THE HAZARDOUS MATERIALS HIGHWAY ROUTING ROUTE PLAN GUIDANCE REPORT TO CONGRESS

A Report Pursuant to Section 1553(a) of the
Implementing Recommendations of the 9/11 Commission Act of 2007
Public Law 110-53
March 2009

Section 1553(a) of the Implementing Recommendations of the 9/11 Commission Act of 2007 (the Act) directs the Secretary of the U.S. Department of Transportation, in consultation with the Secretary of the U.S. Department of Homeland Security (DHS), to complete the following actions:

1. Document existing and proposed routes for the transportation of radioactive and non-radioactive hazardous materials (HM) by motor carriers, and develop a framework for using a geographic information system (GIS) based approach to characterize routes in the national HM route registry.
2. Assess and characterize existing and proposed routes for the transportation of radioactive and non-radioactive HM by motor carrier for the purpose of identifying measurable criteria for selecting routes based on safety and security concerns.
3. Analyze current route-related HM regulations in the United States, Canada, and Mexico to identify cross-border differences and conflicting regulations.
4. Document the safety and security concerns of the public, motor carriers, and State, local, territorial, and tribal governments about the highway routing of HM.
5. Prepare guidance materials for State officials to assist them in identifying and reducing both safety concerns and security risks when designating highway routes for HM consistent with the 13 safety-based non-radioactive materials routing criteria and radioactive materials routing criteria in subpart C part 397 of title 49, Code of Federal Regulations.
6. Develop a tool that will enable State officials to examine potential routes for the highway transportation of HM, assess specific security risks associated with each route, and explore alternative mitigation measures.

The Secretary was also directed to transmit a report to Congress on the programs and activities carried out under the section and any recommended change to the routing requirements for the highway transportation of HM.

The Department's HM initiatives promote safe and secure operations and the best highway practices for commercial motor vehicles (CMV) transporting HM in commerce. The goal of the Federal Motor Carrier Safety Administration's (FMCSA) HM safety program is to reduce HM incidents by 20 percent by December 31, 2010, from the 2000 baseline of 574 incidents. To accomplish this goal, FMCSA broadened the safety activities under its authority to more effectively align safety and security initiatives.

The FMCSA supports the Federal Government's protection of the public and works closely with DHS. The FMCSA's access to the HM industry, through its safety programs, allows it to leverage relationships and experience to identify and address CMV security issues to protect against the risks to life and property that are inherent in the transportation of HM in commerce.

Section 1553(a)(1) – Document existing and proposed routes for the transportation of radioactive and non-radioactive HM by motor carriers, and develop a framework for using a GIS-based approach to characterize routes in the national HM route registry.

Documenting Existing and Proposed Routes

In advance of the Act, FMCSA initiated an update to the existing National HM Route Registry. The routing registry contains HM routes for all 50 States and the District of Columbia. The FMCSA's contractor, Battelle, requested current route information from State contacts through the Commercial Vehicle Safety Alliance. Knowledgeable State officials provided information about the location of existing, proposed, and planned HM routes. Simultaneously, FMCSA Division Administrators completed outreach to the States to elaborate on the purpose of the project and requested the State's cooperation in this effort. This information was captured in a report to FMCSA (Appendix A).

The report showed that approximately two-thirds of the States have designated HM routes. Seventeen States did not have registered assigned HM routes. In addition, the majority of designated HM routes in the United States have been designated for through-shipments. Through-shipments, which are those shipments on HM routes in States other than the point of origin and destination, are easier to regulate since the local area is not dependent on the shipments for their economic viability. For most States, the through HM routes are established to avoid urban populations.

Framework for Using GIS-Based Approach to Characterize Routes

A framework for using a GIS-based approach to characterize routes in the national HM route registry was developed by Battelle under their contract with FMCSA. Battelle conducted a literature review, which examined prior studies that focused on the designation of CMV routes for HM shipments. This information provided lessons learned that might benefit future routing.

Most State and local governments are primarily focused on through routing of HM between entry and exit points in the region. Consequently, the HM routes are largely controlled-access highways and other major arteries. Restraints are used to refine the list of candidate routes. Such restraints are defined as additional requirements for the transport of certain HM (e.g. Class 1 Explosive Material) through bridges and tunnels requiring an escort.

The primary analysis criteria used to evaluate candidate routes are measures of risk and trip efficiency. Risk is typically defined as the likelihood of an accident multiplied by the expected consequence, where population is used as the proxy measure for expected consequence. Trip efficiency is measured as the deviation in trip distance or travel time relative to the minimum

distance or travel time path. A variety of other criteria, including proximity to emergency response, type of HM, and certain roadway and traffic conditions are considered to be of moderate importance. Subjective criteria are also used to further characterize candidate routes, but do not appear to have the same level of importance in the decisionmaking process. Some subjective criteria include HM spill damage potential, number of potential evacuees, and exposure to environmentally sensitive areas.

Different analytical tools and subjective judgments are used in making routing decisions. One approach relies on local knowledge to identify a set of candidate routes from which quantitative analysis is performed to identify preferred routes. In contrast, another approach uses quantitative analysis initially to identify candidate routes, and then relies on local knowledge to select a preferred route from among these candidates. In either case, it is apparent that the routing agency believes that subjective judgment based on local knowledge plays an important role in the decision process. Varying the routing criteria or importance ratings often leads to the identification of different preferred routes. Consequently, routing agencies are usually faced with understanding and accepting tradeoffs in selecting a final route.

Comprehensive off-the-shelf route risk assessment software is already available to support analyses based on multiple criteria in determining a preferred route. These tools can be applied anywhere in the continental United States and produce results in both tabular and map form. Their applicability and ease of use is due to the advent of GIS technology and the proliferation of relevant route data being collected in a GIS format. The Battelle report (Appendix B) provides more detailed information regarding available software and its recommended application.

The incorporation of the route registry into a GIS allows route restrictions to be passed to the routing tool for analysis at any geographic level (i.e., local, regional, or national). This GIS format includes routes prescribed for specific types of HM as well as those with specific restrictions on a certain type of HM. Other restrictions, such as time-of-day restrictions for selected types of HM, permitting, and escort requirements for specified types of HM are placed on the GIS format to ease use for the user to obtain the necessary information to route HM. The GIS format provides the flexibility to select the designated HM routes and obtain information listing the specific restrictions for that route, such as type of HM or time of day. Furthermore, the GIS format allows for easier capabilities to include maps of border areas along the Canadian and Mexican borders with restrictions on the movement of HM.

In summary, routing agencies have shown familiarity with the Federal routing guidelines and demonstrated the ability to apply routing criteria both quantitatively and subjectively in making routing decisions. From these experiences, a hierarchy of important routing criteria has emerged along with recognition that the preferred route may differ depending on what routing criteria are utilized and the importance ratings associated with them. The decision process has been inclusive of other stakeholders and comprehensive tools are available to support identification and evaluation of candidate routes.

Section 1553(a)(2) – Assess and characterize existing and proposed routes for the transportation of radioactive and non-radioactive HM by motor carriers for the purpose of identifying measurable criteria for selecting routes based on safety and security concerns.

The Battelle report to FMCSA (Appendix A) presents a characterization of a selection of routes to test whether the methodology using security criteria to select HM routes functions for a variety of areas. The first step in the route characterization is to evaluate the route based on the route security criteria. The outcome of this step is one or more candidate routes. A single candidate route is carried into the second part of the analysis, considering the routes proximity to iconic structures, only if the route meets the security criteria.

A series of screening criteria have been proposed to prescribe or restrict HM routes and establish HM-free zones. The first step is to identify candidate routes based on the total distance traveled and the portion of each route that passes through areas having urban densities (defined as a population density of 3,000 people per square mile within a half-mile of the roadway).

Two criteria compare the most direct route, *y*, with the proposed alternative route *x*. The first criterion considers the ratio of the distance traveled through urban zones for the most direct route, *A*, divided by the distance through urban zones for the proposed alternative route, *B*. The proposed alternative route is selected if:

$$\frac{A}{B} > 1.5$$

The second criterion is considered only if the ratio is between 1 and 1.5. The second criterion considers the total distance traveled on the most direct route, *D*, compared with the total distance traveled on the proposed alternative route, *C*.

The proposed alternative route is considered a candidate route if:

$$\frac{A}{B} < 1.5 \text{ but } \frac{A}{B} > 1.0 \text{ and } \frac{C}{D} < 1.25 \text{ or 25 miles, whichever is less.}$$

Specifically, if the ratio obtained from dividing the distance traveled through urban areas for the through (or most direct) route by the distance traveled on an alternative route is greater than 1.5, or if the ratio is between 1.0 and 1.5 and the ratio of the total distance traveled on the alternative divided by the distance traveled on the through (or most direct route) is less than 1.25 or the difference in mileage is less than 25 miles, whichever is less, then the alternative route meets the criteria for being selected as a candidate route. For regional route selections, the 1.5 ratio is reduced to 1.25, the 1.25 ratio is reduced to 1.10 and the absolute mileage criterion is not used. If neither criterion is met, then the recommendation is that both routes be selected as candidate routes. When this occurs, subsequent steps in the analysis process are used to identify prescribed or restricted routes or HM-free zones.

In summary, a comprehensive and workable security assessment methodology has been developed. The methodology is flexible enough to handle a wide variety of route characteristics and is able to identify situations where prescribing a route for security has significant benefits. All the information used in these evaluations can be obtained from GIS databases depending on the individuals trained in their use. Most State routing officials would have access to the data and staff trained in the use of GIS databases. A Web-based application that implements the logic described in this section has been developed. While not intended to replace the decision maker, the methodology provides the decisionmaker with information that can be used to justify prescribing or restricting HM routes based on safety and security.

Section 1553(a)(3) – Analyze current route-related HM regulations in the United States, Canada, and Mexico to identify cross-border differences and conflicting regulations.

Routing regulations for HM in the United States, Canada, and Mexico were researched to determine if trans-border conflicts exist. The results of this investigation were submitted to FMCSA in a report entitled, "HM Routing Regulations and Truck Transport Border Conflicts" (Appendix C). This portion of the report was designed to accomplish the following two major objectives related to HM routing regulatory analysis:

1) To describe the most important aspects of the Federal routing regulations; and
2) To describe the major routing conflicts that exist for truck shipments of HM between the United States, Canada, and Mexico.

The major routing conflicts that exist for truck shipments of HM occur mainly between the United States and Canada and, more specifically, between the province of Ontario and the States of Michigan, Minnesota, and New York. There are restrictions at bridge and tunnel crossings that exist between the Canada and the United States. Certain types of HM are prohibited from crossing bridges and all HM is prohibited from tunnel crossings. This leaves motor carriers that transport HM between the two countries with fewer options to transport HM across the United States and Canada border. There are also some routing conflicts at border crossings between the United States and Mexico. The only border restrictions for HM truck shipments along the Mexican border are in California. These restrictions apply to explosives, inhalation hazards, and Highway Route Controlled Quantity (HRCQ) of radioactive materials. All other HM may be shipped across any of the three border crossings between California and Mexico that allow commercial trucks to cross. The following list shows each border crossing and the HM that are restricted from crossing either from or into California at that point:

- San Ysidro Border Crossing (I-5) — No commercial truck traffic at this port
- Otay Mesa Border Crossing — Explosives, Inhalation Hazards, and HRCQ
- Tecate Border Crossing (Route 188) — Explosives, Inhalation Hazards, and HRCQ
- Calexico Border Crossing — Inhalation Hazards and HRCQ

Section 1553(a)(4) – Document the safety and security concerns of the public, motor carriers, and State, local, territorial, and tribal governments about the highway routing of HM.

A cross-section of stakeholders including carriers, shippers, associations, and State officials, using questionnaires tailored for each major stakeholder group, was used to solicit information concerning their views on HM routing.

Results obtained from the surveys administered to carriers and shippers, State agencies, and several transportation associations provided diverse feedback regarding the designation of HM routing (Appendix D). In general, the shippers and carriers believe that although the use of HM routes are beneficial for safety, any diversion from the most direct route adds additional operating costs based on added mileage. Furthermore, the shippers and carriers had mixed opinions as to whether criteria are needed to ensure security. Among those carriers that thought security criteria could be beneficial, they commented that criteria could be applied only to those materials that could be used as a weapon and, specifically, to any materials that would require an evacuation of at least 1,000 feet.

The associations that responded to the questionnaire believe that interstates are much safer than other roads with respect to security because any potential terrorists would have less access to vehicles on limited access highways. The associations were also concerned about the process whereby routes are designated, believe that routes cannot be selected in a vacuum, and that any routing entity must consult with adjacent entities to ensure that routing conflicts do not arise. The associations were skeptical about the benefits that would be derived from adding security criteria. This was, in part, because they were unaware of any terrorist incidents in the United States that stemmed from the hijacking of a HM cargo on the highway.

Results obtained from the State representatives in response to the questionnaire were, for the most part, in favor of using safety and security analyses to derive routes. The State officials believe that, wherever possible, HM should be routed on limited access highways to improve both safety and security. The States were more positive about the impact of HM routing on both safety and security than the shippers and carriers. The States judged both the safety and security benefits to be rated 3.5 on a scale of 1 to 5 where 5 is extremely beneficial. When asked if they believe that the designation of HM routes improves public safety and security, five of the six States replied positively.

Shippers and carriers gave safety benefits a rating of 3.0, but the security benefits a score of only 2.6 out of 7.0 where 7.0 is extremely beneficial. All of the carriers responded that designating HM routes increased their operational costs. The carriers referenced costs associated with additional mileage resulting from traveling along HM designated routes. Other costs described included training costs, additional labor costs, costs associated with changing travel routes, and higher insurance costs due to negative (unintended) safety consequences. Carriers seem to disagree on ways to enhance HM security. Many carriers responded that there needs to be more flexibility in determining HM routes and that the regulations need to account for route exceptions

that will actually work to improve the safety and security for the cargo. On the other hand, one carrier responded that safety and security could be improved by stricter enforcement of the current regulations. Another carrier responded that instead of basing regulations on routing, HM safety and security regulations should focus on utilizing technology to track HM shipments and respond in emergency situations.

