DEVELOPMENT OF A WEB-BASED ROUTING TOOL FOR ROAD TRANSPORT OF HAZARDOUS MATERIALS

Dr. Thomas I. McSweeney
Battelle Memorial Institute

Dr. Arthur Greenberg
Battelle Memorial Institute

Mr. William A Quade
FMCSA, USDOT

Mr. James Simmons
FMCSA, USDOT

ABSTRACT

In 2007, the Federal Motor Carrier Safety Administration of the U. S. Department of Transportation funded a project to develop a Web-Based Hazmat Routing Tool to identify and select alternative routes for the transport of hazardous materials by truck. The current U. S. regulations provide procedures and criteria State and Indian Tribes routing authorities must follow to establish, maintain, and enforce NRHM routes. The goal of the project was to show the feasibility of developing a Web-Based Routing Tool that routing authorities or other organizations, including shippers, could use to compare routes and select a preferred route based on safety and security considerations. The tool was placed on a GIS platform that contains the routes, the population density along the routes, and, for the security assessment, the location of any iconic structures (national monuments or sports venues), and critical infrastructure (bridges and tunnels). The tool first evaluates the routes for safety using the route length, accident rate, and population density along the route. Security is evaluated by considering the distance traveled through urban areas defined has having a population greater than 3,000 people/mi^2 (1,158 people/km^2) and the distance from the routes to the iconic structures in comparison a weighted distance from police stations. Greater weights are given to structures with greater attractiveness. The paper describes the methodology in greater detail and shows how it can be used to compare and designate hazmat routes based on both safety and security considerations. The tool was used to provide data used in a report to Congress on hazardous material routing (Ref. 1).

BACKGROUND

The United States Department of Transportation (USDOT) has enacted regulations that specify the rules motor carriers must follow when designating hazardous material (HM) transport routes. Note that hazardous materials are designated as dangerous goods in the European Union and many other countries. The routing regulations are divided into subparts. Subpart D of 49 CFR 397 presents the routing requirements to be followed for shipping Highway Route Controlled Quantities (HRCQ) of Radioactive Material; Subpart C for Non-Radioactive Hazardous Materials (NRHM) and Subpart E authorizes the Federal Motor Carrier Safety Administration (FMCSA) to act as a judge when an affected party, person, organization, or company requests a preemption to prevent enactment of the HM routing designation. The remainder of this paper focuses on NRHM shipments (Subpart C). For NRHM shipments, the regulations specify that the carrier is expected to avoid tunnels, highly populated areas, areas where crowds accumulate, narrow streets or alleys, and tunnels unless specific conditions exist. The second part of the NRHM regulations, (49 CFR 397.71) specifies the standards state and Indian tribe routing authorities must follow when designating HM routes, the focus of this paper. The default route through a populated area is always the most direct route. An alternative route, even though it will be longer, can be selected if use of the route can be shown to enhance public safety. The regulations do not stipulate that only one alternative route be considered. The proposed security risk assessment that is added on to the regulatory based safety risk assessment permits a routing official to designate a route after considering both safety and security risk. The following sections describe the regulatory procedure that is used to designate routes based on safety, followed by a section that presents a procedure to add security considerations to the risk selection process.

