City of Boston Hazmat Route Evaluation Report Review

Final

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Prepared for

Massachusetts Motor Transportation Association

by

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Executive Summary

This report documents a review of the *City of Boston Hazmat Route Evaluation* report (Boston Report) prepared for the City of Boston by Battelle to support the establishment of new routing requirements for the transportation of hazardous materials (hazmat). The new hazmat routing was necessitated by the Central Artery Tunnel. The Boston Report was commissioned in response to a preemption ruling by the Federal Motor Carrier Safety Administration (FMCSA) that overturned the changes implemented by the City of Boston following the Central Artery Tunnel construction.

The review examines the Boston Report from two perspectives. The first is a review of the conceptual approach and general adherence to the federal regulations and guidance, followed by a more detailed technical review of the implementation of the methodology by Battelle. Findings from the review are summarized and lead to a number of recommendations.

After a thorough assessment of the Boston Report and the methods and data utilized to form conclusions, several key issues were found. In addition, a variety of cases in which there were irreproducible results were evident. The following issues should be addressed before decisions concerning hazmat route designations are finalized.

Key Findings

- The Boston Report does <u>not</u> evaluate the legally designated hazmat route currently in effect. This is a critical procedural error given that any analysis performed under 49 CFR 397.71 must evaluate the relative safety of any alternatives as compared to the current routing (49 CFR 397.71 (9)(ix)).

- The Boston Report lacks discussion of the specific hazmat movements that are under consideration before the alternative selection process is described. The specific origins and destinations used to define the route alternatives are selected without description of the rationale for why they were chosen. Therefore, we must assume they were chosen arbitrarily or out of analytical convenience. Further, the Boston Report does not consider sufficient origin-destination pairs to evaluate the selection of through routes. One analysis endpoint, for example, is more suitable for routing to or from local establishments than through routing.

- The Boston Report only considers Class 3 flammable liquids, suggesting that all other US DOT hazard classes of products would result in identical routing analysis results. Based on the report, these materials only account for 50 percent of the hazardous materials accidents that occur in the area. From the sources cited in the Boston Report, shipments involving Classes 2, 3, 8, and 9 materials are moving regularly within the Boston region. Based on the high degree of variability for exposure distances among US DOT hazard classes, a "one size fits all" conclusion cannot be assumed. As such, a formal analytical validation is required. US DOT regulations require that consideration be "given to the relative impact zone and risks of <u>each</u> type and quantity … of NRHM normally transported along highway routes which are included in a proposed NRHM routing designation."

- It is not clear why a ½-mile impact range was selected, given the discussion in the Boston Report about the remoteness of an impact from a release of a flammable liquid extending to ½ mile.

The report indicates that the likely impacts from a release would mostly affect the occupants of other vehicles on the road. If this is the case, then a much narrower impact area would be appropriate. The guidance document, *Hazardous Materials Routing Using Safety and Security Criteria,* March 19, 2008, Battelle provides two potentially appropriate impact ranges for flammable liquids: 50 meters and 100 meters, both of which are less than 0.1-mile. If the extreme ½-mile case were appropriate for use, it would still require the use of a probability-based component to reflect the remote likelihood of a release given an accident.

- The study utilized TAZ boundaries to facilitate the estimation of residential and employment population along a route; it is not clear why the readily available and more granular Census block boundaries were not used instead. Given the large size of the TAZ areas, there is greater potential to have instances of both over- and under-estimates of population as compared to the use of Census block areas. Because the Boston Report utilizes population exposure as the only quantified consequence metric in the risk formula, any changes in how population is estimated would have an effect on segment-based risk values and thus on the cumulative route risk values. Utilizing Census block areas with population data sourced from either CTPS, Census Bureau, or HAZUS-MH data would help to mitigate these issues and provide a significantly more accurate assessment of risk.

- Reviewing the data included or cited in the Boston Report, we identified errors in the results of consequence estimates for population and environment exposure. For example,

    - Examination of specific routes uncovered some apparent population-related calculation errors.
    - Information presented about the acreage of environmental exposure along a route indicates that there are problems with underlying exposure calculations.