Section 1553(a)(5) – Prepare guidance materials for State officials to assist them in identifying and reducing both safety concerns and security risks when designating highway routes for HM consistent with the 13 safety-based non-radioactive materials routing criteria and radioactive materials routing criteria in subpart C part 397 of title 49, Code of Federal Regulations.

The purpose of the guidance document (Appendix E) is to develop an approach for incorporating security considerations into the existing process routing officials must follow to designate HM truck routes using the safety regulations contained in 49 Code of Federal Regulations Part 397. When designating highway routes for transporting non-radioactive HM, the regulations list 13 standards a routing official must follow. The guidance document will not change or abolish any of the safety standards. Rather, the guidance document proposes to add steps to the route evaluation process so that security concerns are addressed in sync with the safety requirements. While the guidance document attempts to anticipate many of the situations a routing official will face when trying to designate a route that meets both safety and security criteria, there will be cases where the selection of a route will have to rely on current standards in the regulations.

The guidance document was designed to be flexible enough to take advantage of the varying circumstances without being too complex. The guidance was designed to use route selection criteria that will enhance the safety and security of HM transport without overly restricting commerce.

In order to assist officials in making security-based routing decisions, the methodology described in the guidance document uses road type, distance traveled, and the proximity of both attractive targets and law enforcement personnel. The guidance provides an easy-to-use process for routing officials to prescribe or restrict HM routing using such factors applied to specific security conditions. Routing officials also receive guidance on reducing risk where targets remain vulnerable even after HM traffic has been diverted onto more secure routes.

Section 1553(a)(6) – Develop a tool that will enable State officials to examine potential routes for the highway transportation of HM, assess specific security risks associated with each route, and explore alternative mitigation measures.

The guidance document is accompanied by a Web-based routing tool that will guide the routing official through a logical sequence of data collection and evaluation steps. The routing tool is intended as a decision aid and is not intended to replace the judgment of the routing official who must balance the overall need of the region with the need to provide safe and secure HM transport. This tool is Web-based and provides routing officials with an interactive approach to assist in determining the safest and most secure routes in their area.

The approach focuses on identifying road type, distance traveled, and the proximity of both attractive targets and law enforcement personnel. The prototype allows:

- For assessments where there are multiple routes between a given origin and destination.
- For selection of a prescribed route (as appropriate) to help minimize security risks.
- For the application of routing restrictions (as appropriate) to reduce the risk in those situations where targets still remain vulnerable even after HM traffic is diverted onto more secure routes.

The prototype Web-based system facilitates the application of the guidance document through enabling officials to compare routes using data that is available in a GIS format. The guidance document is automated through the Web-based application and additional enhancements will be implemented before the Web-based application is suitable for State use for safety and security routing selections. The Web-based application is currently only available to FMCSA. However, after the enhancements are made in 2009, it will be made available for full implementation for States through FMCSA's Web site.

The prototype allows the user the ability to interact with the system by using a point and click operation to select routes. In addition, the system allows information to be gained from the GIS format and brought the analysis segment of the tool. The system is flexible enough to allow manual input and obtain the information from the GIS format.

The FMCSA plans to provide outreach initiatives that include training for State personnel responsible for routing HM within the State. The FMCSA will announce the release of the Web-based routing tool and present it at various State meetings. The Web-based tool will be presented in various forums to ensure State personnel will obtain the knowledge and functions of the Web-based routing tool.

Final Report:
Hazardous Materials Routing Safety & Security Risk Analysis

Prepared for:

Federal Motor Carrier Safety Administration
U.S. Department of Transportation

March 31, 2008

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1.0 Background

1.1 Introduction

This Final Report provides an overview of the work conducted during a yearlong project conducted for the Federal Motor Carrier Safety Administration (FMCSA). The project had several purposes. Battelle is conducting the Hazmat Routing Safety & Security Risk Analysis Project for the U.S. DOT Federal Motor Carrier Safety Administration (FMCSA) that emphasizes hazardous material routes in the United States. The project has focused on the following items:

1) Determine the location of existing and proposed hazardous material routes in the United States, Canada, and Mexico.
2) Investigate if additional criteria are needed to include security considerations when selecting routes in addition to the current safety criteria.
3) Determine if there are any conflicts between hazardous materials routes in the United States and those in Canada or Mexico.
4) Develop a potential requirement that could be used to apply the security routing methodology.
5) Conduct of preliminary benefit/cost analysis of the routing methodology to determine if benefits would exceed costs if the requirement was implemented.
6) Characterize a sample of hazmat routes to determine if the application of the security routing methodology is effective.

This Final Report briefly summarizes those documents that have already been delivered to FMCSA and includes three new products that are being presented to FMCSA for the first time in this report. These are a Potential Routing Requirement, A Preliminary Benefit/Cost Analysis of the requirement and characterization of a sample of routes to determine if the security routing methodology is effective.

1.2 Documents Submitted to FMCSA for the Hazmat Routing Project

1.2.1 Documenting Hazardous Materials (Hazmat) Routes in the United States

This portion of the project resulted in the preparation of an Updated National Hazardous Materials Route Registry. This electronic spread sheet was submitted under FMCSA's Hazardous Materials Routing Safety and Security Risk Analysis Project in January 2007.

The Battelle Team began this project by utilizing the existing National Hazardous Materials Route Registry list that was converted into an Excel file by Volpe. This listing contained information on all 50 States and District of Columbia. State contacts were primarily collected through the Commercial Vehicle Safety Alliance (CVSA), a project team member, who contacted members via email to explain the purpose of the project and then to request that the member identify the State official knowledgeable about the location of exiting, proposed and planned hazardous materials (hazmat) routes. FMCSA played a key role in this process by

sending a letter to the FMCSA Division Administrators that described the purpose of the project and sought their cooperation in this effort.

State contacts were first sorted by State, and then assigned to team members. Each team member began investigating their assigned State's routes by searching the internet and calling State contacts. Additional calls were often needed because in some cases the incorrect contacts were identified or in others, personnel changes mandated that the replacement be contacted. Changes and updates were made to the spread sheets based on the information collected. All 50 states and the District of Columbia were contacted in order to confirm and/or update the hazmat routes.

The documentation process showed that currently, approximately two thirds of the States have designated hazmat routes. Seventeen States or about 33 percent do not have registered assigned hazmat routes. There are about 760 hazmat routes designated in the United States. Of these, about 30 percent or 226 were created after the November 1994 routing regulations were in place. This means that the majority of hazmat routes were established without the use of the regulations.

The great majority of designated hazmat routes in the United States have been designated for through shipments. Through shipments, those with no origin or destination in an area, are easier to regulate since the local area is not dependent on theses shipments for their economic viability. For most states, the through hazmat routes are established to avoid urban populations. Exceptions to this occur especially in California, Colorado and Alaska where a number of rural routes have been designated for hazmat shipments.

1.2.2 Hazardous Materials Routing Survey Analysis

This task surveyed a cross section of stakeholders including carriers, shippers, associations and state officials and solicited information concerning their views on hazmat routing and specifically on routing following security criteria. A report entitled Hazardous Materials Routing Survey Analysis, summarized the findings and was submitted to FMCSA in December 2006.

Results obtained from surveys administered to carriers and shippers, state agencies, and several transportation associations tended to provide diverse feedback regarding the designation of hazardous material routing. In general, the shippers and carriers believe that although the use of hazmat routes are beneficial for safety, any diversion from the most direct route adds additional operating costs based on traveling added mileage along designated hazmat routes. Furthermore, they had mixed opinions as to whether criteria are needed to ensure security. Among those carriers that thought security criteria could be beneficial, they commented that criteria could be applied only to those materials that could be used as a weapon and specifically to any materials that would require an evacuation of at least 1,000 feet.

The associations that responded to the questionnaire believe that interstates are much safer than other roads with respect to security because any potential terrorists would have less access to vehicles on limited access highways. The associations were also concerned about the process whereby routes are designated and believe that routes can not be selected in a vacuum and that any routing entity must consult with adjacent entities to ensure that routing conflicts do not arise.

The associations were skeptical about the benefits that would be derived from adding security criteria. This was in part because they were unaware of any terrorist incidents in the United States that stemmed from the hijacking of a hazmat cargo on the highway.

Results obtained from the state representatives in response to the questions in the questionnaire were, for the most part, far more favorable towards the concept of enhanced safety and security being derived from routing regulations. The state officials believe that, wherever possible, hazmat should be routed on limited access highways to improve both safety and security. The states were more positive about the impact of hazmat routing on both safety and security than the shippers and carriers. The states judged both the safety and security benefits to be rated 3.5 out of a scale of 1 to 5 where 5.0 is extremely beneficial. When asked if they believe that the designation of hazmat routes improves public safety and security, five of the six states replied positively. On the other hand, the shippers and carriers gave safety benefits a rating of 3.0 but the security benefits a score of only 2.6 out of 7.0. All of the carriers responded that designating hazmat routes increased their operational costs. These carriers referenced costs associated with additional mileage resulting from traveling along hazmat designated routes. Other costs described included training costs, additional labor costs, costs associated with changing travel routes, and higher insurance costs due to negative (unintended) safety consequences. Carriers seem to disagree on ways to enhance hazmat security. Many carriers responded that there needs to be more flexibility in determining hazmat routes and that the regulations need to account for route exceptions that will actually work to improve the safety and security for the cargo. On the other hand, one carrier responded that safety and security could be improved by stricter enforcement of the current regulations. Another carrier responded that instead of basing regulations on routing, hazmat safety and security regulations should focus on utilizing technology to track hazardous material shipments and respond in emergency situations.

1.2.3 Guidance Document

The Guidance Document was developed to provide routing officials with guidance for applying a methodology to apply security criteria to a safety driven routing selection system for selecting hazmat routes. The Guidance Document was submitted to FMCSA in March 2008.

The purpose of this Guidance Document is to provide routing officials with the insights and methodology for selecting hazmat routes that consider security as a major selection factor. The material presented in this Guidance Document provides routing officials with background information, specific guidance, and a method for selecting hazmat routes that includes security as a major selection factor. The method is designed primarily to use information and data sources such as GIS databases that are compiled and maintained by U.S. Government organizations and, to a limited extent, using data identified through Internet searches. While it is impossible to anticipate every circumstance a routing official might encounter, the design is flexible enough to take advantage of the varying circumstances without being overly complex. The method has also been designed to use route selection criteria that will enhance the safety and security of hazmat transport without overly restricting commerce.

This Guidance Document is supplemented by the **Safety and Security Routing Tool** which guides the routing official through a logical sequence of data collection and evaluation steps. The routing tool is intended as a decision aid and is not intended to replace the judgment of the routing official who must balance the overall need of the region with the needs to provide secure hazardous material transport. This tool is Web-based and provides routing officials with an interactive approach for applying the security method to route selection in their area. The Routing Tool can be accessed through FMCSA Website.

In order to assist officials in making security-based routing decisions, the methodology described in this Guidance Document uses road type, distance traveled, and the proximity of both attractive targets and law enforcement personnel. The method provides an easy to use a stepwise process for routing officials to prescribe or restrict hazmat routing using these factors applied to specific security conditions.

Routing officials also receive guidance on reducing risk where targets remain vulnerable even after hazmat traffic has been diverted onto more secure routes.

1.2.4 Regulatory Summary Focusing on Cross Border Conflicts

Routing regulations for hazmat in the United States, Canada and Mexico were investigated to determine if trans border conflicts existed. The results of this investigation were submitted to FMCSA in May 2007 as: Hazardous Materials Routing Regulations and Truck Transport Border Conflicts.

This white paper was designed to accomplish two major objectives related to hazardous materials (hazmat) routing regulatory analysis:

1) To describe the most important aspects of the Federal routing regulations; and
2) To describe the major routing conflicts that exist for truck shipments of hazmat between the United States and both Canada and Mexico.

The Federal Motor Carrier Safety Administration's (FMCSA) regulations for transporting hazardous materials by motor vehicle documented in 49 CFR Part 397 (49 CFR, 2006) Subparts C and D, address the regulations for routing non-radioactive hazardous materials (NRHM) and radioactive hazardous materials (RAM), respectively. Subpart E specifies the preemption procedures to be followed if an individual including state or local government or Indian tribal official desires preemption from a route prescribed under either Subpart C or D. Following a brief summary in Section 2.0, these sections are summarized in detail.

The major routing conflicts that exist for truck shipments of hazmat occur mainly between the United States and Canada and more specifically between the province of Ontario and the states of Michigan, Minnesota, and New York. Specific routing conflicts are summarized in table of the white paper. However, there are also some "routing conflicts" at border crossings between the United States and Mexico. The only border restrictions for HM truck shipments along the Mexican border are in California. These restrictions apply to explosives, inhalation hazards and highway route controlled quantities of radioactive materials (HRCQ). All other HM may be shipped across any of the three border crossings between California and Mexico that allow

commercial trucks to cross. The bulleted list below lists each border crossing and those hazardous materials that are restricted from crossing either from or into California at that point.

- San Ysidro Border Crossing (I-5) — None*
- Otay Mesa Border Crossing — Explosives, Inhalation Hazards and HRCQ
- Tecate Border Crossing (Route 188) — Explosives, Inhalation Hazards and HRCQ
- Calexico Border Crossing — Inhalation Hazards and HRCQ

* None of the HM classes are restricted from traveling to or from the Mexican border. However, this crossing is closed to all commercial truck traffic. Therefore, no HM truck shipments can cross the border at San Ysidro.

2.0 Potential Security Routing Requirement

2.1 Introduction

Until recently, the approach to routing hazardous materials (hazmat) by highway assumed that when man-made disasters occurred, they were accidental in nature and not due to malicious intent. Terrorist activities, leading to the tragic events in Oklahoma City and on September 11, 2001, as well as those that have occurred in other countries have changed this assumption. We now know that terrorists consider vehicles carrying hazardous materials to be one of the instruments that could be used to further their cause. As a result, terrorism scenarios which previously would have been considered too unlikely to warrant the attention of routing officials must now be considered when designating or restricting routes on which hazardous materials can be transported. Specifically, we must consider hazmat incidents that are or maybe the direct result of terrorist acts; incidents in which hazmat are used as the weapon.

If a routing authority decides to take action and implement security-based routing restrictions, there are currently **no requirements** that enable the authority to implement such routing restrictions. The potential security requirements described below could provide them with the requirements to establish security based routing of hazmat within their jurisdictions.