Federal Standards for Selecting NRHM Routes

The regulations a State or Indian Tribe must follow to establish, maintain, or enforce routing designations for NRHM contain nine federal standards: (1) *Enhancement of Public Safety,* (2) *Public Participation,* (3) *Consultation with Others,* (4) *Through Routing,* (5) *Agreement with Other States,* (6) *Timeliness,* (7) *Reasonable Routes to Terminals and Other Facilities,* (8) *Responsibility for Local Compliance,* and (9) *Other Factors to Consider*. The first standard, *Enhancement of Public Safety*, is addressed by evaluating each of the routes being considered using the 13 factors listed under (9) *Other Factors to Consider*. They are: (i) *Population Density,* (ii) *Type of Highways,* (iii) *Types and Quantities of HM,* (iv) *Emergency Response Capabilities*, (v) *Results of Consultation with Others,* (iv) *Exposure and Other Risk Factors,* (vii) *Terrain Considerations,* (viii) *Continuity of Routes,* (ix) *Alternative Routes to the extent necessary,* (x) *Effects on Commerce,* (xi) *Traffic Delays,* (xii) *Climatic Conditions*, and (xiii) *Congestion and Accident History.* Of the nine standards, several focus on the process to be followed by the state and Indian tribe routing authority; factors like (2) *public participation* and (3) *consultation with others.* The 13 factors listed under (9) are to be uniformly quantified for the most direct and each alternative route, e.g., the *congestion and accident history* for each route in sufficient detail to identify any differences. A finding will then be made if these differences have an effect on public safety. Of the nine federal standards, there is one, (4) *Through Routing*, that has measurable criteria. The risk for the most direct through route is compared with the risk for all the alternative routes being considered. Here risk is defined as the product of the consequences of an accident times the likelihood of an accident. The likelihood of an accident is the accident rate times the length of the route. The guidelines book prepared to assist in complying with the routing regulation (Ref. 2), suggests estimating the consequences by selecting a hazard distance from the roadway and using the total number of people residing and working within that distance as a measure of the consequences for that roadway. The total number of people potentially affected for a route is then multiplied by the likelihood of an accident on that route to get a measure of the safety risk for the route. The (4) *Through Routing*, paragraph states that if risk of the most direct route is greater or equal to 1.5 times the risk an alternative route then the alternative route becomes the prescribed HM route. The (4) *Through Routing* regulation further states that if the risk of the most direct route is between 1.0 and 1.5 times the risk of an alternative route, then the alternative route becomes the prescribed route if the distance traveled on the alternative route is not more than 25 percent longer or greater than 25 miles (40.2 kilometers) longer.

The requirements under *(1) Enhancement of Public Safety* refer to *(9) Other Factors to Consider*, thus the routing official must also consider the 13 additional factors under (9) before making any decision. If there are no significant differences among routes based on the 13 criteria, then the routing official, after consulting with other affected parties, could designate a hazmat route and base the decision on the (4) *Through Routing* analysis results. There is enough flexibility in the regulations to allow the routing official to also consider security before making the final routing decision. The following section shows how security considerations can be integrated into the current safety based routing regulations.

Selecting NRHM Routes Based on Security Considerations

No routing regulations have been specified for addressing security concerns. However, some surrogates have been proposed and evaluated here. One is the total distance traveled in urban populated areas, defined as areas having more than 3,000 people per square mile (1,158 people per square kilometer). The rational is that a lesser distance traveled through urban areas enhances security. The total distance through urban areas for the most direct route is divided by the total distance through urban areas for the alternative route; if the ratio is greater than 1.5, the alternative is also prescribed based on security considerations. If the ratio is between 1 and 1.5, the alternative is still prescribed for security if the distance traveled on the alternative route is not more than 25 percent longer or 25 miles (40.2 kilometers) longer.

A second security measure to be evaluated relates to the proximity of the routes to iconic targets, which are structures of national, regional, or local significance. They include structures of historic significance, government buildings, sports stadiums, major museums, convention centers, and symphony halls. To have adequate protection from the security perspective, the distance from the iconic structure to the closest police station must be greater than the distance from the iconic structure to the point of exit from the hazmat route divided by a significance factor of 3 for icons of national significance, 2 for icons of regional significance and 1 for icons of local significance. Thus, if the police station is 4 miles from the iconic structure and the distance from the closest exit on the hazmat route is 10 miles, the iconic structure is not adequately protected only if it is an icon of national significance, 10/3 is not greater than 4, but 10/2 and 10/1 both are greater than 4.

The final security measure relates to critical infrastructure. Note that in some cases, critical infrastructure would be classified as an icon. For example, a bridge or a dam may be so designated. If there is a structure on a route whose destruction would pose a major economic hardship on the region, the route having such a structure would require additional safeguards. If the route could be avoided and does not pose an undue hardship on commerce then the routing official may choose identify the types of hazardous materials that could damage the structure and either restrict their travel of those shipments or require escorts.

Web-Based Routing Tool

Almost all the data required to designate routes based on the existing routing criteria for safety and the proposed routing criteria for security are available as layers in a GIS. Thus to develop the web-based routing tool, the process began by identifying the layers needed to evaluate the criteria and then moving them from existing GIS's to the GIS that will be part of the routing tool. The only dataset that could not be transferred or developed was the truck serious accident rate data. It simply does not exist. However all the components exist so it can be estimated once the routes have been selected. The following sections will show the results using the web-based routing tool.

EXAMPLE APPLICATIONS OF THE WEB-BASED ROUTING TOOL

The first example is Columbus Ohio. The map of the selected HM routes is shown in Figure 1.