Other Findings

- Security issues are not addressed in any way even though the Boston Report analysts were the authors of the most recent federal hazmat routing guidance document, which was specifically written to incorporate security components into the safety-based approach. Instead, the Boston Report relies on a pre-9/11 document from 1996.

- The Boston Report does not consider any low-probability, high-consequence events, even to address why they were not included. For example, a release from a cargo tank carrying anhydrous ammonia.

- The study utilized a very conservative approach and did not consider a release probability component in the risk evaluation. Conditional release probabilities can be appropriate to reflect different impact velocities (which can be tied to roadway functional classification) and container integrity (only useful if multiple commodity types are considered). For example, the BLEVE assessment in the Boston Report utilizes a rail car, not a cargo tank, which presents very different protections against a BLEVE. The 1996 Route Guidance (p. 19) discusses the potential use of conditional release probabilities.

- The Boston Report was remiss in not presenting information related to a route's average accident rate and accident expectancy. While these factors can be derived from the information provided in the report, one would need subject matter expertise to be able to do so. Based on the findings of the Boston Report, the recommended route (RA3) has an accident expectancy double that of the through-route alternative. Acceptance of the recommended route implies a willingness to accept twice as many accidents occurring due to increased speed and trip distance.

- There is an inconsistency in the Battelle Report between the text and Table 1 showing the accident rates. The calculations are likely correct but the text is incorrect and that should be verified.

- The Boston Report clearly highlights the difference in preparedness between the response capability in the City of Boston and the rest of the region. Boston-based response units can respond within 5 to 10 minutes; whereas, getting an operational team on-scene in other areas can take up to 30-60 minutes. Even at this conservative estimate, this is a significant difference. In locations where significant congestion might occur, the ability for adequate response to arrive on the scene of an accident would further increase these times. The 1996 Routing Guide instructs analysts to use a 10-minute response time to determine adequate emergency response coverage from adequately capable teams. Response times greater than the 10-minute window are, therefore, not meeting the defined adequacy.

- Although the Boston Report focused on Class 3 flammable liquids, they did not mention the growing national trend toward increased use of ethanol. This may be an important emergency response-related issue due to the specialized fire suppression foam required to fight ethanol fires and which is different and more expensive than the foam used to fight oil and gasoline fires.[1] The availability of this foam to response units throughout the area would be an appropriate item to address.

- The Boston Report states that a 140 percent difference between two routes' environmental exposure values is not significant. This statement referred to RA4 and RA5; however, the difference is 1,350 percent when comparing RA1 and RA3. As the speeds on the routes around downtown Boston are generally greater than those through the city, one would expect the conditional release probabilities, if they were used, to create an even larger difference between the routes.

- The Boston Report uses the argument that US DOT regulations adequately protect the population and the environment, so there is no need to consider the increased environmental risk. If this were a valid argument, which it is not, then by inference, it could also be applied to population-based risk, eliminating the need to do any comparative route risk assessment at all.

- In the Boston Report, a ½-mile impact distance was used for both population and environmental consequence measurement. In route risk assessments, the impact distance used to measure environmental exposure often does not match that used to measure population exposure. A 0.1-mile impact distance is commonly used for measuring environmental exposure. 49 CFR 397.71(9)(vi) states that "The distance to sensitive areas shall be considered."

[1] http://www.iafc.org/files/1HAZ/haz_Advisory_Guidance_Ethanol_Gas_Mixtures.pdf; http://www.usatoday.com/news/nation/2008-02-26-2111231703_x.htm

- One area of confusion is the basis for the coefficient of variation for employment population and how it was converted into a standard deviation. The coefficient of variation is the standard deviation divided by the mean, yet Appendix F of the Boston Report states that "the coefficient of variation of the employment numbers is estimated to be about 1 percent." The reference cited is specific to government employment estimates only (not commercial) and does not provide specific values.

- The selection of an alternate endpoint to investigate the sensitivity of the through route analysis is inappropriate and does not constitute a sensitivity analysis. If the data or collected information (through the surveys or interviews) indicates that through transportation of hazardous materials follow that route, then it should be considered as part of the base analysis framework.