The following paragraph provides a potential security requirement that FMCSA may consider as a framework for developing a draft regulation. Such a regulation would specify the steps and the types of evaluations routing officials would use to identify security vulnerabilities and actions these officials should take to reduce the risk of terrorists exploiting these possible vulnerabilities. While the language of the potential security requirement does not dictate the exact methodology a routing official must use to assess route security and designate (or restrict) hazmat transport routes, the language does dictate the types of information that should be considered when developing and implementing a hazardous materials route security assessment methodology. Such standardization would provide uniformity in how security vulnerabilities are addressed, in itself a security benefit, and help ensure that routing officials will not specify overly cumbersome hazardous material transport routes. **The proposed security requirements are designed to work in concert with and not replace the current safety routing regulations**.

The proposed requirement includes the following major sections:

- An approach for determining if hazmat routes should be designated for security
- The desirable characteristics of through hazmat shipment routes
- The desirable characteristics of local hazmat routes.
- The approach for designating hazmat routes for security.
- Discussions of state and tribal routing officials with local officials
- Public information and reporting requirements

2.2 Determining if Hazmat Routes Should be Designated for Security

The focus of a security assessment is to protect areas that are highly populated or contain iconic structures or critical infrastructure. Areas with important cultural, economic and symbolic resources such as historic sites and monuments, government offices, stadiums, convention centers, schools, bridges and tunnels might be designated as having iconic structures/critical infrastructure by the Federal government, State routing authorities or Indian tribes. Note that for the purposes of this proposed requirement, iconic structures and critical infrastructure are referred to as iconic structures.

A determination of adequate hazmat route security should address the following questions:

1) Does an existing or potential credible terrorist threat exist that could result in hazmat cargo being used as a weapon to damage or destroy nationally, regionally or locally recognized iconic structures or critical infrastructure?
2) Do current designated hazmat routes sufficiently protect these iconic structures/critical infrastructure by ensuring that hazmat shipments travel at sufficient distance from the potential targets?
3) Would imposing restrictions on through and/or local hazardous material routes significantly augment the security measures already in place to protect potential targets (i.e., physical barriers and stationing police close to the structure)?

Where hazmat routes have previously been designated based on safety criteria, these routes should be examined to determine if they also provide adequate security protection. Such an evaluation should be performed before reaching a decision that the previously performed safety assessment is adequate for security. If the routing officials deem this protection to be adequate, a report documenting the decision and its basis would be issued. The report would summarize the routes evaluated, there relative characteristics, and how the routes compare against the safety and security routing criteria. If the routing official chose to discount some of these analysis findings, the rationale for discounting the criteria would also become part of the documentation. This report would be provided to potentially affected parties (e.g., individuals, businesses and governmental entities).

Should the routing official make a determination that the security protection provided by the hazardous material routes prescribed for public safety may be inadequate when considering security concerns, the routing official should perform a more in depth evaluation to determine if additional route designations or restrictions would improve the security of hazmat transport.

A different evaluation approach should be used depending on whether the route serves *through* or *local* shipments. For through shipments, routing authorities may establish designated or restricted routes for all hazardous material shipments by truck or for selected classes/divisions of hazardous materials (e.g., toxic by inhalation (TIH), explosive) based on the proximity of the routes to icons and the presence of critical infrastructure on the routes. For local shipments, restricted zones may also be considered, which would include prohibiting hazmat shipments on all streets in the zone; this could be designated by listing just the streets forming the boundary. Based on the nature of the sensitive zone, the routing authorities can restrict travel of all

placarded vehicles or selected types of hazardous materials, and may also restrict travel during specific time periods.

2.3 Characteristics of Through Hazmat Shipment Routes

For security purposes, within urban areas, where they exist, *divided, limited access highway* bypasses or beltway*s* are the preferred hazardous material routes for through shipments. Divided, limited access highways are considered to be attractive routes for security purposes because they generally provide poorer access for potential terrorists to reach cargo and critical infrastructure of interest. Beltways or bypasses are desirable routes because they tend to be more remote from densely populated areas and are less exposed to icons/critical infrastructure than highways passing through the central core of an urban area.

2.4 Characteristics of Local Hazmat Shipment Routes

Preferred routes for local hazardous material shipments are divided, limited access highways traversing the urban area. Unless specifically restricted, major thoroughfares designated as truck routes are considered to be designated hazardous material truck routes. For pickup and delivery to locations not on designated routes, the route must be the shortest-distance from pickup and delivery location to the nearest access/egress point on the designated hazardous material route. Routes which do not meet this criterion should be considered only if the shortest route would result in the transport of hazardous material through highly populated areas or through zones established to protect icons/critical infrastructure. Pickup and delivery routes need not be specifically listed. In accordance with 49 CFR 397.67(b), a motor vehicle that requires to be placarded shall operate the vehicle over routes that do not go through or near populated areas or near heavily populated places where crowds are assembled, tunnels, narrow streets or alleys unless no practical alternatives exist. For explosives and shipments of Highway Route Controlled Quantities of Radioactive Material, additional route requirements are imposed. These requirements are intended to reduce the risk to the public posed by shipping these materials.

Where explosives, TIH shipments (and any other designated hazmat) must be made to/from customers located on restricted routes or in restricted zones, the cargo should be either shipped by a vehicle equipped with a unique identification system for shipments of hazmat in the restricted area. This entrance sticker would be provided to a carrier by local officials and would be visible and easy to read by observers either on the street or in another vehicle. Although the FMCSA requires shippers of radioactive materials, explosives, TIH and methane (liquefied natural gas) to possess a safety permit, this permit is not related to permission to operate in specific areas or zones. Currently, a permit system is in operation in Yellowstone National Park where all HM carriers entering the park must be permitted.

49 CFR 397 Subpart B specifies the procedure State and Indian Tribe routing officials must follow to prescribe or restrict routes for Non-radioactive Hazardous Material (NRHM). In the absence of any federal regulations, these officials could decide to require additional security controls. A vehicle could be equipped with deterrent security features or escorted by law enforcement (or a certified escort). Deterrent security features would enable law enforcement officials to be warned and interdict shipments following any attempt made to take unauthorized

control of the shipment. Security features would include but not be limited to: GPS tracking, communication devices for continuous driver contact with law enforcement, and the ability to stop the vehicle by locking its brakes remotely. Deterrent security features could be documented in a confidential route security plan that has been approved by law enforcement authorities having jurisdiction within the restricted zone. Similarly, escort personnel that are candidates for certification would be included in the security plan, if required. Plan approval would represent "certification" of escort personnel as well as deterrent security features. It should be noted that the regulations currently require that some high risk materials, specifically Division 1.1, 1.2 and 1.3 Explosives and HRCQ radioactive material shipments have some of these deterrent safety features.

2.5 Designating Routes for Security

If there is no existing hazmat route in the area, the routing authority would apply a similar approach but would select alternate routes to evaluate. These would usually include the most direct route through the area and an alternative bypass route.

Routing officials would assess potential hazmat routes for security criteria following a three step process, as outlined below. Note that the FMCSA Hazmat Routing Guidance document (FMCSA-2007) provides specific steps for conducting an evaluation of potential hazmat routes with respect to safety and security by designating and restricting routes and establishing restricted hazmat zones.

1) For the most direct route through the urban area and the proposed alternative route(s), determine the total distance traveled and the distance traveled though densely populated areas. An area is defined as densely populated if the population density on either side of the route is greater than 3,000 persons per square mile. If the evaluation is for the transport of all types of hazardous materials, the distance used to calculate density should be one half-mile on either side of the highway. If the route is being considered for specific types of hazmat, a different distance from the roadway could be used to estimate population density, taking into account the impacts from releases of the material in question. In order for an alternative route to be selected as a candidate for designation as a hazardous materials route on the basis of security criteria, the following two characteristics must be present.

    a. The ratio of the distance traveled through densely populated regions for the most direct route divided by the distance traveled through densely populated areas for the alternative route is greater than 1.5. This value was selected because there is a precedent in the current safety regulations [49 CFR 397.71(b)(4)(i)] to not select the most direct route through an urban area if the safety risk is 1.5 times larger that risk for an alternative route that avoids the populated area.

    b. If the criterion in (a) is not met but the ratio calculated in (a) is between 1.0 and 1.5, the alternative route is considered a candidate route if the total distance on the alternative route is not more than 25 miles or 25 percent greater than the most direct route, whichever is greater. This value was selected because it parallels the performance measure currently in the regulations [49 CFR 397.71(b)(4)(ii)] to select routes based on safety considerations.

2) The second step evaluates the candidate routes identified in Step 1 to determine if they provide adequate security to local, regional or national icons or critical infrastructure. A designated hazmat route cannot meet this security requirement if the roadway has a component on the critical infrastructure list. Note that both critical infrastructure and icons were identified through research of local websites and maps. This step also considers the accessibility of icons or critical infrastructure with respect to the potential use of hazmat cargo to attack these targets. The need to restrict routes or establish zones around potential targets should be based on the distance from designated hazardous material routes and the distance from law enforcement facilities to the icons/critical infrastructure. If the distance from the icons/critical infrastructure to the candidate route is significantly greater than the distance from the nearest emergency presence, then the candidate route provides adequate security for the iconic structures. If the two distances are not significantly different, the decision might be made to not establish any prescribed or restricted routes for enhancing security and to rely instead on other security methods (e.g., protective services and/or concrete barriers).
3) The third step encompasses the establishment of zones where the movement of hazmat is tightly controlled. If routing officials are unable to successfully protect icons/critical infrastructure from the use of hazmat cargo as a weapon, they may consider establishing restricted zones. In most cases, this situation would occur when performing an analysis of either through or local hazmat travel. For those icons/critical infrastructure that cannot be protected from hazmat shipments, a restricted zone with a buffer area of 0.25 miles around the structure would be established. In this area, if it were necessary to transport hazmat shipments, then such transport would be controlled by a system that might include advance notification, special equipment on the transport vehicle and, in some unique cases, escorts.

2.6 Discussions of State and Tribal Routing Officials with Local Officials

Prior to formally deciding to designate or restrict hazmat routing, the routing official must consult with potentially affected individuals, including governmental entities. These discussions must present the basis for the conclusion that designating or restricting the routes will improve safety and security and to not unnecessarily restrict commerce. **These consultations should ensure that any designated routes or restricted areas have adequately considered local situations related to such factors as the unrestricted flow of normal commerce, congestion of major routes and use of certain hazardous materials by local communities and industry.** After these discussions have occurred, routing official can issue the formal finding and disclose that the designated or restricted routes improve safety and security and do not overly restrict access to businesses receiving or shipping hazardous materials.

3.0 Preliminary Benefit/Cost Analysis

The potential routing requirements presented in Section 2.0 of this Final Report were examined in order to determine whether the enhanced benefits associated with routing hazardous materials (hazmat) around both national, regional, and local iconic structures as well as critical infrastructure exceeded the societal costs associated with applying security criteria to hazmat route selection and specifically to implementing the potential requirements. Note that in this benefit-cost analysis iconic structures and critical infrastructure are both discussed as iconic structures. Benefits to society are entirely derived from the improved safety and security of hazardous material shipments traveling on routes meeting the potential routing requirements. The vast majority of the costs are tied to the additional operating costs incurred by transporters of hazardous materials as they take more indirect routes around city centers when traveling near urban areas. Costs also include those expected to be incurred by cities when establishing and operating an entrance sticker system program, as well as costs incurred by HM carriers through the completion of entrance sticker paperwork and payment of related fees. Finally, cities would incur any signage costs associated with establishing prescribed and restricted routes. The preliminary benefit/cost analysis presented below provides an initial estimate of the anticipated benefits and costs associated with implementing the routing program. While the findings appear to be robust, the estimate was **not** prepared with the detail required for a rulemaking. In order to prepare a more reliable estimate, the estimated costs should be benchmarked against the costs currently being incurred by carriers required to meet the current security regulations imposed on Division 1.1, 1.2 and 1.3 Explosives and HRCQ shipments of radioactive materials. .

The analysis presented in this section assumes that the vast majority of routes selected for security purposes will be selected in urban areas with populations in excess of 150,000. Further, most cities with more than 150,000 inhabitants have beltways or bypass highways, enabling the comparison of these routes with the Interstate routes passing nearer the center of the city.

To determine the impact of routing restrictions on hazmat carrier operating costs, this analysis focuses on seven urban areas selected to be representative of U.S. cities:

- Baltimore, Maryland
- Columbus, Ohio
- Denver, Colorado
- Providence, Rhode Island
- Indianapolis, Indiana
- Phoenix, Arizona
- Portland, Oregon

The characteristics of these selected urban areas (e.g., the route characteristics, distance differences between alternative routes and average annual daily traffic (AADT) data for large trucks) were extrapolated to the remaining 135 urban centers in the United States.

The benefit-cost analysis presents streams of benefits and costs over a 20-year (2007-2026) timeframe but compresses these streams into present value benefits and costs using a real discount rate of 7 percent, as is prescribed by the Office of Management and Budget (OMB) for analysis of government programs.[1] The 20-year time frame was selected because this is the time

[1] Office of Management and Budget. OMB Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. October, 1992. Washington D.C.

period that is typically used for this sort of calculation. Growth in the hazmat fleet and hazmat travel was assumed to be 1.5 percent annually, which is consistent with the 5 and 20 year averages in gasoline deliveries in the United States as reported by the U.S. Department of Energy's Energy Information Administration.[2]

3.1 The Mileage of Through Hazmat Truck Traffic Potentially Affected by Increased Routing Restrictions

One of the most significant data elements required to determine the costs of re-routing hazmat traffic around city centers is the number of additional miles that would be traveled by hazmat carriers in order to comply with the potential routing restrictions. To estimate the mileage of hazmat truck traffic potentially affected by the application of security criteria, data gathered from the examination of seven representative cities in the U.S. was extrapolated to the nation as a whole. First, the percentage population found in of all urban areas with populations in excess of 150,000 captured by the seven selected cities was calculated (7.57 percent). Next, the daily large truck traffic for the major through Interstates in the seven selected urban areas was calculated (88,951 vehicles).[3] The share of the total truck traffic represented by hazmat transporters was estimated at 5 percent.[4] Thus, the daily hazmat truck traffic for the seven selected cities was estimated at 4,448 (88,952 * .05).