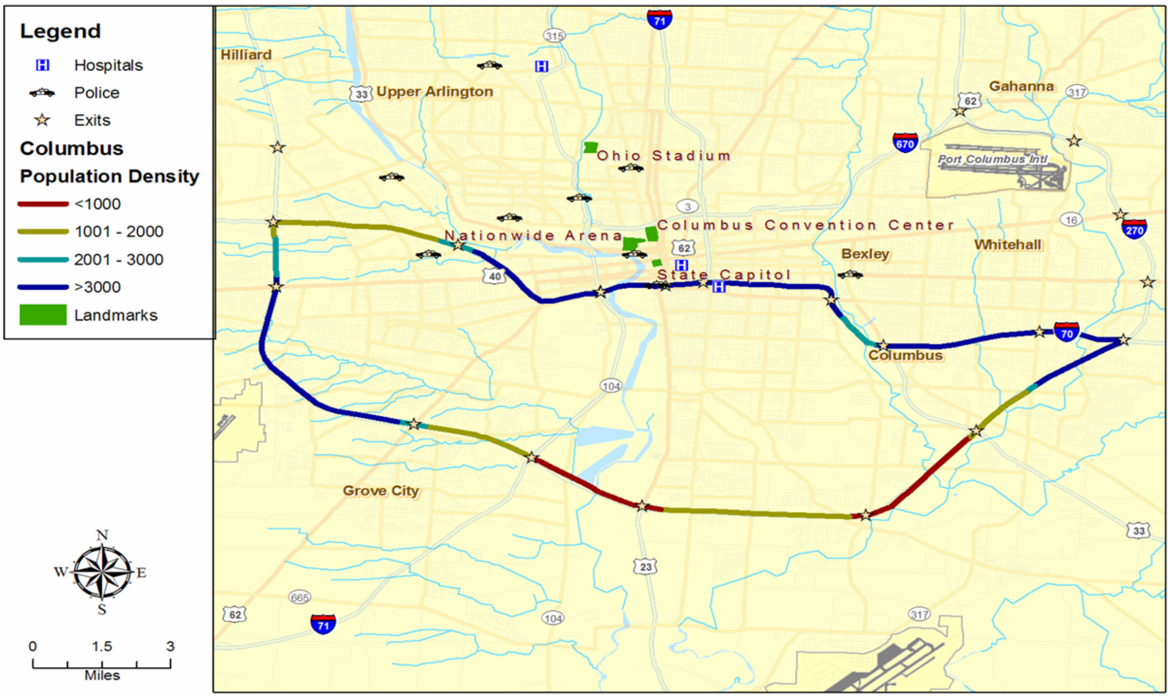

Figure 1. Map of Columbus Ohio Showing Routes and Iconic Structures

Columbus is an urban area of slightly more than a million people; it has two major interstate highways, Interstate 70 and 71, passing through the urban center and a beltway around the city, Interstate 270. The beltway has been designated as the hazmat route for through shipments. Figure 1 shows the map displayed by the routing tool after Interstate 70 through Columbus and the southern portion of the Interstate 270 bypass were selected for analysis. The map displays the population density on the routes by shading the road based on adjacent population density, beginning with less than 1000 people/mi^2 (386 people/km^2) and continuing in increments of a 1000, the last being more than 3000 people/mi^2. The shading shows there are more people within a half mile (0.8 km) the through route, I-70.

The safety risk part of the analysis is not completely automated. Accident rates for the various route segments are not available as a layer in the GIS and must be calculated in a side calculation and then entered. Table 1 shows the data used to estimate the truck accident rate. The second column, AADTT is the average annual daily truck traffic is available as a GIS layer as is the route distance shown in column 3. The total number of serious truck accidents was obtained from a query of the Motor Carrier Management Information System (MCMIS) Crash database maintained by FMCSA. With this missing piece of information, the accident rate was calculated for both routes being evaluated.

Table 1. Columbus Safety Risk Calculation for Through Route (I-70) and Southern Bypass (I-270S)

Route	AADTT	Distance (miles)	Total Serious Truck Accidents (4 Years)	Truck Accident Rate/mile
I-270S	12,334	20	37	1.03E-07
I-70	14,498	15	104	3.28E-07

The truck accident rate is calculated by taking the total number of accidents, dividing by the distance, the AADTT value, and then 1457, the number of days in 4 years.