- With the exclusive focus on Class 3 flammable liquids, an important sensitivity analysis that was not performed would be to vary the impact ranges used to measure population exposure associated with Class 3 flammable liquids.

- Another useful sensitivity analysis would have been to utilize multiple impact ranges, which model the varying potential impacts of different commodities. This would help to reduce the concern about the limited commodity flow analysis and is more in line with regulatory expectations.

- The analysis of the burden on commerce in the Boston Report is exclusively focused on the local transportation of petroleum products and particularly those that are moved in the greater Boston area. The report also makes some assumptions about the movement of petroleum products in the greater Boston area that are not supported by any data. There are other product movements that should be considered as well, including long-haul shipments moving longer distances than those analyzed, specifically to communities in other areas that will be impacted by reduced product delivery and by increased cost.

- Travel time estimates from CTPS used in the Boston Report are based on mid-day field observations rather than averages, which would include peak congestion time periods. The effects of the significant congestion in the Boston region do not appear to be captured by these estimates. To the extent that the shipments along the alternate routes may have even longer travel times than the through routes due to congestion has not been evaluated. Not only does this impact emergency response time, it may underestimate the burden on commerce, particularly during the 6-10 am and 3-7 pm rush hour periods.

- Finally, the burden on commerce analysis did not consider that the additional travel time required to use the alternate routes has the potential to extend the workday for each of the drivers. The Boston Report assumes that each driver has only sufficient time to complete two round trips per day in a normal workweek. The current federal hours of service rules include both driving and non-driving work time and this would result in a reduction of 50 percent over current delivery expectations.

Conclusions

- As currently written, the Boston Report is too narrow in scope to serve as the only justification for a change in hazmat route restrictions.
    - The current legal hazmat routing restriction is not evaluated and did not serve as the basis of comparison.
    - A single DOT Hazard Class was evaluated instead of a mix of representative commodities (hazard classes).

- The presence of apparent calculation errors in the consequence estimates:
    - Requires verification and validation of all data and calculations, and
    - Reduces confidence in the results for the analysis conducted.

- If the issues raised in this review were addressed, the resulting relative risk values would not be as presented in the Boston Report. This may affect whether the risk ratios exceed the threshold at which the deviation from the current routing (in miles or percentage increase in miles) is subject to the 25-percent/25-mile limitation.

1. Background and Conceptual Review

1.1. Federal Routing Regulations

The current federal routing requirements for non-radioactive hazardous materials (NRHM) have components directed to States, Indian tribes, and motor carriers codified in 49 CFR Subpart C. The requirements for States and Indian tribes apply to any new routing designations—whether prescriptive or restrictive—as well as to the maintenance or enforcement of routing designations.

The requirements that apply to motor carriers direct them to follow State or Indian tribe designations, where present, and to avoid "heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys," with some allowable exceptions.

The requirements for designating routes include a list of federal standards that must be followed. These include some that apply directly to the mandatory analyses and others that ensure the consultative process obtains and addresses concerns from the public, neighboring jurisdictions, and other States and Indian tribes. Of primary relevance in this review are the standards that address enhancement of public safety, through routing, and reasonable routes to terminals and other facilities.

According to 49 CFR 397.71(b)(1)(ii), the analysis of the effects of a routing designation on public safety should consider a range of listed factors in accordance with the "DOT 'Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials,' DOT/RSPA/OHMT–89–02, July 1989 or its most current version; or an equivalent routing analysis which adequately considers overall risk to the public."

There have been two updates to the US DOT Guidelines document since the referenced 1989 version. The first was an update published in 1996 that reflected regulatory changes since the original publication. This is the update that Battelle used as the basis for their analyses. The second update was included in "The Hazardous Materials Highway Routing Route Plan Guidance Report to Congress" that was submitted by FMCSA in 2009 pursuant to Section 1553(a) of the Implementing Recommendations of the 9/11 Commission Act of 2007 (Public Law 110-53). This report to Congress included a "Guidance Document: Hazardous Materials Routing Using Safety and Security Criteria" as Appendix E. Note that Appendix A in the report to Congress contains the final report for the project that developed the updated guidance. Battelle was the contractor that developed the guidance and the final report for the 2009 submission.