To estimate the total annual hazmat traffic for all urban centers with populations in excess of 150,000, the daily hazmat traffic in the seven selected cities was multiplied by 365 and divided by the percentage of all urban areas represented by the seven selected cities (4448 * 365 / .076). The result is 21.4 million annual hazmat vehicles potentially impacted by the application of security criteria.

The data collected for this project to document current hazmat routes, shows that 31 percent of urban areas with populations in excess of 150,000 have already established hazmat routes. A tabulation of cities and their populations can be found in the U.S. Census Bureau's County and City Data Book 2007 in Table C. The total hazmat traffic represented by these jurisdictions was, estimated at 6.6 million (21.4 million * .31). Thus, there are an estimated 14.8 million annual hazmat truck movements that are not affected by current regulations. **The assumption used for this analysis is that the great majority of these existing designated hazmat routes would not be affected by the application of security criteria and the great majority of urban areas that currently have hazmat routes will retain these routes and utilize them for security purposes**. We also assume that the urban areas that have not been affected by current hazmat routing regulations would apply security criteria for selecting hazmat routes in about the same percentage (31 percent) as found for those cities with routes selected for safety.[5] Applying this assumption, 31 percent of these currently unregulated through hazmat vehicle movements would be affected by the application of new security criteria (.31 * 14.8 million or 4.6 million hazmat traffic movements). It is further assumed that only one-third of these movements would

[2] http://tonto.eia.doe.gov/dnav/pet/hist/mgfupus1A.htm, last accessed December 21, 2006.
[3] FHWA, 2004, Freight Analysis Framework for Large Trucks in 2002.
[4] FMCSA, 2001, Comparative Risk of Hazmat and Non-hazmat Materials Truck Movements.
[5] Data developed for FMCSA under this hazmat routing project.

represent through traffic.[6] Thus, the number of through hazmat truck trips potentially affected by the application of security criteria is estimated at 1.5 million.

To estimate the added miles required for through hazmat movements if forced to use longer routes that bypass the center of the urban areas, the direct Interstate routes for the seven urban areas were compared to the beltway routes. For the seven urban areas, the direct Interstate routes represent about 137.3 miles and the beltway routes are approximately 203.9 miles. For the seven urban areas examined for this analysis, the average mileage on the beltway is 29.1 miles while the average mileage on the direct routes was 19.6 miles, measuring a difference of 9.5 miles. Thus, 9.5 miles was used to represent the additional mileage that must be traveled to avoid the center of the urban area.

Based on the total hazmat traffic of 1.5 million hazmat trips potentially affected by the new security requirements, multiplying these trips by the average additional mileage of 9.5 results in a total of 14.5 million miles of additional driving as a result of the new regulations. In order to make this estimate more realistic, a sensitivity analysis was performed by using a lower and higher value for some of the key costs. If the range of values accurately represents the range of uncertainty, and the cost benefit ratio is still favorable, then there is greater certainty that the ratio is robust and will actually be realized if the program is implemented. When the sensitivity analysis was performed on this estimate, low- and high-end assumptions (plus or minus 10 percent), the range of potential impacted miles was 13.1 million to 16.0 million.

3.2 The Costs of Complying with New Hazmat Routing Restrictions

This analysis examines four cost elements:

- additional operating costs to hazmat carriers associated with diverting around city centers,
- costs to cities associated with signage on prescribed and restricted routes,
- costs to cities for establishing and maintaining an entrance sticker program, and the costs to local carriers to obtain an entrance sticker for a restrictive zone.

These costs were examined over a 20-year analysis time horizon. The basis of each cost estimate is provided in the remainder of this section.

The vast majority of the costs are those tied to the operating costs to hazmat carriers when diverting around city centers on beltways circumnavigating major urban areas. To calculate the annual operating costs, the miles affected by the new security requirements, identified as 13.1 to 16.0 million in the preceding section, were multiplied by an average per-mile operating cost of $3.10. This value is an escalation of the average per-mile operating cost estimate calculated in 2003 by the American Trucking Associations of $2.80 per mile. That included $0.551 for driver wages, $0.804 for other wages and benefits, $0.198 for fuel, and $0.651 in equipment rents and

[6] FMCSA, 2001 Comparative Risk of Hazmat and Non-hazmat Materials Truck Movements; based on analysis of hazmat commodities and assumed percentage distributed locally.

purchased transportation.[7] The per-mile operating cost of $2.80 was then inflated to 2007 dollars using the consumer price index to result in the $3.10 figure used in the analysis. Applying this operating cost assumption results in initial year costs to motor carriers of $40.5-$49.5 million. Further, it is assumed that an additional 10 percent of costs would be incurred by motor carriers navigating around cities with fewer than 150,000 inhabitants. The costs associated with avoiding smaller urban areas are estimated at $4.1-$5.0 million in the initial year following implementation of the restrictions. Thus, total initial year costs to motor carriers associated with diverting around city centers are estimated at $44.6-$54.5 million.

This analysis also considers the costs to establish restricted zones for local hazmat traffic, including the costs to establish and maintain an entrance sticker system. Although the FMCSA requires shippers of radioactive materials, explosives, TIH and methane (liquefied natural gas) to possess a safety permit, this system is not related to permission to operate in specific areas or zones. The entrance sticker system would enable local authorities to easily spot if unauthorized HM trucks were traveling in a restricted HM zone. For this analysis, the assumption was made that in order to travel in restricted zones, hazmat carriers would be required to purchase a sticker that would be exhibited prominently on the vehicle. This entrance system was assumed to be more conservative than such solutions as using a bill of lading system to demonstrate that a carrier was authorized to travel in a restricted zone. The planning costs associated with establishing the restricted zone were estimated at $3,033 per city based on the assumption that it would require 80 labor hours to establish the zone and that the average hourly wage plus fringe for state employees is $37.91.[8] The cost to establish the entrance sticker system was estimated at $1,516 per city based on the assumption that it would take 40 hours of labor to complete. The annual recurrent costs associated with maintaining the entrance sticker system were estimated at $3,033 based on an assumption of 80 annual labor hours.

To determine the total costs of establishing and maintaining an entrance sticker system, it was necessary to determine the number of new urban areas that would prescribe hazmat routes based on security considerations. This analysis assumes there are 29 such urban areas. This estimate is based on the assumption that 42 of the 135 urban areas with populations in excess of 150,000 currently have prescribed routes and that 31 percent of the remaining 92 urban areas, or 29 urban areas, would prescribe hazmat routes based on security considerations.[9] Thus, the costs associated with establishing the entrance sticker system in large urban areas with populations in excess of 150,000 were estimated at $43,976 (40 hours * $37.91 * 29 cities), while the costs of both planning for the restricted zone and maintaining the entrance sticker system were estimated at $87,951 (80 hours * $37.91 * 29 cities). As is the case with all cost elements examined within this analysis, it is assumed that an additional 10 percent ($4,398 to establish the entrance sticker system and $8,795 to establish the zones and maintain the entrance sticker system) in costs would be incurred in smaller urban areas with populations smaller than 150,000.

The costs to hazmat carriers was estimated as the product of the number of hazmat carriers operating on local routes in each city (6), the number of cities issuing entrance stickers (29) and the costs in terms of entrance sticker fees and the costs to complete the entrance sticker

[7] http://www.oregon.gov/ODOT/MCT/CVISN.shtml
[8] Bureau of Labor Statistics, National Compensation Survey. http://www.bls.gov/news.release/ecec.t03.htm
[9] Based on the survey of hazmat routes in the United States conducted for this project.

paperwork ($81.1). Based on these assumptions, the costs to carriers to obtain entrance stickers in large urban areas was estimated at $14,111, with an additional $1,411 in smaller urban areas, for a total cost of $15,522 in the initial year following establishment of the entrance sticker process. The sticker fee was assumed to be $50 while the labor costs associated with completing the entrance sticker application was estimated as the product of the time required to complete the application (1.5 hours) and the average hourly wage plus fringe benefits for office staff estimated in the Bureau of Labor Statistics' National Compensation Survey ($20.73).[10]

The cost of signage in each city was estimated as those tied both to the establishment of prescribed routes and warning sings posted along restricted routes. The cost of signage for prescribed routes in the 29 urban areas was estimated based on the assumptions that there would be 6 signs per urban area, or a total of 174 signs, installed at a cost of $3,400 per sign. Thus, the cost to install signs on prescribed routes was estimated at $591,600. Once again, to account for the signage costs at smaller urban areas, and additional $59,100 was added to the total. The costs of signage for restricted routes were estimated based on the assumptions that there would be 12 signs installed in each urban area at a cost of $500 each (total cost of $6,000). This cost was applied to all 29 large urban areas ($174,000) and an additional 10 percent ($17,400) was added to account for smaller urban areas.

The findings of the cost analysis are presented in Tables 1 (low-end cost scenario) and 2 (high-end cost scenario). The difference in terms of costs between the two scenarios reflects the impact of the sensitivity analysis conducted with respect to additional miles traveled while diverting around city centers. Based on the aforementioned assumptions, the total cost of complying with the new security requirements ranges from $1.0 billion or $51.7 million average annual (low-end scenario) to 1.3 billion or $63.2 million average annual (high-end scenario) in undiscounted 2007 dollars and $567.7-$693.4 when compressed into present value terms using a real discount rate of 7 percent. As noted previously, the most significant cost element is associated with the additional operating costs paid by hazmat carriers ($1.0-$1.3 billion). The costs to cities and motor carriers associated with identifying HM local traffic within restricted zones is relatively small at $2.6 million. The costs to cities associated with signage along prescribed and restricted routes are estimated at $842,160.

Total costs to cities include the costs associated with establishing and maintaining restricted zones and a system to allow local hazmat traffic into these zones. These costs over the 20-year analysis time period (2007-2026) are estimated at $3.1 million ($156.4 thousand average annual) in undiscounted 2007 dollars. The total 20-year costs to carriers associated with additional operating costs resulting from the requirement to divert around city centers and to obtain entrance stickers to travel in restricted zones is estimated at $1.0-$1.3 billion ($51.6-$63.0 million average annual) in undiscounted 2007 dollars.

[10] http://www.bls.gov/news.release/ecec.t01.htm

Table 1. Annual Costs Associated with Hazmat Traffic Diversion, Entrance Sticker Program and Planning, and Signage (Low-End Scenario)

Year	Hazmat Traffic Diversion Costs	Signage Costs	Entrance Sticker Planning Costs	Total Costs	Discounted Total Costs
2007	44,578,997	842,160	160,641	45,581,798	45,581,798
2008	45,247,682	-	113,952	45,361,633	42,394,050
2009	45,926,397	-	115,661	46,042,058	40,214,917
2010	46,615,293	-	117,396	46,732,689	38,147,795
2011	47,314,522	-	119,157	47,433,679	36,186,927
2012	48,024,240	-	120,944	48,145,184	34,326,851
2013	48,744,604	-	122,759	48,867,362	32,562,387
2014	49,475,773	-	124,600	49,600,373	30,888,619
2015	50,217,909	-	126,469	50,344,378	29,300,886
2016	50,971,178	-	128,366	51,099,544	27,794,766
2017	51,735,745	-	130,291	51,866,037	26,366,063
2018	52,511,782	-	132,246	52,644,028	25,010,798
2019	53,299,458	-	134,230	53,433,688	23,725,196
2020	54,098,950	-	136,243	54,235,193	22,505,677
2021	54,910,435	-	138,287	55,048,721	21,348,843
2022	55,734,091	-	140,361	55,874,452	20,251,473
2023	56,570,102	-	142,466	56,712,569	19,210,509
2024	57,418,654	-	144,603	57,563,257	18,223,053
2025	58,279,934	-	146,772	58,426,706	17,286,354
2026	59,154,133	-	148,974	59,303,107	16,397,803
Total	1,030,829,877	842,160	2,644,419	1,034,316,456	567,724,765
Annual Average	51,541,494	42,108	132,221	51,715,823	28,386,238

Table 2. Annual Costs Associated with Hazmat Traffic Diversion, Entrance Sticker System Program and Planning, and Signage (High-End Scenario)

Year	Hazmat Traffic Diversion Costs	Signage Costs	Entrance Sticker Planning Costs	Total Costs	Discounted Total Costs
2007	54,485,440	842,160	160,641	55,488,241	55,488,241
2008	55,302,722	-	113,952	55,416,674	51,791,284
2009	56,132,263	-	115,661	56,247,924	49,129,115
2010	56,974,247	-	117,396	57,091,643	46,603,787
2011	57,828,860	-	119,157	57,948,017	44,208,265
2012	58,696,293	-	120,944	58,817,238	41,935,878
2013	59,576,738	-	122,759	59,699,496	39,780,295
2014	60,470,389	-	124,600	60,594,989	37,735,514
2015	61,377,445	-	126,469	61,503,914	35,795,838
2016	62,298,106	-	128,366	62,426,472	33,955,865
2017	63,232,578	-	130,291	63,362,869	32,210,470
2018	64,181,066	-	132,246	64,313,312	30,554,791
2019	65,143,782	-	134,230	65,278,012	28,984,218
2020	66,120,939	-	136,243	66,257,182	27,494,375
2021	67,112,753	-	138,287	67,251,040	26,081,113
2022	68,119,445	-	140,361	68,259,806	24,740,495
2023	69,141,236	-	142,466	69,283,703	23,468,787
2024	70,178,355	-	144,603	70,322,958	22,262,448
2025	71,231,030	-	146,772	71,377,803	21,118,116
2026	72,299,496	-	148,974	72,448,470	20,032,606
Total	1,259,903,183	842,160	2,644,419	1,263,389,762	693,371,499
Annual Average	62,995,159	42,108	132,221	63,169,488	34,668,575

3.3 The Benefits of New Hazmat Routing Restrictions

The benefits associated with establishing new security criteria and routing hazmat traffic around city centers are entirely tied to the probability of a terrorist attack using hazardous materials on structures of national, regional, and local significance and the costs associated with such an attack. The likelihood of a terrorist attack on national, regional, and local structures was estimated at 10 percent per year, 5 percent per year, and 1 percent per year, respectively. This estimate was base on the frequency and target selection of terrorist attacks during the past twelve years in both the U.S. and to U.S. facilities abroad. Because the number of attacks is uncertain, a factor of ten is used for the estimate. This analysis assumes that the adoption of security based routing restrictions would not eliminate all terrorist attacks. Therefore, the probability that the adoption of security based routing restrictions would prevent an attack was estimated. For this

analysis, it is assumed that routing regulations would be 50 percent effective in preventing an attack.[11] Finally, the cost of a successful terrorist attack was estimated as follows:

- National structure – $40 billion
- Regional structure – $10 billion
- Local structure – $1 billion[12]

The cost estimates shown above, were based on those prepared for a limited access report prepared by Battelle for FMCSA in a 2004 project.

