Railroads.”

<sup>187</sup> Giesler Statement before PHMSA and FRA.

## V. Policy Options and Assessment

TIH stakeholders have taken some important initiatives to reduce the risks of a breach of TIH safety or, to a lesser degree, a breach of security, and to minimize the negative impacts if a release does occur. However, the actions taken have generally been uncoordinated and have focused on objectives of specific stakeholders. Such an approach is likely to lead to suboptimal outcomes. For example, improved tank car design without product substitution might reduce the probability of a release if there is an accident or terrorist attack, but does not address the underlying dangers of shipping such hazardous materials. Similarly, creating a fund to pay for catastrophic damage due to a TIH release does nothing to improve safety and security of the TIH supply chain. Successfully tackling the TIH issue requires a more coordinated set of policies that address the volume of TIH moved, the safety and security with which they move, effective responses to a release, and mechanisms to limit or share liability where appropriate and to compensate victims when needed.

Such a comprehensive and coordinated response must take into account the following key factors:

- the risks to the public and to all elements of the supply chain from a TIH release;
- the importance of TIH products to the economy;
- the externalization of the costs of TIH risk;
- the distribution of interest and accountability among numerous industries, including rail, chemical, agricultural, and water treatment entities;
- the difficulties of quantifying a low-probability, high-consequence TIH event;
- the inestimable possibility of an accident or terrorist act releasing TIH material;
- the large number of variables in any prediction of damage;
- the large geographic area requiring protection;
- the variety of costs and benefits of substituting safer products;
- the cost and uncertainties involved in planning appropriate capabilities and emergency responses;

- the difficulty of coordinating approaches by a broad range of governmental regulators, each of whose responsibility is somewhat isolated (or “stovepiped”) from the rest.

Approaches used to address other types of externalities provide some guidance; environmental externalities, in particular, have many close analogies to TIH. Legislative, regulatory, activist, and business interests have come together to craft many solutions to environmental problems that may delight few, but are acceptable to most, and taken together have had strong positive effects. They offer some lessons that are relevant for addressing TIH:

- All stakeholders need to be at the table; each must “give and get.”
- Regulatory authority must be clear and, if not focused in a single organization, must be consistently coordinated.
- Economic incentives influence business and consumer decision making.
- Taxes, broadly defined include government levies or industry fees, can be an effective tool to internalize external costs into the price of goods and services.
- Markets can be effectively used to cap and trade external costs.
- Operating practices and technology can be used to minimize external costs.
- A well-designed set of actions can lead to successful outcomes for business and society.

Policy solutions should be guided by clearly stated principles to ensure that they are effective, cost-efficient, and acceptable. The guiding principles we propose are:

- Policy solutions should recognize the risk of TIH carriage as an externality, and should aim to incorporate external costs into the cost of TIH products and their transportation.
- There is no single solution; instead, a menu of policies aimed at reducing risk and consequences should be adopted, such as:
  - product substitution by chemical users,
  - relocation of production, to reduce the need for transportation and resulting exposure,

- improvements in rail safety, such as better tank car design, and
  - operational changes in TIH transport, including routing and timing of shipments and other security measures.
- Unintended consequences should be part of the assessment of policies that appear to optimize the safety of the parties and the public while minimizing costs. For example, attempts to internalize the TIH externality through higher rail transportation prices could lead to the diversion of TIH transport to trucks and other modes that are actually less safe.
  - To the extent practical, solutions should allow markets to allocate accountability equitably, effectively, and with incentives for all of the parties to invest in mitigation of consequences of accidents.
  - The interests, financial and otherwise of all of the stakeholders and all elements of the supply chain — TIH chemical producers, railroads transporting TIH, producers of TIH tank cars, industrial consumers of TIH chemicals, and first-responder institutions — in the management and financing of externalities associated with TIH production, transport, and use must be taken into account when safety policies are made.
  - Regulatory authority should be as clear and concentrated as possible to simplify policy creation and enforcement.
  - Participation by the government is particularly necessary for assessment and mitigation of the risk of terrorist attack, because the consequences of a well-planned and executed attack, however improbable, could far exceed those of TIH accidents. The resulting financial burden would require a special role for government, because private insurance would be inadequate.<sup>188</sup>