Figure 2 shows the screen capture of the safety risk calculation using the web-based routing tool. The accident rate, shown is the accident rate times 10 million, was the only hand-entered data. Not shown is the consequence measure, the total number, or people residing within a ½ mile (0.8 km) of the route obtained from the census data contained in the GIS. The calculation shows that I-270 meets criteria for being designated as a HM route based on safety considerations. It is shown as a prescribed route until the all the security factors have been evaluated. The safety risk is the product of the accident rate times the total population times the route distance. It can be seen that the safety risk ratio, obtained by dividing the risk for the through route (I-70) by that of the bypass route (I-270) is greater than 4. This is well above the 1.5 risk ratio stipulated in the regulations so based on safety, the bypass route should be the recommended for through hazmat traffic. In this calculation it will be considered the prescribed route pending the security evaluations.

The security risk calculation can be developed entirely from the data in the GIS because accident rate is not considered. The first measure is the ratio of the total number of urban miles (defined as the miles with a population density of greater than 3,000 people/mi^2 (1156 people/km^2) on each route.

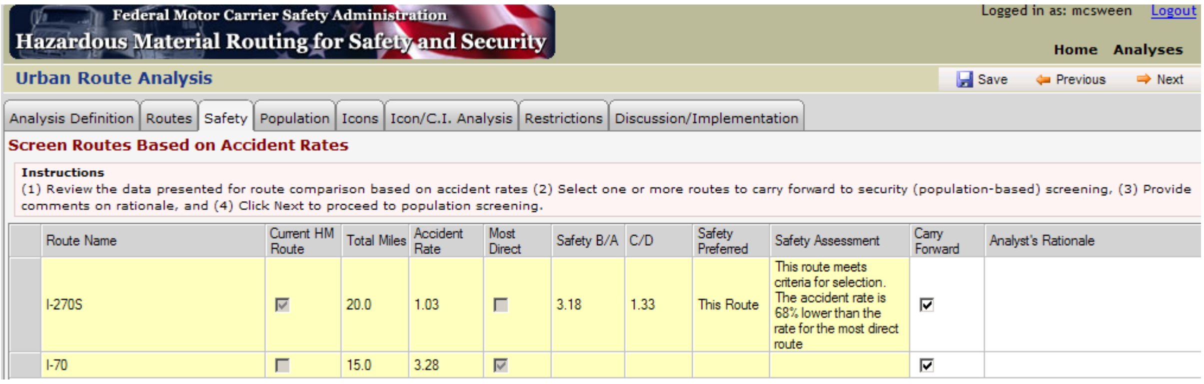

Figure 2. Screen clipping of the Safety Tab in the Web-Based Routing Tool for Columbus, Ohio

As shown in Figure 3, there are 9 miles of the 15 miles on the through route that are considered urban, having a population density adjacent to the route of more than 3000 people/mi^2 (1156 people/km^2) and only 3 of the 20 miles on the bypass route that are considered urban. The urban mileage ratio B/A is

3.0, which is greater than the 1.5 criteria proposed for making it a prescribed route using security concerns and therefore the bypass has been identified as a prescribed route for both safety and the first of the security criteria. They are carried forward to allow additional security measures to be evaluated.

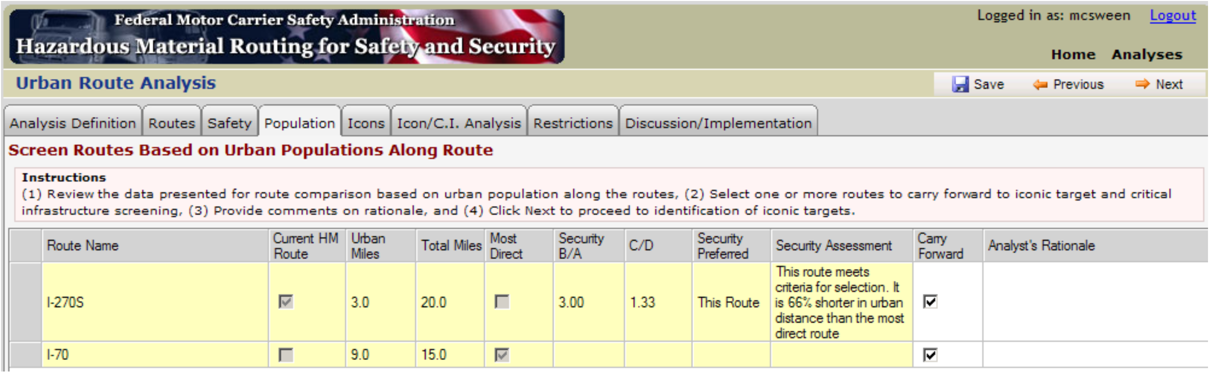

Figure 3. Screen Capture of the Security-Based Risk Calculation for Columbus, Ohio

The second security measure is based on the proximity to iconic structures. Figure 4 shows the screen clipping for the determination of effective response distances. The three iconic structures considered are the State Capital buildings, the Nationwide Arena where the Columbus Bluejackets Team of the National Hockey League plays, and the Columbus Convention Center.