Based on these assumptions the benefit of protecting structures using local routing restrictions was estimated as the product of the cost of a terrorist attack ($40 billion per national structure, $10 billion per regional structure, $1 billion per local structure), the probability that a terrorist attack will occur (10 percent per year all national structures, 5 percent per year all regional structures, 1 percent per year all local structures) and the probability that routing regulations would prevent an attack (50 percent). Based on these assumptions, the estimated benefits associated with new hazmat routing restrictions is estimated at $45.1 billion ($2.3 billion average annual) in undiscounted 2007 dollars and $25.6 billion (average annual benefit of $1.3 billion) in discounted present value terms over the 20-year analysis time horizon (Table 3).

3.4 Preliminary Benefit-Cost Analysis Results

The results of the benefit-cost analysis are presented in Table 4. In both the low- and high-end cost scenarios, the benefits associated with reducing the probability of a terrorist attack on structures easily exceed the costs associated with implementing new routing restrictions based on the assumptions used in this analysis. Using low-end cost scenario assumptions, the net benefits of the routing restrictions would exceed the costs of imposing them by $24,994,042,507 (present value discounted benefits) over the 20-year analysis time horizon (2007-2026). The benefits and costs presented in Table 4 generate a benefit-cost ratio (benefits divided by costs) of 45.0. In the high-end cost scenario present value net benefits remains $24,868,395,773, generating a 36.9 benefit-cost ratio.

Using the assumptions outlined within this analysis, the benefit-cost ratio within the low-end cost scenario would remain above 1.0 provided the annual probabilities of a hazmat terrorist attack on a national, regional, and local structure were more than 0.2 percent, 0.1 percent, and 0.1 percent, respectively. The benefit-cost ratio for the high-end estimate would remain above 1.0 if the annual probabilities of a hazmat terrorist attack on national, regional, and local structures were more than 0.3 percent, 0.1 percent, and 0.1 percent, respectively. Thus, using the assumptions outlined within this analysis, even the slight risk of a hazmat-oriented terrorist attack on national, regional, and local structures would appear to validate additional hazmat routing restrictions.

[11] Based on engineering judgment.
[12] Based on estimates in a confidential FMCSA report investigating the consequences of terrorist incidents.

Table 3. Annual Benefits Associated with New Hazmat Security Requirements

Year	Benefits of Protecting Structures			Total Benefits	Discounted Benefits
	National	Regional	Local		
2007	2,000,000,000	250,000,000	5,000,000	2,255,000,000	2,255,000,000
2008	2,000,000,000	250,000,000	5,000,000	2,255,000,000	2,107,476,636
2009	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,969,604,332
2010	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,840,751,712
2011	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,720,328,703
2012	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,607,783,835
2013	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,502,601,715
2014	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,404,300,668
2015	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,312,430,531
2016	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,226,570,590
2017	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,146,327,654
2018	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,071,334,256
2019	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,001,246,968
2020	2,000,000,000	250,000,000	5,000,000	2,255,000,000	935,744,830
2021	2,000,000,000	250,000,000	5,000,000	2,255,000,000	874,527,878
2022	2,000,000,000	250,000,000	5,000,000	2,255,000,000	817,315,774
2023	2,000,000,000	250,000,000	5,000,000	2,255,000,000	763,846,518
2024	2,000,000,000	250,000,000	5,000,000	2,255,000,000	713,875,250
2025	2,000,000,000	250,000,000	5,000,000	2,255,000,000	667,173,131
2026	2,000,000,000	250,000,000	5,000,000	2,255,000,000	623,526,291
Total	40,000,000,000	5,000,000,000	100,000,000	45,100,000,000	25,561,767,272
Average Annual	2,000,000,000	250,000,000	5,000,000	2,255,000,000	1,278,088,364

Table 4. Benefit-Cost Results
(High- and Low-End Cost Scenarios)

	Low-End Cost Scenario	High-End Cost Scenario
Benefits	25,561,767,272	25,561,767,272
Costs	567,724,765	693,371,499
Net Benefits	24,994,042,507	24,868,395,773
Benefit-Cost Ratio	45.0	36.9

4.0 Characterization of Routes

This section presents a characterization of a selection of routes to test whether the methodology using security criteria to select hazmat routes functions for a variety of areas. The first step in the route characterization is to evaluate the route based on the route security criteria. The outcome of this step is one or more candidate routes. A single candidate route is carried into the second part of the analysis, considering the routes proximity to iconic structures, only if the route meets the security criteria.

4.1 Identification of Selected Candidate Routes Based on Security Criteria

A series of screening criteria have been proposed to prescribe or restrict hazmat routes and establish hazmat free zones. The first step is to identify candidate routes based on the total distance traveled and the portion of each route that passes through areas having urban densities (defined as a population density of 3,000 people per square mile within a half-mile of the roadway).

Two criteria compare the most direct route, y, with the proposed alternative route x. The first criterion considers the ratio of the distance traveled through urban zones for the most direct route, A, divided by the distance through urban zones for the proposed alternative route, B. The proposed alternative route is selected if:

$$\frac{A}{B} > 1.5$$

The second criterion is considered only if the ratio is between 1 and 1.5. The second criterion considers the total distance traveled on the most direct route, D, compared with the total distance traveled on the proposed alternative route C.

The proposed alternative route is considered a candidate route if:

$$\frac{A}{B} < 1.5 \text{ but } \frac{A}{B} > 1.0 \text{ and } \frac{C}{D} < 1.25 \text{ or 25 miles which ever is less.}$$

Expressed in words, if the ratio obtained from dividing the distance traveled through urban areas for the through (or most direct) route by the distance traveled on an alternative route is greater than 1.5, or if the ratio is between 1.0 and 1.5 and the ratio of the total distance traveled on the alternative divided by the distance traveled on the through (or most direct route) is less than 1.25 or the difference in mileage is less than 25 miles, whichever is less, then the alternative route meets the criteria for being selected as a candidate route. For regional route selections, the 1.5 ratio is reduced to 1.25, the 1.25 ratio is reduced to 1.10 and the absolute mileage criterion is not used. If neither criterion is met, then the recommendation is that both routes be selected as candidate routes. When this occurs, subsequent steps in the analysis process are used to identify prescribed or restricted routes or hazmat free zones.

Table 5 shows the results of route evaluations for 18 different urban or regional settings in various locations within the U.S. These settings are provided to illustrate the considerations that might be encountered when selecting candidate routes. The first part of the table shows urban analyses, with regional analyses shown toward the end of the table.

In reviewing the results, it can be seen that the bypass or beltway around the urban area is selected as a candidate route in the majority of cases. Where the city is completely ringed by a beltway, the shorter arc is selected as a candidate route over the longer arc. Figures 1 and 2 show the beltways around Columbus and Indianapolis, respectively, with the darker shading corresponding to areas of urban population density. In Columbus, when considering the direct route through the urban area, I-70, denoted on Figure 1 as 10 A, it is very evident from the map that using the northern beltway is much longer than using the southern beltway, denoted in the Figure 1 as 10 B. While the analysis shown in Table 5 compare the most direct route on I-70 to both the northern and southern routes on I-270, unless the shorter southern beltway is shown to be unfavorable, the longer northern beltway would probably never be considered. The same situation exists for Indianapolis, shown in Figure 2. In both cases, the northern route is the longest. Also, in both cases, the distance traveled through urban areas is greater for these northern routes; however, this may not always be the case, particularly when the lengths of the northern and southern routes are more similar. Thus, where there are two reasonable alternative routes, both should be evaluated, because the longer one might travel through mostly unpopulated areas and therefore represent a better candidate route based on security considerations.

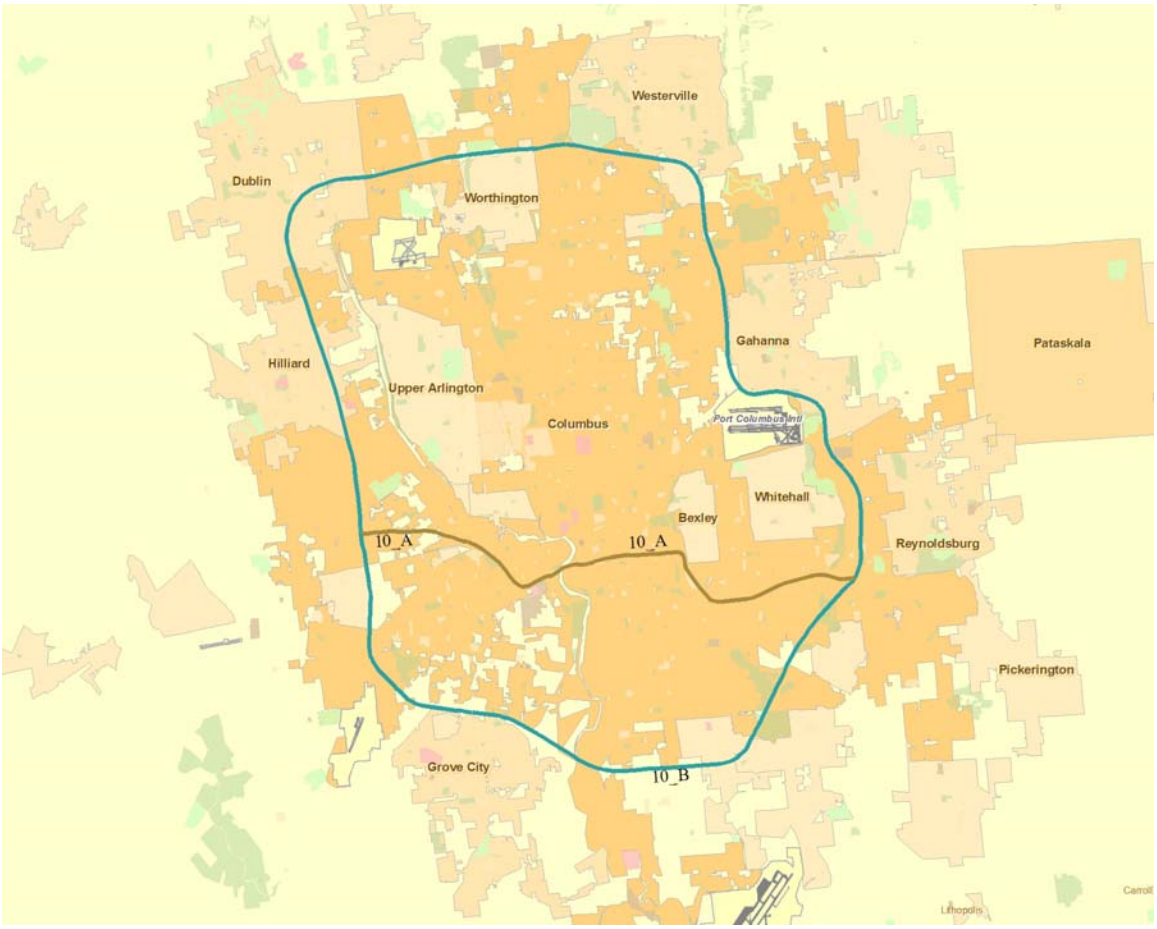

Figure 1. Possible Through Hazmat Routes for Columbus, OH

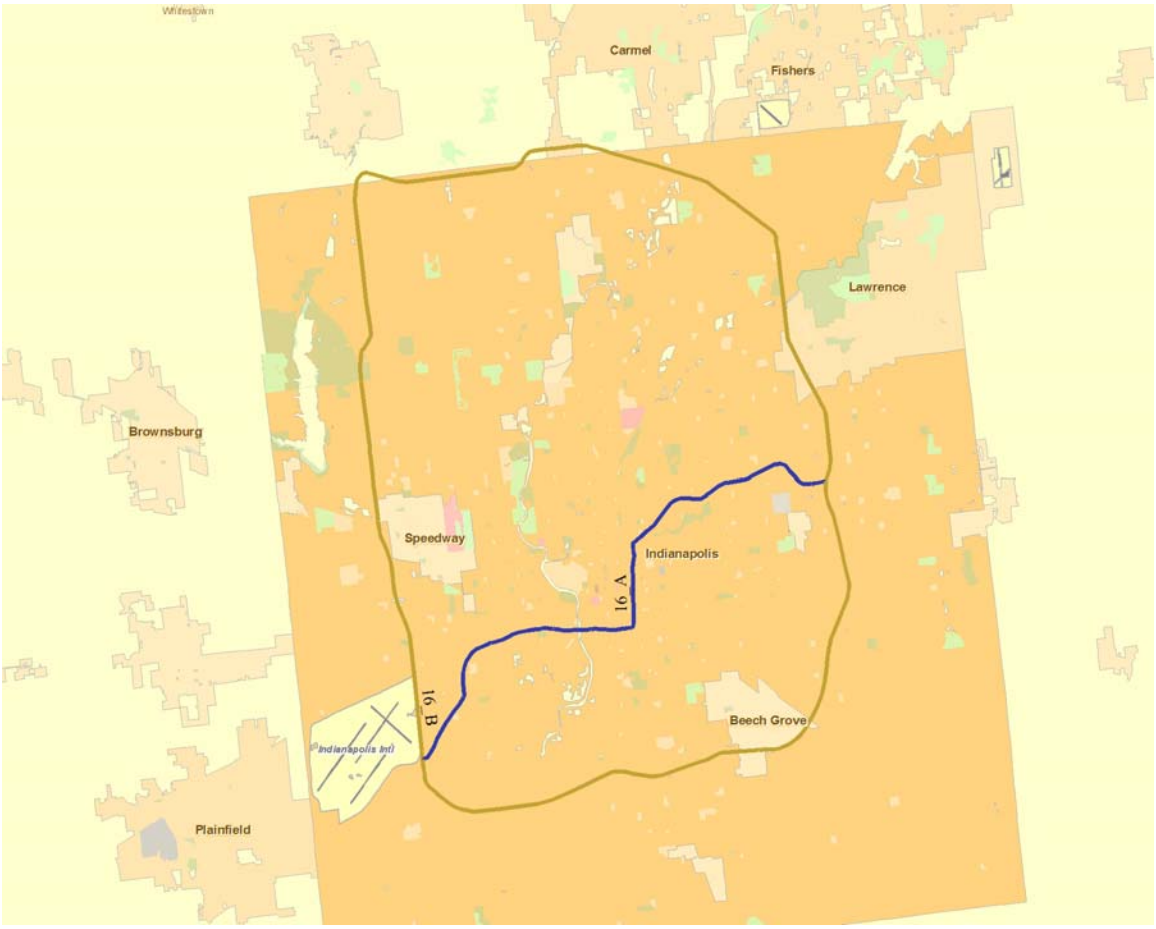

Figure 2. Possible Through Hazmat Routes for Indianapolis, IN

The shading in Figure 2 shows that both the direct route and the southern beltway are almost entirely in urban areas and the total length of both routes appear to be quite similar. This is a good example of cases where the beltway and the most direct through route have similar characteristics. The analysis results in Table 5 for Indianapolis shows that either route can be selected as the candidate route, as the differences are so small. The logic suggests that both be carried into the subsequent steps in the analysis. In this case, because the most direct route is likely to be in close proximity to several iconic structures, such as the state capitol and a major arena, one of the candidate routes, I-70, will probably fall out of the analysis as subsequent security features of the routes are evaluated.