1.2. Boston Report Approach

1.2.1. Following the Federal Requirements

The technical components from the "routing process" outlined in the 1996 Routing Guide include: define alternatives for analysis, analyze risk, apply through routing criteria, consider additional factors, and identify routing. At a high level, the Boston Report does show that their analysis follows the prescribed methodology; however, there are some significant issues that warrant discussion.

1.2.1.1. Analysis Framework and Alternate Route Selection

The Boston Report lacks discussion of the specific hazmat movements that are under consideration before the alternative route selection process is described. The change in the Boston hazmat routing that prompted the federal preemption ruling involved a change to a small section of the route in downtown Boston and the prohibition of through movements from downtown altogether (through their permitting process). There is no context or discussion about the specific origins and destinations used to define the alternatives, and the rationale for why they were chosen or why they should be chosen. The 18 alternative routes are not all candidates for the same movements. As will be discussed in the Technical Review section of this report, the proper selection of representative origins and destinations is critical to the analysis.

A key issue to point out is that the Boston Report does <u>not</u> evaluate the designated hazmat route currently in effect. This is a critical procedural error given that any analysis performed under 49 CFR 397.71 must evaluate the relative safety of any alternatives as compared to the current routing (49 CFR 397.71(9)(ix)). It is inappropriate to select a route that is not the currently designated hazmat route, use it as the benchmark route in comparisons against potential alternatives, and then conclude that any of the route alternatives is better than the unanalyzed currently designated hazmat route. We acknowledge that the currently designated hazmat route (using Commercial Street) and the study's benchmark route (using Cross Street) would likely have similar risk profiles, but procedurally this is irrelevant. A comparison to the currently designated hazmat route is required.

1.2.1.2. Risk Parameters

The Boston Report did include certain accident rate and population data in their analysis; however, there was no consideration for the different conditional release probabilities or consequences that would be appropriate for hazmat other than flammable liquids. In fact, the entire analysis was based on flammable liquids. Consistent with current transportation risk analysis best practices, each of the routes under analysis should be analyzed for the specific mix of commodities present and evaluated for each US DOT Hazard Class. For example, a movement of a Class 6 toxic by inhalation gas on one route may present unacceptable risk; whereas, movement of Class 3 flammable liquids on the same route would result in acceptable risk.

The through routing analysis presented in the 1996 Routing Guide provides support to analysts and decision makers on how to make an initial selection between route alternatives based on risk (safety) and distance (economics).

1.2.2. Application of Security Criteria

As mentioned in Section 1.1, Battelle authored the most recent update to the federal hazmat routing guidelines. That update focused on adding security-related criteria to the route determination process. The Boston Report does not address security in any way even though the authors were aware of the new guidance.

2. Technical Review

The following sections discuss the specific implementation of the routing analysis in the Boston Report and provide expert observations and opinions.

2.1. Establishing an Analysis Framework

As directed by 49 CFR § 397.71, the Commonwealth of Massachusetts is responsible for ensuring that local NRHM highway routing designations do not impede or unnecessarily delay transport of NRHM shipments, thus protecting the continuity of movement of these shipments through adjacent communities within the Commonwealth. In essence, the Commonwealth must consider a system view when evaluating the impact of specific NHRM routing designation and determine its effect on the overall continuity of flow. The Commonwealth is to ensure that there is a balance among its constituents in the allocation of the burden of risk (associated with NHRM shipments) while maintaining safety and the flow of commerce through the transportation system. Every community rejecting the flow of NHRM through its jurisdiction is not an option, but could be the result if analysis does not view the region as an interconnected system.