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<sup>188</sup> Mitigation of the terrorism threat has been discussed above in each of the relevant sections: rerouting shipments, avoiding large concentrations of people potentially exposed, investments in faster, technically trained and equipped response capability, and public training sufficient to save significant numbers of lives. While most of these steps are to some degree cost-justified as protections of the public from accidental releases, for such steps to be sufficiently rigorous to prevent massive loss of life from a terrorist attack would require very large government and private investments, especially since one cannot know in advance what cities might be targeted. Using \$10 million per life saved as a criterion, the analysis by Barrett shows that an effective degree of mitigation from a successful terror attack would be greater than this threshold. See Barrett, “Mathematical Modeling and Decision Analysis for Terrorism Defense.”

Taking these principles into account, we recommend four approaches by which Congress and federal regulators should create incentives, funding, and mandates to address the TIH challenge:

- internalizing external costs, and creating a fund for claims;
- improving supply chain operations;
- enhancing emergency response; and
- focusing regulatory authority.

We discuss each in turn in the last part of this paper.

### ***Internalize External Costs and Create a Fund for Claims***

A key obstacle to minimizing the risks of TIH products is that the external costs of risk are not included in the decision making process of the supply-chain participants. Since there are in many cases products or processes that can substitute for TIH materials, increasing the price of TIH products by incorporating the costs of risk should lead to less TIH usage. Thus, the first action recommended is that the supply chain participants should estimate the cost of risk and internalize it into the price of TIH products.<sup>189</sup>

For the reasons described in this paper, estimating the cost of risk is extremely challenging and potentially controversial. Nevertheless, a first approximation of the cost of risk already exists in the price of private insurance. Each supply-chain participant faces some exposure to an accidental or intentional release of TIH material. In order to protect themselves, the producers, transporters, and users may seek insurance. The cost of such insurance is high, however, because of the limited pooling opportunity for this type of risk and the potential for substantial damage payouts.<sup>190</sup>

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<sup>189</sup> The recommendations in this section address the internalization of risks from an accidental release. A more complex analytical approach would be needed to assess the risks of a terrorist attack.

<sup>190</sup> Because the insurance is very costly, most participants self-insure for damages up to around \$25 million and then buy high-deductible insurance coverage of approximately \$1 billion. Railroads report that TIH insurance with low deductibles is very costly, and protection is not available above \$1 billion. Availability of coverage has decreased over the past few years, as has the number of insurance companies willing to cover freight rail. See Testimony of James Beardsley, Managing Director, National Rail Transportation Practice, Aon Risk Services, before U.S. House of Representatives Committee on Transportation and

A first step towards reflecting these costs would be to incorporate insurance costs for the entire supply chain into the freight rates. However, this approach faces an institutional barrier, in that product-specific insurance costs cannot be included in the Surface Transportation Board (STB) tests of rate reasonableness. The STB would need to modify its current rules to facilitate implementation of this concept. Internalizing the external cost of TIH risk via this insurance model would be a market-based but indirect approach.

A more comprehensive approach would require calculation of the expected costs of risk per ton-mile of TIH moved, once all required operational improvements have been included. A potentially useful quantification methodology would center on an analysis of the probability of an accident resulting in a release, and the expected costs of such an incident. Establishing these parameters is challenging, because they are sensitive to a multitude of assumptions.

The problem could be viewed as analogous to estimating the health effects of air pollution in the 1970s. Those analyses were not analytically elegant and were highly controversial, but establishment of at least a rough estimate was essential to understanding the magnitude of the external costs, mobilizing stakeholder interest in resolving the problem, and determining the allocation of resources. The same may be true for TIH. Analysis could be sponsored by a federal agency such as the FRA or PHMSA; and sensitivity tests could be used to test assumptions and specify a range of reasonableness around the external costs. The results of such an analysis could be incorporated into the cost of TIH transportation by one of the means described above (insurance, rate calculations, etc.).