The State Capital and the Nationwide Arena are designated as Regional Iconic Structures and the Convention Center as a Local Iconic Structure. The first two are given an iconic weight of 2, the last an iconic weight of 1. The proximity of the police station to the facilities was determined and once that distance was specified, it was possible to determine the distance from I-70 to each of the Iconic Structures, divide by the Icon Weight, and then divide by the distance to the closest police station. Only the buildings associated with the State Capital do not meet this security criteria. Figure 4 show that the bypass is far enough from the iconic structures to meet the security criteria. Since the southern bypass meets the safety and security criteria the results justify that the route currently designated as the HM route based on safety considerations would still be designated as a HM route after considering the security criteria.

It should also be pointed out that the evaluation shown above is just for through hazmat traffic. The iconic structure analysis could easily be applied to local hazmat traffic, traffic whose origin and or destination is within the Columbus outerbelt (I-270). Local hazmat traffic is currently allowed in I-70 which passes close by the State Capital Buildings. This calculation could be used as a basis for restricting some classes of hazmat traffic from using I-70. The restrictions might be applied to those classes that could do significant damage to the iconic structures.

The second example considers Baltimore, Maryland and only the iconic structure analysis is shown. The route map is shown in Figure 5 and the results of the analysis in Table 2.

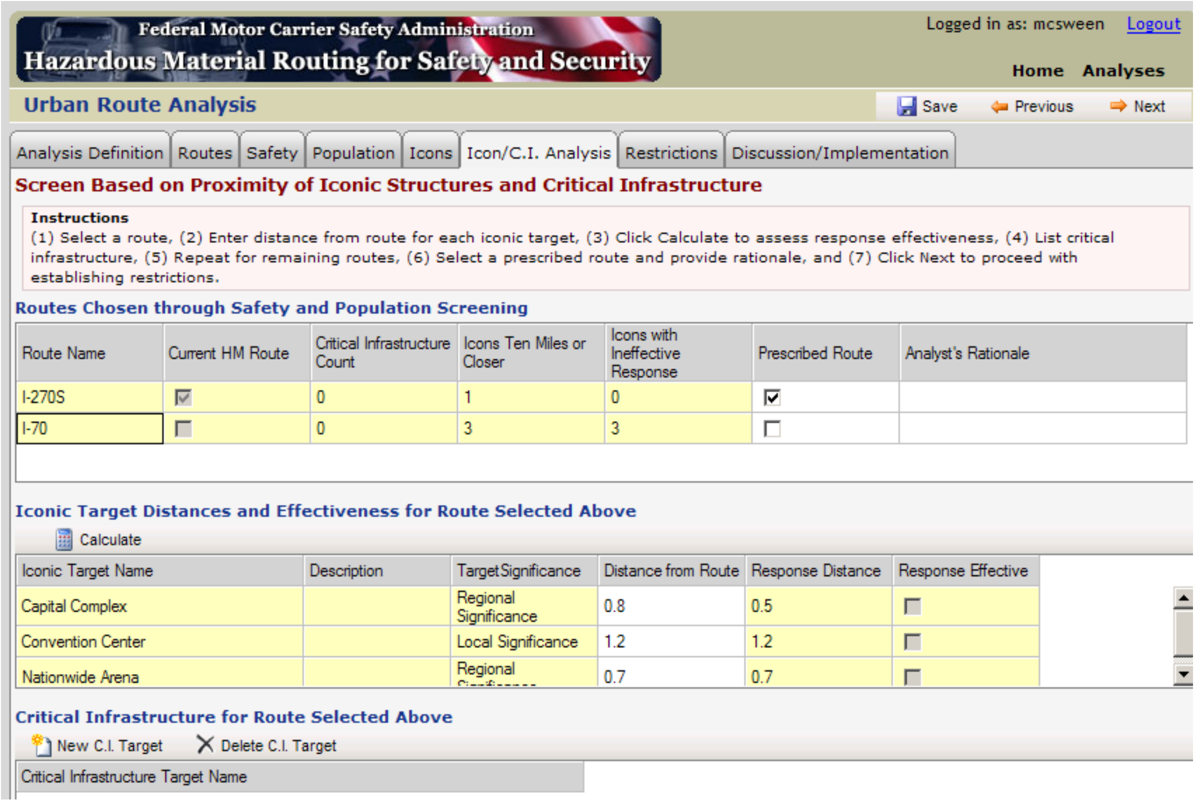

Figure 4. Analysis of Security for Iconic Structures for Columbus Ohio

Figure 5. Route Map aid Iconic Structures for Baltimore. Maryland

Table 2. Iconic Structure Analysis for Interstate Routes in Baltimore

Route	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 structure

Baltimore has an additional feature that is not present in the Columbus analysis. Three of the routes have 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 could be flagged as requiring escorts for some classes of hazardous materials if they are chosen after the iconic structure analyses as the prescribed route for through hazmat traffic in Baltimore.

Similar calculations were performed for several other urban areas to demonstrate that the methodology could be applied equally well to other urban areas.

SUMMARY

This paper demonstrates that it is possible to address both security and safety concerns when selecting hazmat routes. In addition, it demonstrates that it is possible to develop a web-based routing tool that contains the parameters needed address the safety and security routing criteria a routing official must use to designate a HM route.

The advantage of the web-based tool is that anyone given a username and password could use the tool. Since the GIS based network is maintained at a central location, the user need not have to maintain the network nor be an expert in using a GIS. A State, Indian Tribe routing officials, carriers, or even an interested citizen could request a username and password and begin to address the safety and security concerns of the people along HM routes.