The Boston Report documents the use of one[2] origin-destination pair (I-93 exit 16 and Alford Street Bridge/MA-99) for its analysis of the "through routing" of NHRM shipments. From a systems-level approach, the selection of the of Alford Street Bridge/MA-99 location as an analysis point is not sufficient for an investigation of the transportation system's "through routing." The Alford Street Bridge/MA-99 location is a terminus point supporting only subsequent localized pick-up/delivery movements as opposed to subsequent transportation destinations beyond the Greater Boston Area (e.g., points in northeastern Massachusetts, New Hampshire, or Maine). This is not to say that there is no value in the selection of this particular analysis point (for localized evaluation), but it is not adequate as the only origin-destination pairing when the Commonwealth must look at a broader view of NRHM movements through the Commonwealth's highway transportation system.

Figure 1 below presents a depiction of the two analysis points used in the Boston Report. One can see that only the northbound/southbound flow in close proximity to Boston is evaluated. Battelle performed route risk evaluations on three route alternates between these two analysis points in both the northbound and southbound directions. Figure 1b depicts the general flow of these route alternatives.

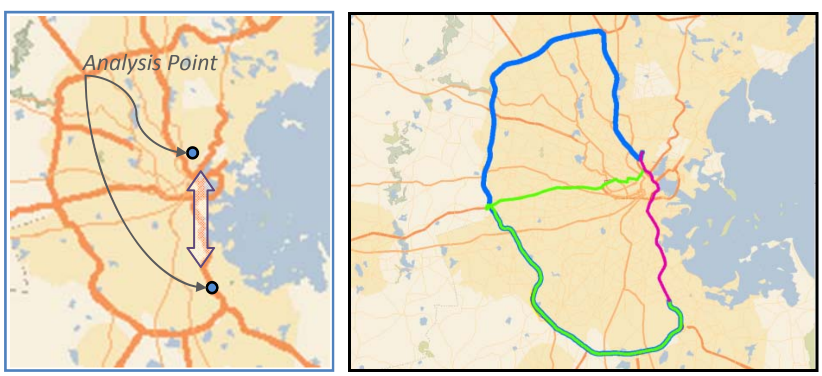


Figure 1. Boston Report: (a) Through-Route Analysis Points and (b) Evaluated Route Flows

One cannot assume that by evaluating the risk associated with route alternatives between these two relatively close analysis points that the differences in risk would be the same or worse than if the

[2] Later in a sensitivity analysis, one of the endpoints being evaluated was moved from I-93 Exit 9 to I-95 Exit 12.

analysis framework was expanded to a system approach that considered more distant origins and destinations. Only an analysis can confirm such a hypothesis.

As discussed in the 1996 Routing Guide, information on commodity flows helps to establish the appropriate parameters and framework for the risk analysis. Figure 2 depicts some of the dependencies found between commodity flow information and impact considerations within the risk assessment framework. For example, by considering commodity *X*, we know the potential emergency response needs and associated impact distances if a release were to occur. Knowing the impact distances of concern establishes the risk analysis parameter for measuring potential consequence. Additionally, by knowing the commodity, we have an understanding of the type of container in which the commodity is general transported and thus the risk analysis can utilize container type-specific conditional release probabilities, which in some cases, have a speed-related component. Conditional release probabilities will be discussed further in Section 2.4.2.2.