Because both Colorado and California have designated hazmat routes in rural areas, a rural routing scenario in Colorado is shown in Table 5. Based on safety considerations, the I-141 route through the mountains was selected over the more heavily traveled US highways. Note that the security evaluation methodology was not developed to distinguish a route which is lightly traveled from one that is also rural but more heavily traveled. From a security perspective, staying on the more heavily traveled routes would provide greater security. Similarly, for Las Cruses, NM, the comparison is between a direct route that is not an interstate highway with a beltway that is an interstate highway. While the evaluation shows that the

beltway should be selected as the candidate route, there could be situations, such as Amarillo, TX, where the beltway is not built to interstate highway specifications, yet the analysis might show the beltway should be selected over the more direct through route, because no weighting has been used to distinguish routes built to interstate highway specifications from those that are not.

There is no clear dividing line between urban and regional analyses in Table 5. As the urban areas increase in size, the setting begins to resemble a regional analysis. The analysis of possible routes in Denver shows that even in a large urban area, there are sometimes bypasses with highly favorable characteristics. In this instance, State toll road SR-470 bypasses the entire Denver urban area.

Baltimore also shows an interesting characteristic that could be encountered when identifying candidate routes. The possible interstate routes for through traffic are shown in Figure 3.

Figure 3. Possible Through HM Routes for Baltimore, MD

The shortest route through Baltimore is I-95 and the shortest arc around Baltimore is I-695 on the eastern side of the city. The portion of I-695 around the western side of Baltimore is the longest of the routes shown. The population criteria are not distinguishable among the routes. If the ratios were reversed, the route with the most favorable characteristics would be the direct route through the city. The most direct route uses the Fort McHenry Tunnel and the portion of I-695 around the eastern side of Baltimore uses the Francis Scott Key Bridge. Since the distance traveled through urban areas is not a discerning factor, it is suggested that all three alternatives be designated as candidate routes. It is highly likely that the tunnel and bridge routes will subsequently be eliminated or restricted based on iconic structure (critical infrastructure) considerations.

The final part of the Table 5 describes several routes that are clearly regional. The one in Northern New Jersey considers the I-80 and I-95 route between New Jersey and Connecticut using the George Washington Bridge, and the I-287/I-87 route that bypasses much of New York City and uses the Tappan Zee Bridge over the Hudson River. The bypass is designated as the candidate route and, while both bridges might be on the critical infrastructure list, one or the other must be used. Since the Tappan Zee Bridge can be used to bring hazardous materials into New York City, it is likely that a state routing official, when considering security, would also select the I-287/I-87 route as the candidate route between New Jersey and Connecticut.

The routes in California, one in Oakland, one in San Francisco and two in Los Angeles, are situated almost entirely within urban areas. The two Los Angeles routes shown in Figure 4 are I-5 and US-101, both built to interstate highway specifications. Because the differences in route length and population density are small, both should be considered as candidate routes for the next step in the analysis process.

Figure 4. Los Angeles, CA Routes

The second Los Angeles routing evaluation compares the eastern route, I-210 and I-605, to the I-5 corridor. As shown in Table 5, since both routes are almost entirely in urban areas, if one candidate route were to be selected, it would be the shorter I-5 route. Once again, however, proximity to iconic structures might provide a basis for selection of a prescribed route. For this reason, it is suggested that all be carried into the second screening phase as candidate routes.

The analysis summarized in Table 5 shows that the proposed security evaluation using distance through urban population zones is capable of discriminating between the most direct route and proposed less direct alternative routes. In the case of Columbus, the beltway meets the security criteria. It is already prescribed as a hazmat route based on the safety regulations so in this case, there is no conflict between the proposed security criteria and the existing safety criteria. In Indianapolis the situation is much less clear because the city has spread beyond the southern beltway and travel on both the direct route and the possible alternative southern route would not suggest making the southern route a prescribed hazmat route. Indeed, the State of Indiana has specified no prescribed routes for Indianapolis based on safety and based on the information in Table 5, the security criteria would not suggest identifying a prescribed hazmat route. In the security area, there is another consideration which is not discussed in these examples, the avoidance of iconic structures. In the proposed methodology, when the population based

security and/or safety criteria do not distinguish among routes, the methodology maintains both as candidate routes and uses the next security evaluation, discussed in Section 4.2, the relative distance from the routes to iconic structures, as a possible discriminator that will enable the State or Indian Tribe routing official to recommend a prescribed or restricted hazmat route for trucks.

Overall, the results in Table 5 show that the measures used in the proposed methodology is appropriate for identifying candidate security routes in urban areas. For regional areas, the results are somewhat mixed, consequently in many cases, multiple routes should be selected as candidates that are carried forward into the next step of the analysis.

Table 5. Analysis of Urban and Regional Routing Alternatives for Selected Settings

Urban or Regional Area	Rte x (Alt)	Rte y (Direct)	Rte x Urban (A)	Rte y Urban (B)	Rte x Total (C)	Rte y Total (D)	(B/A)	(C/D)	Selection
San Antonio, TX	I 410 SE section	I-35 through rte	2.50	7.40	25.8	21.8	2.96	1.18	Alternate route (beltway) selected as candidate route
Omaha, NE	I-680	I-80	4.18	9.04	42.11	36.65	2.16	1.15	Alternate route (beltway) selected as candidate route
Oklahoma City, OK	I-240 and I-44	I-40	8.47	1.67	20.33	17.08	0.20	1.19	Direct route has less urban distance than beltway, both retained as candidate routes for iconic structure evaluation
Oklahoma City, OK (switch direct and alternative route)	I-40	I-240 and I-44	1.67	8.47	17.08	20.33	5.06	0.84	This shows that by reversing the routes and selecting the most direct route as the alternative, it would be selected as the candidate route based on the selection criteria, rather than selecting it both will be carried into the iconic structure evaluation as candidate routes
Las Cruses, NM	I-25 and I-10	US-70 (not limited access)	3.30	4.40	16.87	9.10	1.33	1.85	I-25 and I-10 not selected because of urban mileage but might be selected because they are limited access highways, retain both as candidate routes
Columbus, OH	I-270 South	I-70	13.41	14.11	20.63	15.33	1.05	1.35	Based on criteria, the alternative can not be selected as a candidate security route so both should be retained as candidate security routes and carried into the iconic structure evaluation
Columbus, OH	I-270 North	I-70	26.81	14.11	34.59	15.33	0.53	2.26	Based on criteria, the alternative can not be selected as a candidate security route so both should be retained as candidate security routes and carried into the iconic structure evaluation
Western Colorado – Whitewater to Cortez	US 50, US 550 and US 160	SR 141 and US 491	5.53	0.00	206.14	194.99	0.00	1.06	This compares a deserted State route to US Highways - from a security standpoint designate the US highway as the candidate route - have not covered in logic diagrams
State of Delaware, north of Wilmington DE	I-495	I-95	6.25	10.05	10.81	10.41	1.61	1.04	I-495 selected as candidate route

Table 5. Analysis of Urban and Regional Routing Alternatives for Selected Settings (Continued)

Urban or Regional Area	Rte x (Alt)	Rte y (Direct)	Rte x Urban (A)	Rte y Urban (B)	Rte x Total (C)	Rte y Total (D)	(B/A)	(C/D)	Selection
Lubbock, TX	SR-289 North beltway (limited access)	US-62/82 (non-limited access highway	5.47	8.92	11.91	9.32	1.63	1.28	SR-289 selected as candidate route – selected as if US-62/82 were a limited access highway
Davenport, IA	I-280	I-74 and I-80	0.00	5.92	17.92	17.92	Inf	1.00	I-280 selected as candidate route
Phoenix, AZ	I-17 from x194 to x200	I-10 from x143 to x150	2.94	4.72	6.16	6.31	1.61	0.98	I-17 is selected as the candidate route
Indianapolis, IN	I-465 South and I-74	I-70	13.48	12.16	18.50	16.14	0.90	1.15	The beltway is entirely within the urban area, can not distinguish between the beltway and the direct route, choose both as a candidate routes to be carried into the iconic structure evaluation
Indianapolis, IN	I-465 North	I-70	24.60	12.16	34.87	16.14	0.49	2.16	A large portion of the north beltway is within urban areas such that it can not be selected as a candidate route. Both should therefore be carried into the iconic structure evaluation.
Oakland to Durban, CA	SR-24 and I-680E	I-580	26.13	20.42	29.81	23.92	0.78	1.25	Alternate route not selected as candidate route so both would be carried into the iconic structure evaluation.
Oakland to Durban, CA	I-580	SR-24 and I-680E	20.42	26.13	23.92	29.81	1.28	0.80	I-580 would be selected as a candidate route if the analyses were considered to be a regional analysis; otherwise both would be retained as candidate routes to be carried into the iconic structure evaluation.
San Francisco (Golden State NP) to Daly City	U-101 and I-280	SR-1 (surface street)	11.83	7.38	12.54	7.61	0.62	1.65	Surface street better meets population criteria, but considered less secure, comparison of different highway types not considered in logic diagrams

Table 5. Analysis of Urban and Regional Routing Alternatives for Selected Settings (Continued)

Urban or Regional Area	Rte x (Alt)	Rte y (Direct)	Rte x Urban (A)	Rte y Urban (B)	Rte x Total (C)	Rte y Total (D)	(B/A)	(C/D)	Selection
Los Angeles, CA	I-5 Sun Valley to Los Angeles	SR 170, US 101 and SR 10	18.63	18.04	18.63	18.04	0.97	1.03	Both routes are urban limited assess highways and since selection criteria are not met, both would be retained as candidate routes and carried into the iconic structure evaluation.
Los Angeles, CA (switch direct and alternate route)	SR 170, US 101 and SR 10	I-5 Sun Valley to Los Angeles	18.04	18.63	18.04	18.63	1.03	0.97	Both routes are urban limited assess highways and since selection criteria are not met, both would be retained as candidate routes and carried into the iconic structure evaluation.
Los Angeles, CA	I-410 and I-605	I-5 Sun Valley to Sante Fe Springs	47.37	34.79	52.34	37.23	0.73	1.41	Both routes are urban limited assess highways, the alternative actually has more urban miles and since selection criteria are not met, both would be retained as candidate routes and carried into the iconic structure evaluation.
Los Angeles, CA (switched route designation to see if direct route should be candidate)	I-5 Sun Valley to Sante Fe Springs	I-410 and I-605	34.79	47.37	37.23	52.34	1.36	0.71	Both routes are urban limited assess highways, the alternative actually has more urban miles and since selection criteria are not met, both would be retained as candidate routes and carried into the iconic structure evaluation.
Baltimore, MD	I 695 (Francis Scott Key Bridge)	I-95 (Ft McHenry Tunnel)	15.20	9.88	24.22	14.79	0.65	1.64	Both routes are urban and the alternative actually has more urban miles does not meet the selection criteria so both routes should be taken into the critical infrastructure/iconic structure evaluation
Baltimore, MD	I-695 West	I-95 (Ft McHenry Tunnel)	25.43	9.88	26.95	14.79	0.39	1.82	The alternative route has many more urban miles and thus does not meet the selection criteria so both routes should retained as candidate routes and taken into the critical infrastructure/iconic structure evaluation.
Baltimore, MD	I-695 West	I 695 (Francis Scott Key Bridge)	25.43	15.20	26.95	24.22	0.60	1.11	Both routes are urban, the alternative actually has more urban miles and since selection criteria are not met, both would be retained as candidate routes and carried into the critical infrastructure/iconic structure evaluation.

Table 5. Analysis of Urban and Regional Routing Alternatives for Selected Settings (Continued)

Urban or Regional Area	Rte x (Alt)	Rte y (Direct)	Rte x Urban (A)	Rte y Urban (B)	Rte x Total (C)	Rte y Total (D)	(B/A)	(C/D)	Selection
Baltimore, MD (switch I-695 West and I-95 - Ft McHenry Tunnel to show I-95 has lowest urban mileage)	I-95 (Ft McHenry Tunnel)	I-695 West	9.88	25.43	14.79	26.95	2.57	0.55	The most direct route is really the only route that meets the selection criteria. Rather than removing the others, all should be retained as candidate routes and taken into the critical infrastructure/iconic structure evaluation. In that evaluation one of the routes with critical infrastructure might be selected with the restriction that placarded vehicles be escorted.
Denver, CO	SR-470 East Branch (Toll)	I-25	0.10	11.00	46.8	33.8	110.00	1.38	SR-470, a limited access toll road, selected as candidate route
Parsippany, NY to Port Chester, NY	I-287/I-87 via the Tappan Zee Bridge	I-80 and I-95 via George Washington Bridge	12.40	29.00	56.40	51.60	2.34	1.09	I-287 selected as candidate - both might have critical infrastructure elements – major bridges over Hudson River – Tappan Zee Bridge designated HM route into NYC based on safety criteria and might be the prescribed regional route based on security as well.