The examples described above use three security criteria to evaluate routes. These are not regulatory-based criteria as is the case with the safety criteria. It would be expected that as more and more organizations attempt to balance safety and security when selecting HM routes, these organizations may suggest other security criteria that would better suit their region. It is through this iterative process that the criteria will be developed and may eventually be introduced by FMCSA as a proposed regulatory requirement when selecting HM routes. No decision in this regard has been made by FMCSA. It must also be pointed out that the results shown here focus on one of the major criteria for HM route selection, (4) Through Routing. There are other factors, 13 are listed under *(9) Other Factors to Consider,* that must be evaluated that are not part of the web-based routing tool and must be analyzed by a routing official.

At the present time the national system is under development. There are only a few urban areas where the key information necessary to address safety and security concerns has been entered into the GIS. About 25 percent of the states and a few Indian Tribes have designated HM routes and or restrictions to the use of selected routes and while aware of this information, it has not been entered as a GIS layer that would be directly accessible to a user. The user currently has to go to an Excel file published and downloadable from the FMCSA website to obtain the information.

The important things to take away from this paper is that information to simultaneously address safety and security concerns is available and has been collected for several major urban areas in the United States. The use of a web-based routing tool could certainly be adapted for use with the dangerous goods regulations in other countries. Much of the information, such as the population census information, the truck average annual daily traffic data by route segment and the road way characteristics by route segment have already been placed on layers in the GIS and are directly accessible. Much of the remaining information as found on websites, which could easily be geo-located and placed in the GIS. The accident data is available from the FMCSA's Motor Carrier Management Information System (MCMIS) Crash file and while it is not currently possible to geo-locate the crashes, it is possible to identify the route and county where the crashes occurred and thereby relate an average AADT for trucks for that route to the crashes and obtain a truck accident rate. For the urban areas where the routing tool has been applied, about half the parameters required to address safety and security risk are automatically populated when the route is selected. Additional developments would make it possible to populate all the required data fields when a route is selected for analysis. This is our goal and this paper demonstrates that the goal is obtainable.

REFERENCES

(1) *The Hazardous Materials Highway Routing Route Plan Guidance – Report to Congress pursuant to Section 1553(a) of the Implementing Recommendations of the 9/11 Commission Act of 2007, Public Law 110-53,* Federal Motor Carrier Safety Administration, U. S. Department of Transportation, Washington DC, March 2009.

(2) National Highway Institute, *Highway Routing of Hazardous Materials, Guidelines for Applying Criteria*, FHWA-HI-97-003, Federal Highway Administration, U. S. Department of Transportation, Washington, DC, November 1996.