Incorporation of the risk of TIH release into transportation costs might appropriately be accompanied by creation of a liability fund to pay claims in the event costs of a release exceeded insurance coverage. Otherwise, a large accident, or multiple accidents, might bankrupt one or more supply chain participants. Following the Oil Spill Liability Trust Fund (OSLTF) model, a federally-sponsored TIH liability fund could create a pool of money for damage from releases beyond insurance coverage. The OSLTF funding mechanisms (the tax on oil, cost recovery from negligent parties, and the interest earned on the fund) could serve as a model.

In contrast to the OSLTF, which is not a no-fault model, the desirability of a no-fault insurance model for TIH should be evaluated, since the possibility and extent of damage may be affected by the actions of multiple players. From the design of the tank cars to

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Infrastructure, Subcommittee on Railroads, "Current Issues in Rail Transportation of Hazardous Materials," June 13, 2006, p. 44.

their maintenance to the movement over the nation's rail system, the actions of each participant affect the overall integrity of the system. Attempts to assign fault for anything short of gross negligence could result in unproductive finger-pointing and litigation. In recent accidents, rail employee (human-factor) causes contributed to the accidental release of TIH, but often the railway may be sued even if fault apparently lies with the shipper's loading procedures, simply because the railroad company's pockets may be seen as deeper than those of other participants in the supply chain. Railroads are required to move TIH shipments under their common-carrier obligation and cannot decline to accept TIH risk. With all these factors in mind, the Price-Anderson Act, FDIC, and OSLTF models should be evaluated by policymakers to determine which elements of each model can be applied to the TIH supply chain to minimize risk.

Another model that might help minimize use of chlorine gas in water treatment is the "stranded asset recovery" model found in the electricity industry. Under this model, electric utilities were allowed to add a small surcharge to the electricity price they charged their customers to recapture the foregone value of assets sold below book value due to regulatory requirements. The same rationale could be used if water authorities, especially those in high-threat urban areas, are required to eliminate the use of chlorine gas. They could be allowed to recapture costs to convert to a substitute technology through a small "product substitution fee" added to water users' bills.<sup>191</sup>

Another possible model to encourage substitution of safer products for TIH materials is cap-and-trade. This approach could be applied to TIH transportation by awarding a fixed number of TIH permits for production, for use, and for transportation. Limiting the total quantity of TIH produced, consumed, and transported would create incentives for product substitution and relocation of production or use. Permits could be decreased over time to push for further replacement of TIH chemicals with less toxic alternatives. Cap-and-trade has not been applied to analogous situations, so significant analysis would be necessary to decide at what point in the supply chain to award allowances, and also whether allowances should be grouped, or instead separated by TIH commodity.

Whatever solution is ultimately created, internalizing costs and creating a fund for damages could lead to a price shock for TIH users, who have made investment and production decisions based on prices that did not include the external costs. Changing the economics in "mid-stream" raises equity issues, especially for users who made long-term investments in fixed assets such as water treatment plants and complex chemical

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<sup>191</sup> Some may challenge such an approach as heavy-handed, but there is ample precedent for such mandates that support the safety and welfare of the public, even in the realm of rail transportation: mandated positive train control and was largely unfunded by the government.

facilities. To address this issue, transitional phase-in could spread the external costs over a number of years. The transition could be accelerated by government-offered low interest loans or tax advantages, which would be justified by the social welfare gains of reducing the volume of TIH usage. A recent precedent for similar government conversion subsidies is the federal government's funding of television converter boxes as a result of the mandated shift to digital broadcasting. Determination of the most effective approach should be made by the DOT and enacted into law by Congress.