4.2 Evaluation of Candidate Through Routes based on Proximity to Iconic Structures

This part of the analysis evaluates the candidate routes carried forward from analyses shown in Table 5 of Section 4.1 and first determines if there is any critical infrastructure on the candidate routes and then evaluates the proximity of the remaining candidate routes to iconic structures. Throughout the document, the term iconic structure has been used to include both iconic structures and critical infrastructure. In this part of the evaluation it is necessary to treat any critical infrastructure on the candidate routes separately from other critical infrastructure and iconic structures near the route. This is because, if the critical infrastructure on a particular route is treated as an iconic structure, the distance criteria used to evaluate the adequacy of the response will never be met.

If there are multiple candidate routes and only one has critical infrastructure, it is logical to flag the candidate route as requiring escorts and then continue with the assessment of any iconic structures, including other critical infrastructure, not on the candidate route.

The first application of the iconic structure evaluation is Columbus, OH. Figure 5 presents a map of Columbus, Ohio, showing the direct route, I-70, the southern bypass, I-270S and the Iconic Structures in downtown Columbus.

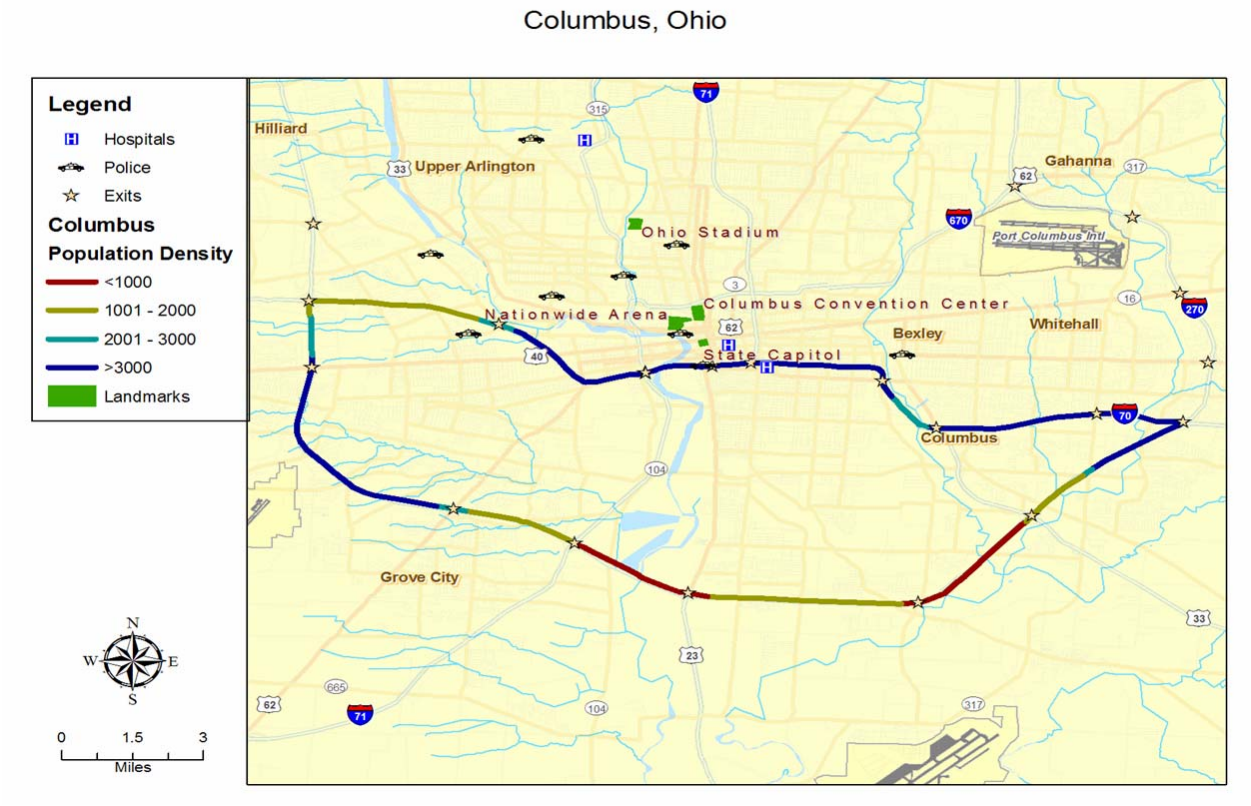

Figure 5. Map of Columbus Ohio Showing Routes and Iconic Structures

In Section 4.1, both the direct route, I-70 and the southern beltway, I-270 were retained as candidate routes. As a point of reference, Columbus already has a designated through hazmat route, the I-270 beltway that completely encircles the city. A map of the Columbus area showing the through route, the southern bypass route, and the iconic structures appears in Figure 5. The color codes clearly show that there are more sections of I-70 having high population densities than the beltway. The reason why the bypass could not be selected as the sole candidate route was because of the significant portions of the route that are classified as urban.

No critical infrastructure elements have been identified on the interstate highways in Columbus, Ohio. However, iconic structures have been identified in Columbus. The State Capitol and the Nationwide Arena are considered to be regional icons and the Convention Center is considered to be a local icon (see Figure 5). Although not shown in Figure 5, the Columbus Central Police Station is located equidistant from all three iconic structures, approximately 0.5 miles away. All three structures are located well away from I-270, so any security concerns related to through hazmat transport are easily met. However, local hazmat routing would take the hazmat vehicles much closer to all three iconic structures. Table 6 shows the results of the calculation for through hazmat transport on I-70, travel currently prohibited because the bypass highway has already been prescribed as the through hazmat transport route based on safety considerations.

Table 6. Security Evaluation of Iconic Structures for I-70 though Columbus

Icons	Symbol	State Capitol *Region*	Nationwide Arena *Region*	Convention Center *Local*
Distance from Prescribed Route (mi)	A	0.64	1.36	5
Icon Weight (C)	C	2	2	1
Weighted Distance	A/C	0.32	0.68	5
Distance from Police Facility (mi)	B	0.47	0.25	0.55
Response Effective?	B < A/C	No	Yes	Yes

It can be seen that the closest weighted distance (A/C) from I-70 to each of the iconic structures is greater than the distance from a law enforcement facility for all but the State Capitol. The analysis will now be continued for the other candidate route, I-270, the southern bypass. The results are shown in Table 7.

Table 7. Security Evaluation of Iconic Structures for I-270 around Columbus

Icons	Symbol	State Capitol *Region*	Nationwide Arena *Region*	Convention Center *Local*
Distance from Prescribed Route (mi)	A	6	7	7
Icon Weight (C)	C	2	2	1
Weighted Distance	A/C	3	3.5	7
Distance from Police Facility (mi)	B	0.47	0.25	0.55
Response Effective?	B < A/C	Yes	Yes	Yes

It can be seen that the closest weighted distance (A/C) from I-270 to each of the iconic structures is greater than the distance from a law enforcement facility for all three iconic structures. This from a security standpoint, the southern bypass, I-270 would be the prescribed through route using both safety and security considerations.

Figure 6 and Table 8 shows a map and iconic structure analysis for Baltimore, Maryland. Both I-95 and I-895 traverse the Baltimore Harbor in a tunnel. In Figure 6, I-895 is not highlighted it goes under the harbor near the same eastern location as the I-95 tunnel but goes southwest thereby avoiding the urban center of Baltimore, eventually rejoining I-95 in Elkridge, Maryland.

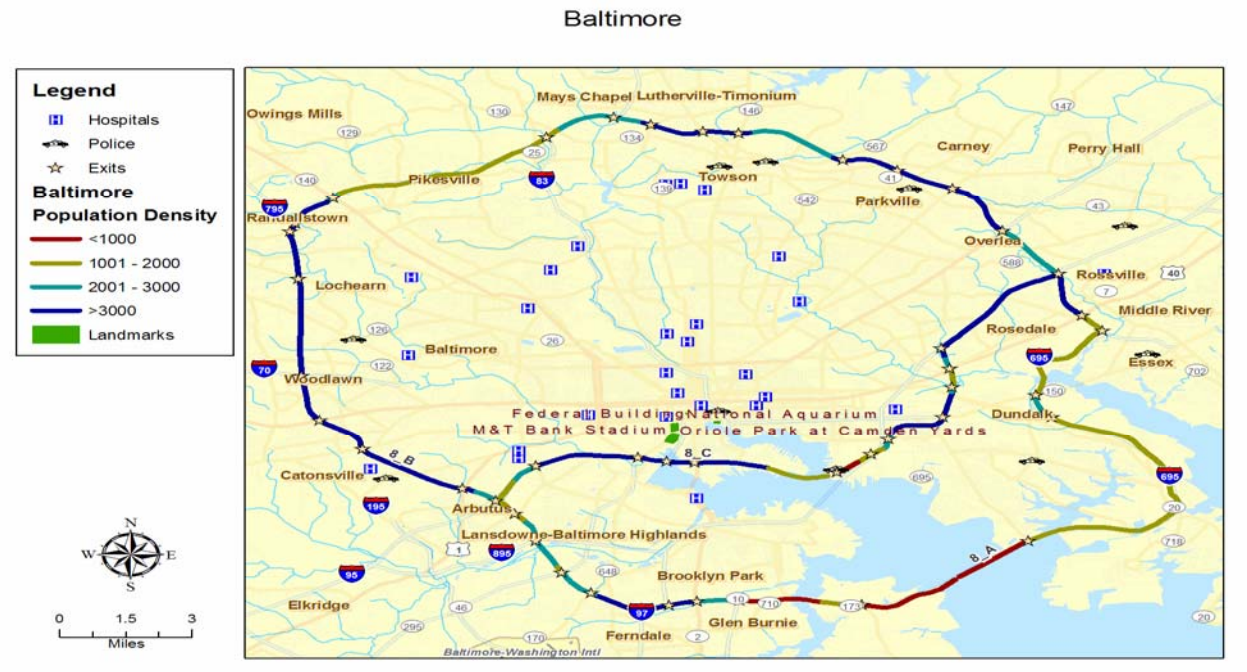

Figure 6. Route Map aid Iconic Structures for Baltimore, MD

Table 5 in Section 4.1 concluded that all the routes remained as candidate routes after the first security evaluation step. Regarding critical infrastructure, I-95 has the Fort McHenry Tunnel, I-895 has the Harbor Tunnel and I-695 south has the Francis Scot Key Bridge. Only I-695 on the north and west side of Baltimore does not have critical infrastructure elements. Thus, I-95, I-896 and I-695 must be flagged as requiring escorts if they are chosen after the iconic structure analyses as the prescribed route for through hazmat traffic in Baltimore.

Table 8. Iconic Structure Analysis for Interstate Routes in Baltimore

Iconic Structures	Federal Building	National Aquarium	Oriole Park at Camden Yard	M&T Bank Stadium	Meets Iconic Structure Distance Criterion
Distance from I-95 (A1)	1.74	1.72	0.98	0.66	
Distance from I-895 (A2)	4.71	4.34	4.55	3.81	
Distance from I-695S (A3)	5.51	5.81	5.36	4.21	
Distance from I-695W (A4)	5.9	6.21	5.74	4.61	
Attractiveness Scale (C)	2	2	2	2	
Police Station Distance (B)	0.64	0.25	1	1.44	
A1/C>B for I-95	Yes	Yes	No	No	No for I-95
A2/C>B for I-895	Yes	Yes	Yes	Yes	Yes for I-895[a]
A3/C>B for I-695S	Yes	Yes	Yes	Yes	Yes for I-695S[a]
A4/C>B for I-695W	Yes	Yes	Yes	Yes	Yes for I-695W

[a] This route has critical infrastructure so may require using escorts for HM that could damage structures

It can be seen from Table 8 that all the routes except I-95 meet the separation distance criterion between the routes and the four iconic structures being considered in this analysis. Thus the routing official would have the choice of selecting I-695W as the prescribed route for through hazmat traffic with no restrictions or picking either I-895 or I-695S as the prescribe route with the additional restriction that escorts be required for all placarded shipments or for just those shipments that could damage the critical infrastructure on those routes.

A similar analysis was also performed for Indianapolis, Indiana. The map is shown in Figure 7 and the results of the iconic structure evaluation are shown in Table 9.