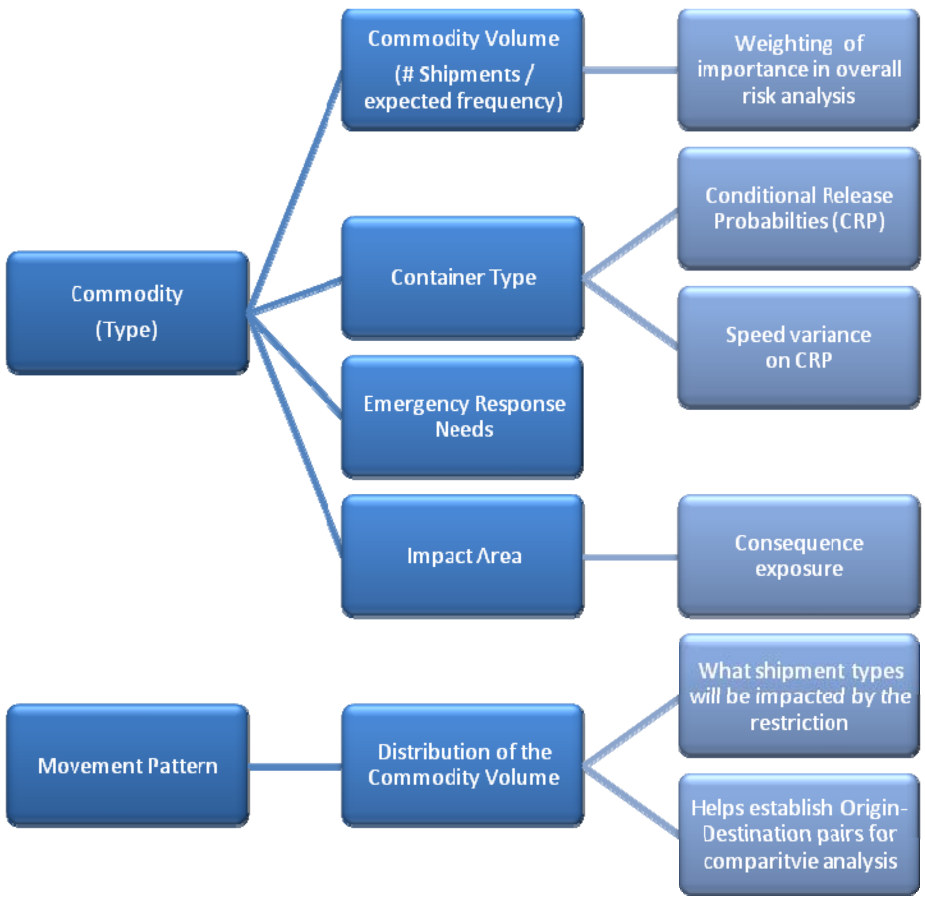


Figure 2. Relationships between Commodity Information and Risk Analysis Parameters

Commodity flow information is also useful from a movement perspective and can help characterize commodity flow patterns, thereby helping to ensure appropriate analysis points are established for the risk analysis framework. For example, review of commodity flow information could potentially return movement characterizations, such as those shown in Figure 3.

Northeast Corridor Shipments	• Utilization of downtown Boston routing for the transport of shipments of various hazard classes with origin-destinations beyond the greater Boston Area
Localized Hazard Class 3 Shipments	• Utilization of downtown Boston routing almost exclusively for the transport of Hazard Class 3 shipments within the greater Boston Area
Combination of Northeast Corridor and Localized Shipments	• Shipments of various hazard classes with O/Ds beyond the Boston Area • Localized Hazard Class 3 shipments

Figure 3. Sample Movement Characterizations Provided from Review of Commodity Flow Information

The movement characterizations can have an impact on the subsequent risk analysis framework. If it was found that NHRM shipments of various hazard classes currently utilize the downtown Boston routing, the risk analysis framework would then need to consider the multiple impact areas (one associated with each commodity) as well as utilize analysis points that were beyond close proximity of downtown Boston (i.e., as utilized in the Boston Report). Such a finding about the characterization of hazmat movements would warrant the evaluation of additional route alternatives flowing between numerous analysis points (see the potential analysis points and flow patterns in Figure 4 below). Each route alternative would need to be evaluated with multiple impact distances (both larger and smaller than the ½-mile mile distance utilized in the Boston Report). The risk analysis for both multiple commodities and for various outlying destinations were not analyzed consistent with requirements.