None of these policy options are, however, sufficient to compensate for the potential worst-case consequences of a terrorist attack on a shipment of TIH through a highly populated area. For such a situation, the government's terrorism re-insurance system (TRIA, described above) is available. TRIA might also be extended to cover particularly damaging accidents, as well, since the consequences of accidents occurring at midday in a city might approach those of a terror attack. This might mitigate some of the financial pressure on of internalizing the risk of TIH accidents into product and shipping costs.

These suggestions, targeted at internalizing the TIH externality and creating a fund for TIH release-related damages, should yield three positive outcomes. The first is to reduce the volume of TIH materials used, through encouragement of product substitution and increasing the proximity of producers and users. Second, these options would enable compensation for TIH-related damage without bankrupting producers, transporters, or users. The third benefit is a transition plan that would balance equity and speed.

### ***Improve Supply Chain Operations***

While internalizing the TIH externality will encourage product substitution and shorten transportation risk through production or usage relocation, TIH shipments will undoubtedly continue. Therefore efforts to improve the quality and reliability of the TIH supply chain must continue. This paper has described an array of industry initiatives aimed at improving safety and security of TIH shipments. Many of these efforts are already in the design or implementation stage, such as tank car redesign and improvements in rail employee hours-of-service rules and better chain-of-custody procedures. When positive train control is implemented, it should also enhance the safety and security of TIH shipments.

Routing TIH shipments to minimize risk is another operational action which is being undertaken. The supply chain participants consider routing in decisions on production, transportation, and sourcing. Recent rail regulations require railways to undertake more

formal assessment of routing options but, while there are some opportunities to improve safety, the tradeoffs are complex and do not yield simple solutions.<sup>192</sup> As the rail industry learns to optimize the tradeoffs, the desirability of implementing event-related re-routing rules should also be explored. For example, federal regulations might be instituted to limit TIH shipments from passing within a certain number of miles of an outdoor event where the expected attendance is above a certain threshold number. Such rules might substantially reduce the availability of attractive targets for terrorists hoping to use TIH against crowds as a weapon of mass destruction, and also would limit the damage resulting from any accidental release, while keeping disruption of the TIH supply chain at more manageable levels. Any such limitations should be based on rigorous risk assessment that balances safety and security with the operational impact to the supply chain.

### ***Enhance Emergency Response and Public Information***

The extent of human injury and property damage from a TIH release is directly related to the effectiveness of the emergency response. Several factors limit the ability of TIH emergency responders to mitigate losses. First, immediate and accurate information about the specific product that has been released and the conditions and circumstances of the release are essential, because TIH products with different characteristics require different actions to mitigate damage. Confusion about what product was released has, in past accidents, resulted in injury to first responders and the public. Second, a release could take place anywhere along 140,000 miles of freight rail infrastructure, and thus any and all of approximately one million first responders must have at least a rudimentary understanding in dealing with a TIH release. Third, better and more quickly available meteorological information is needed to improve public protection and mitigation measures.

The adoption of crisis management best practices into the emergency response process should provide first responders with better information for decision making, decreasing the risk of damage to themselves, the general populace, and property. Information is of limited value without local emergency response capabilities to take advantage of that information in order to contain released chemicals and protect residents. Therefore the challenge of TIH requires broad support for both the specific challenges and the more general emergency response infrastructure. Ongoing and increased support for a robust

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<sup>192</sup> Glickman, Erkut, and Zschocke, “The cost and risk impacts of rerouting railroad shipments of hazardous materials.”

emergency response infrastructure capable of addressing diverse public health challenges is essential to minimizing the damages associated with the transportation of TIH.

In addition to better training for first responders, public education will be needed on how to interpret and follow warnings and instructions from emergency operation centers, such as the best direction to flee a release cloud, or when and how to seek shelter in place. Education will also need to be repeated from time to time as populations move and age.