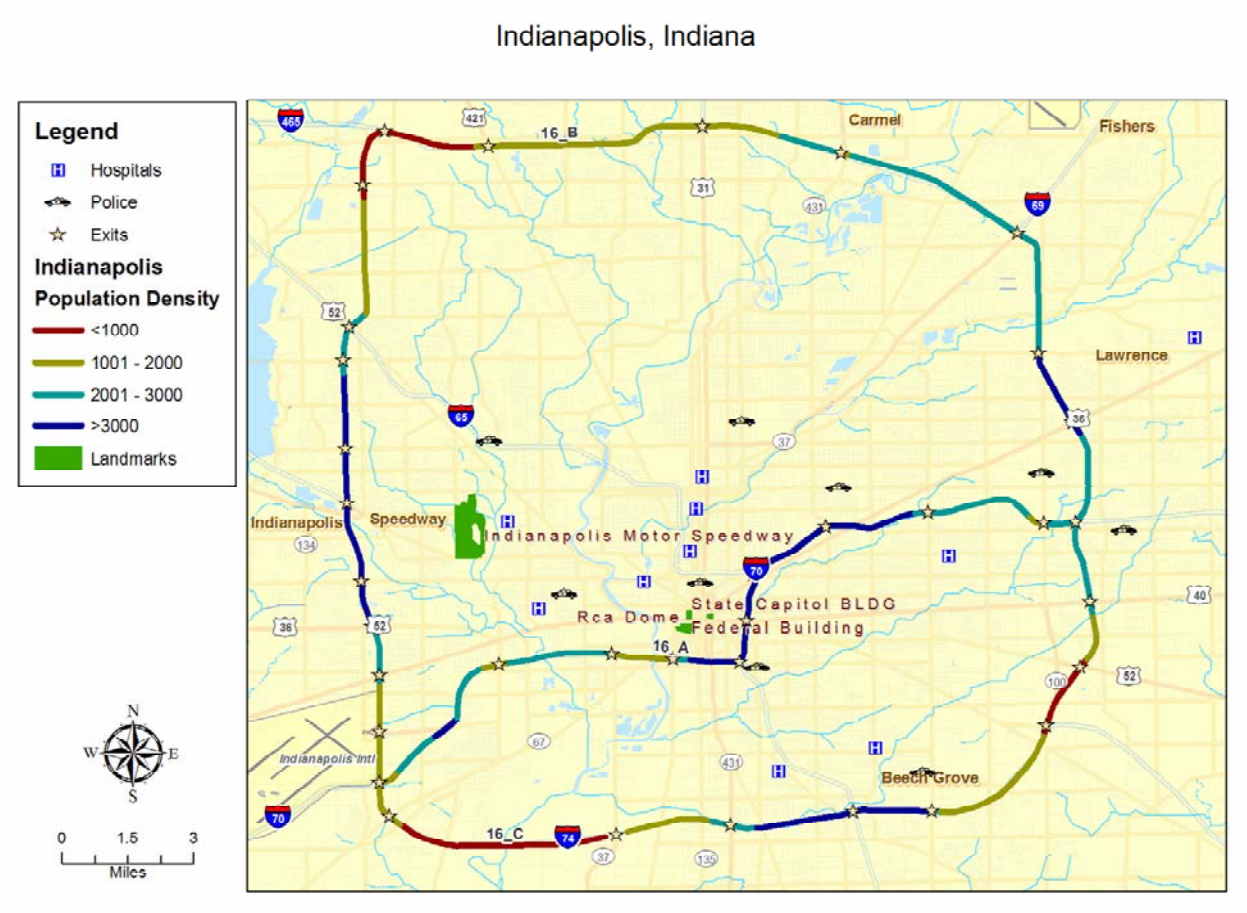

Figure 7. Map of Indianapolis, Indiana Showing Routes and Iconic Structures

Just as with the cases for Columbus, Ohio and Baltimore, Maryland, following the first security screening step, all the routes remained as candidate routes. In the case of Indianapolis, even the beltway had too much urban density along the route to meet the security criteria for being picked as the sole candidate route to be evaluated for iconic structures. Like Columbus, there are no critical infrastructures on the routes being evaluated in Indianapolis. The two routes are I-70 through downtown or I-465S/I-74 between the east and west junction with I-70. The results of the Iconic Structure evaluation are shown in Table 9.

Table 9. Iconic Structure Analysis for Interstate Routes in Indianapolis

Iconic Structures	Federal Building	State Capital	RCA Dome	INDY 500 Speedway	Meets Iconic Structure Distance Criterion
Distance from I-70 (A1)	0.67	1.02	0.73	7.17	
Distance from I-465 (A2)	6.2	6.32	6.03	7.17	
Attractiveness Scale (C)	2	2	2	2	
Police Station Distance (B)	0.85	0.8	1.09	2.006	
A1/C>B for I-70	No	No	No	Yes	No for I-70
A2/C>B for I-465	Yes	Yes	Yes	Yes	Yes for I-465

Based on the separation distance calculation shown in Table 9, of the two candidate routes, I-465S/I-74 meets the Iconic Structure separation distance criterion and therefore could be selected as the prescribed through hazmat route based on security criteria.

4.3 Evaluation of Local Hazmat Routes based on Security

The through hazmat iconic structure tables, Tables 6 through 9 can all be used to evaluate the security of local hazmat travel. If the routes are acceptable for through hazmat traffic, they are certainly acceptable for local hazmat traffic. The only question arises when the iconic structure criteria are not met for the routes. In that case, additional routes may have to be considered. Looking at the situation in Columbus, Ohio, I-70 is shown to be too close to the State Capital in Table 6. The first consideration would be to restrict travel on I-70 on the portion of the route shared with I-71. For the local analysis to be comprehensive, additional local analyzes would have to be performed for other limited access routes near the three icons considered in Table 6. If this were done, both Nationwide Arena and the Convention Center are adjacent to I-670 so that route would have to be blocked as well. If both the northern and southern parts of the inter beltway surrounding downtown Columbus must be blocked, then there is really no way for local hazmat traffic to freely traverse the city from west to east. Since the data in Table 6 show that hazmat travel on I-70 is considered too close to just the State Capital, a good compromise for local hazmat traffic would be to establish a hazmat restricted zone around the State Capital and allow local hazmat traffic on I-70 but restrict it on I-670 between SR-315 and I-71. If a quarter-mile hazmat-free zone was established around the Capitol, it would be approximately bounded on the north by Spring Street, on the west by the Scioto River, on the south by Main Street, and on the east by Grant Street. Within that zone, all hazmat travel would be restricted and any required hazmat transport other security measures would be considered that provide some level of monitoring of these shipments. It could be a GPS tracking system that alerts law enforcement personnel when a hazmat vehicle approaches the area containing the iconic structure. In some cases, for example Yellowstone Park, advance approval is required for a HM vehicle to use the main park roads and then only at specific times of the day. Some have proposed use of immobilizing devices such as required by the Nuclear Regulatory Commission for HRCQ shipments. The exact form of the security feature used is really at the discretion of the routing official. Since it must not pose an undue burden on commerce and any proposed measure will

have to be discussed with local representatives and affected parties, the exact nature of such measures will vary from one community to the next and is impossible to predict.

For local hazmat travel in Baltimore and Indianapolis, restricting local hazmat traffic on the portion of I-95 between its juncture with I-895 would appear not to restrict local hazmat traffic. For Indianapolis, to restrict local hazmat traffic on I-70 between the eastern junction with I-465 and the west junction with I-74 might be too restrictive. The alternative would be to restrict just a downtown segment of I-70 between the northern and southern interchange with I-65, thereby permitting hazmat traffic to service locations near downtown from either the west or east. Basically, a local hazmat shipment originating on the western side of Indianapolis and ending on the eastern edge of downtown would be expected to use the I-695 beltway to I-70 on the east and then use the eastern portion of I-70, getting off before it joins with I-65 and turns south past the eastern side of downtown where most of the iconic structures are located.

4.4 Summary of Route Security Evaluations

This section has evaluated possible hazmat routes using two sets of security screening criteria. The first set of screening criteria evaluated the population near a route with the goal of selecting a candidate route that put fewer people at risk of exposure to a release of the hazardous material. These screening criteria are very similar to the screening criteria currently being used for prescribing a through hazmat route based on safety considerations. The only difference in the method is the replacement of population risk safety criteria with miles through an urban area representing security criteria. Analyses were performed for over a dozen routes with the results summarized in Table 5. The goal of the evaluation was to look at both some typical and atypical route conditions that might be encountered by a state routing official. The conclusion drawn from the security evaluation is that the beltway around the urban area should always be considered as a possible candidate route when performing the security evaluation. Such an evaluation would be consistent with the evaluations currently being performed to demonstrate the beltway as a designated hazmat route using safety considerations. Since many of these routes have already been prescribed at the through hazmat route based on safety considerations, for these cities the security designation simply gives added weight their current designation as a prescribed route. The analysis also shows that for some urban areas, particularly large urban areas, there is little difference between the most direct and alternative routes all have major route segments that must be considered to be urban. For these situations, the security methodology employees an additional screening step, the proximity of the routes to iconic structures.

The iconic structure evaluation was performed for three urban areas, Columbus, Ohio; Baltimore, Maryland; and Indianapolis, Indiana. The results of these evaluations are shown in Section 4.2. These evaluations basically show that even where a route can not be designated for through hazmat traffic based on population considerations, this second screening, their proximity to iconic structures, is frequently able to prescribe through hazmat routes. In all three of the cities evaluated, several candidate routes remained after the first population screening criteria were used and it all cases, by looking at their proximity to iconic structures, it was possible to discriminate among the routes and designate one or more alternatives as the prescribed through hazmat route. By looking at Baltimore, it was possible to look at critical infrastructure (a subset of iconic structures) on the routes since three of the four routes considered had major tunnels or

bridges. In this case, it was possible to show that one of the routes, the most direct route, was too close to iconic structures but that the other three were not. Two of the three had critical infrastructure. If the routing official decided to pick one of the routes with critical infrastructure as the prescribed route, the methodology proposes that some restrictions be imposed. Escorts are commonly used to address safety concerns for these structures and such a restriction would also address security concerns. In one case the damage would be accidental in the second, purposeful.

In summary, a comprehensive and workable security assessment methodology has been developed. The methodology is flexible enough to handle a wide variety of route characteristics and is able to identify situations where prescribing a route for security has significant benefits. All the information used in these evaluations can be obtained from GIS databases by individuals trained in their use. Most State routing officials would have access to these data and staff that is trained in the use of GIS databases. A web based application has been developed that implements the logic described in this section. While not intended to replace the decision maker, the methodology provides the decision maker with information that can be used to justify prescribing or restricting hazmat routes based on safety and security.

5.0 Conclusion

This hazmat routing project has seven objectives. The accomplishment of each objective resulted in the production of a product. The major project objectives are listed below.

1) To survey the existing and proposed hazmat routes in the United States
2) To determine if there are obstacles to hazmat truck traffic between the United States and either Canada or Mexico
3) To survey stakeholders to determine their positions and concerns on establishing hazmat routes for security reasons
4) To develop a guidance document that contains a methodology for selecting hazmat routes based on security criteria
5) To develop an internet based routing tool that provides routing officials with user friendly assistance in applying the methodology
6) To prepare potential requirements for security based hazmat routing
7) To conduct a preliminary benefit/cost analysis of the potential requirement

The project team has achieved all of the project objectives. An evaluation of each follows with conclusions relating to achieving each objective.

1) To survey the existing and proposed hazmat routes in the United States

   This labor intensive effort resulted in the production of a thorough and consistent update of the 2000 Federal Register listing. Officials in every state were contacted to survey existing and proposed hazmat routes. Officials in the western states were asked if they were aware of any Indian Tribes in their state who may have passed regulations. In Oregon and Idaho, Indian officials responsible for routing were contacted and their regulations were included in the state listings. Their responses were tabulated to produce and updated compilation. The updated compilation of hazmat routes can be used by Federal and state officials and carriers to identify hazmat routes for travel. Surprisingly, the majority of hazmat routes were designated before the safety based routing regulations were developed. Furthermore, despite the events of 9/11, relatively few new hazmat routes have been designated since 2001.

2) To determine if there are obstacles to hazmat truck traffic between the United States and either Canada or Mexico.

3) Commerce between the United States and Mexico and the United States and Canada is important to the economic health of all three nations. Achieving this objective was designed to show if there were any specific obstacles to trans-border truck movement between the United States and its neighbors to the north and south. Research to achieve this objective showed that restrictions to the free flow of hazmat existed predominantly between the United States and Canada. The major obstacles to cross border hazmat truck traffic are restrictions to hazmat travel on bridges between Ontario Canada and the United States. By careful routing, carriers hauling certain hazmat should be able to avoid

these chokepoints and select crossings with no restrictions on their hazmat cargo. With route planning hazmat cargo should move smoothly between the United States and Canada. There are also some "routing conflicts" at border crossings between the United States and Mexico. The only border restrictions for HM truck shipments along the Mexican border are in California. These restrictions apply to explosives, inhalation hazards and highway route controlled quantities of radioactive materials (HRCQ). All other HM may be shipped across any of the three border crossings between California and Mexico that allow commercial truck traffic. At the San Ysidro Border Crossing, although none of the HM classes are restricted on I-5 down to the border, commercial truck traffic is not permitted to cross the border.

4) To survey stakeholders to determine their positions and concerns on establishing hazmat routes for security

   The success of developing and implementing a requirement for hazmat routing using security criteria, or convincing carriers or state officials to use a security based routing methodology, is dependent on stakeholder input and buy-in. To achieve this objective, a survey of stakeholders concerning their feeling about the development of a potential requirement for applying security to hazmat routing was conducted. Responses to the stakeholder survey were mixed. In general, carriers were hesitant about taking on additional regulations requiring routing. State officials on the other hand, were far more willing to consider any potential regulation relating to establishing routes based on security criteria.

5) To develop guidance document that contains a methodology for selecting hazmat routes based on security criteria

   The development of a methodology for selecting a hazmat route based on security criteria is probably the most innovative part of the project. The methodology was designed to enable a routing official to employ the security related criteria of population, distance, the relative location of iconic structures (including icons and critical infrastructure) and the location of law enforcement personnel to select a route that would help protect the security of both the cargo and potential targets. Sufficient flexibility was built into the methodology to address a variety of situations that might be encountered by a routing official. These include the ability to perform route assessments for through transport of hazmat in a regional and urban setting and local hazmat in an urban setting. In addition, the methodology provides assistance for dealing with areas where hazmat cargos cannot be conveniently kept away from a potential target by recommending establishing restrictive zones. The Guidance Document provides the routing official with a step by step method to select hazmat routes with respect to safety and security criteria. As shown in Section 4, the methodology provides a comprehensive and workable security assessment methodology. It is flexible enough to handle a wide variety of route characteristics and is able to identify situations where prescribing a route for security has significant benefits. All the information used in these evaluations can be obtained from GIS databases by individuals trained in their use. Most State routing officials would have access to these data and staff that is trained in the use of GIS databases. The methodology is not intended to be completely prescriptive so as to replace the decision maker; instead, the methodology provides the decision maker with information that gives

good justification for prescribing or restricting hazmat routes based on security. The methodology can also provide information to the decision maker that would justify that no prescribed or restricted hazmat routes are necessary based on security considerations.

6) To develop an internet based routing tool that provides routing officials user friendly assistance in applying the methodology

   The routing tool complements the Guidance Document by providing a web based tool that enables the routing official to follow a clear set of steps that allow the methodology to be ore easily used. The tool provides interactive screens that move the user smoothly from step to step in the methodology and from screen to screen and facilitates applying security criteria to the selection of a route. Only those screens that meet the requirements of the user will be used to direct the routing official towards selection of the final route.

7) To prepare potential requirements for security based hazmat routing

   The potential security based routing requirement is included in Section 2.0 of this Final Report and provides FMCSA with a practicable potential requirement for implementing a process to select hazmat routes based on security criteria.

8) To conduct a preliminary benefit/cost analysis of the potential requirement.

   The preliminary benefit/cost analysis of the potential requirement is included in this Final Report. The preliminary analysis shows that if the potential requirement for security were adopted, the benefits from this adoption were unlikely to outweigh the costs.