### ***Rationalize Regulatory Framework***

A broad range of federal, state, and local regulatory agencies are involved in rule making and oversight that applies to TIH. As part of the U.S. Department of Transportation, the Pipeline and Hazardous Materials Safety Administration (PHMSA) has broad responsibilities for hazardous materials regulation. The agency also provides grants to states to improve HAZMAT emergency response. Within PHMSA, the Office of HAZMAT Safety (OHM) oversees HAZMAT transportation, by issuing regulations and performing inspections of shipper and carrier facilities. Also part of the DOT, the Federal Railroad Administration (FRA) regulates rail operations and supports rail safety research.<sup>193</sup> The FRA has more rail inspectors in the field than any other agency. However, the Homeland Security Act of 2002 gave lead authority to the Department of Homeland Security (DHS) for “security activities in all modes of transportation”; within DHS, the Transportation Security Administration (TSA) is designated as the “lead federal entity” in transportation security matters.<sup>194</sup> Memoranda of Understanding between DHS and DOT are supposed to coordinate the roles of TSA, PHMSA, and FRA in transportation security, so that TSA has the lead in developing national strategy for transportation security, PHMSA has the lead on pipelines and the responsibility for “promulgating and enforcing regulations and administering a national program of safety, including security, in multimodal HAZMAT transportation,” and FRA has the lead on rail safety. However, significant potential for confusion or conflicting priorities remains.

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<sup>193</sup> FRA, “Regulatory Overview: Safety Rulemaking, Reports, and Program Development,” September 28, 2007, <[www.fra.dot.gov/downloads/Safety/regulatory\\_overview.pdf](http://www.fra.dot.gov/downloads/Safety/regulatory_overview.pdf)>.

<sup>194</sup> “Annex to the Memorandum Of Understanding between the Department of Homeland Security and the Department of Transportation Concerning TSA and PHMSA Cooperation on Pipeline and Hazardous Materials Transportation Security,” <[www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Annex%20to%20MOU%20between%20TSA-PHMSA.PDF](http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Annex%20to%20MOU%20between%20TSA-PHMSA.PDF)>.

A key lesson from the experiences with environmental externality was that concentrating responsibility at a single federal agency, the EPA, was critical for addressing these controversial issues successfully. In the case of TIH, multiple regulatory bodies provide unique and specialized capabilities, but whether it is desirable to concentrate more authority under one agency should be evaluated. It might well improve the focus on TIH priorities and make the regulatory process more efficient. PHMSA might be well-positioned to take on the lead regulatory role for TIH, because the organization has a deep technical foundation in TIH and other hazardous materials. It also has a view of the entire supply chain, unlike other agencies such as the FRA that are more centered on one aspect of the overall TIH safety and security issue. However, these advantages would have to be weighed against PHMSA's lesser knowledge of railroad operations.

Achieving consensus on regulatory rationalization is likely to be difficult, as each regulatory agency has its own constituents and may be reluctant to relinquish responsibilities and power. The recommended action in this area is, therefore, that the Secretary of Transportation, in consultation with the DHS and the EPA, should assess the specific regulatory items that should be centralized and analyze which organization would provide the best umbrella. An optimal outcome would be a TIH regulatory body with a critical mass of technical skill and political stature to convene interested parties, make difficult decisions, and create a unified course of action. Even before this happens, however, the other recommendations made in this paper can proceed.

### *Conclusions and next steps*

To achieve the goals outlined in these four broad areas for addressing the TIH rail transportation risk, four concrete next steps should be taken.

First, we recommend that the Secretary of Transportation, in collaboration with DHS and other relevant federal agencies, should convene a discussion among representatives of the affected parties to seek consensus on the principles to apply to policy development concerning safety and security of shipment of TIH chemicals. The most important issue is designing a claims fund, deciding how such a fund should be financed, and for what purposes its assets should be expended.

Second, this discussion should also seek a consensus on schedules and economic costs of initiatives ranging establishment of a liability or claims fund to encouragement of product substitution. The programs are proceeding and the technologies need to be encouraged. The more difficult issues involve timing for these efforts. What are realistic completion dates and priorities for deployment or adoption? How quickly should the old systems be

phased out? These questions require the collaboration of the private sector with government, and involve difficult economic and risk tradeoffs.

Third, to address regulatory rationalization, the Secretary of Transportation should evaluate whether PHMSA, FRA, or another agency is best suited to take the lead in working with other agencies on redefining the roles of federal regulatory bodies to deal more effectively and efficiently with problems raised by TIH safety and security externalities.

Fourth, the Surface Transportation Board should examine how the common carriage obligations of the railroads and their rate regulation might be modified to include all the external risks as well as operating costs for incorporation in rate regulation for rail transport of TIH cargoes.

Finally, we recommend that the Department of Homeland Security, in collaboration with the Department of Transportation and other appropriate federal and state agencies initiate a focused study of specific security issues including: timing and routing of TIH shipments, preparedness of emergency management organizations and first responders, public education, and the role of intelligence and policy agencies and their sharing of information with private actors in the TIH supply chain.

There are many issues to address and challenges to overcome in addressing TIH transportation. A comprehensive supply-chain view of the safety and security externality of TIH rail transportation should make it possible to make significant progress in substantially reducing the risk of harmful TIH release.

<b>Glossary</b>	
AAR	Association of American Railroads
ACC	American Chemistry Council
AFG	Assistance to Firefighters Grant
BNSF	Burlington Northern and Santa Fe Railway
BOE	Bureau of Explosives
CHEMTREC	Chemical Transportation Emergency Center
CP	Canadian Pacific Railway
CPR	Conditional Probability of Release
CSX	major east coast railroad [Not an acronym]
DHS	Department of Homeland Security
DOT	Department of Transportation
EAS	Emergency Alert System
EMS	Emergency Medical Services
EPA	Environmental Protection Agency
FAST3D-CT	Three-dimensional computational fluid dynamics model for contaminant transportation
FDIC	Federal Deposit Insurance Corporation
FRA	Federal Railroad Administration
GATX	Formerly General American Transportation Company (Note: No longer its name)
HAZMAT	Hazardous Materials
HEMP	Hazardous Materials Emergency Preparedness Grant
ICC	Interstate Commerce Commission
IST	Inherently Safer Technologies
LEPC	Local Emergency Planning Committee
NFPA	National Fire Protection Association
NGRTC	Next Generation Rail Tank Car Project

NO <sub>x</sub>	Nitrous Oxide
NRC	National Response Center or National Research Council
NS	Norfolk Southern Railway
NTSB	National Transportation Safety Board
O-D	Origin-Destination
OHM	Office of HAZMAT Safety
ONR	Office of Naval Research
OSLTF (or OSL-TF)	Oil Spill Liability Trust Fund
PHMSA	Pipeline and Hazardous Materials Safety Administration
PHMSA-RSPA	Pipeline and Hazardous Materials Safety Administration, Research and Special Programs Administration
PTC	Positive Train Control
R&D	Research and Development
R/VC	Revenue to Variable Cost
RAR	Railroad Accident Report [this acronym not used in the paper]
RFIT	Radio Frequency Identification Tag
SAC	Stand Alone Cost
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SARA	Superfund Amendment and Reauthorization Act of 1986
SEPC	State Emergency Planning Committee
SO <sub>2</sub>	Sulfur Dioxide
STB	Surface Transportation Board
TCC	Tank Car Committee
THREAT	Tool for HAZMAT Rerouting Evaluation and Alternative Transportation
TIH	Toxic Inhalation Hazards
TRANSCAER	Transportation Community Awareness and Emergency Response
TRB	Transportation Research Board

TRIA	Terrorism Risk Insurance Act of 2002
TSA	Transportation Security Administration
TTC	Transportation Technology Center
UP	Union Pacific Railroad
URCS	Uniform Rail Costing System