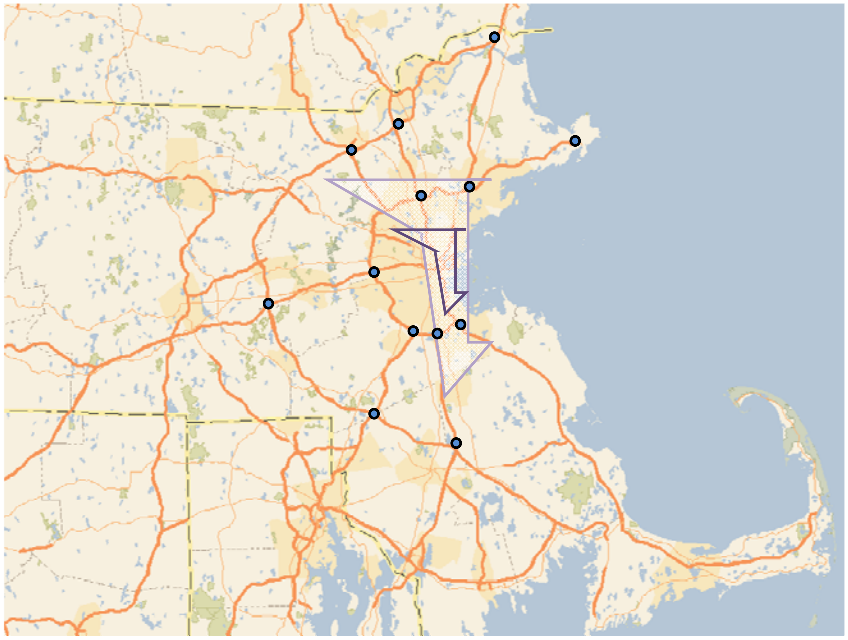


Figure 4. Potential System Review – Commodity Flow Analysis Points

At the other extreme, if it was found that the downtown Boston routing was almost exclusively used for the transport of shipments with pick-ups and deliveries within the greater Boston area (the focus of the Boston Report), then analysis points at the specific beginning and end of the current hazmat route designation would be appropriate. This change of the analysis point locations could alter the findings of the Boston Report as the distance associated with the reference route (i.e., Route 1 – Through Boston) would be reduced and the distance of the alternatives increased. The "transfer" of route mileage between the alternatives would affect their risk values and thus the relative ratio, potentially having the achieved risk reduction fall below 50 percent and, therefore, subject to the 25-mile/25-percent increase stipulation in the routing guidance.

2.2. Selected Route Alternatives

As introduced in Section 1.2.1, the change in the Boston hazmat routing that prompted the federal preemption ruling involved a change to a small section of the route in downtown Boston and the prohibition of through movements from downtown altogether (through their permitting process). The Boston Report's through-route analysis uses the preempted route as the "reference" (or benchmark) route. The Report does not include the existing, legal hazmat route as the reference route, which misses the intent of the routing analysis in the first place. As required by federal regulations, the relative safety of any alternatives must be compared to the currently designated route. While the expected differences between the current route and the reference route analyzed may be small, the analysis is required to verify that is indeed the case.

Of the 18 routes analyzed in the Boston Report, six of them were related to the through-route analysis and had northbound and southbound components. Of the other 12 routes, not all of them had northbound and southbound components and many of them had two origins or destinations (only one of which was ever used to compute a risk score). One route (RA7) was included in the local route analysis, but could not be compared to any other route because it had a unique origin-destination pair.

As the relative risk values are meaningful only in a comparison with another route, it is unclear why this route was included.

While the elimination of potential routes due to bridge characteristics and clearance issues is appropriate, it is not clear what is meant by the phrase on page 3 of the Boston Report that states that "Battelle staff added a couple of routes with common starting and ending points *in order to facilitate risk comparisons.*" (emphasis added)

2.3. Evaluated Hazardous Materials – Limiting the Analysis

In order to analyze the impact of a restriction within a transportation system (e.g., a route designation that alters the normal expected flow of movement), one must first have an understanding of what would normally be moving through that system. If an NRHM route restriction is being considered, then the commodity type, volume, and pattern of flow of the NRHM shipments currently moving through the system should be established. This type of information is generally acquired with a commodity flow study for the area.

A commodity flow study helps to answer what, how much, how often, and where shipments are moving through the transportation system. The information gained by understanding the flow of commodities through the system helps to frame any subsequent analysis of the impact of a restriction within the system. The regulations stipulate that the analysis to determine the impact of a route designation should be assessed in terms of risk (safety and, as of 2009, security). Typically, a comparative risk analysis is performed in order to evaluate the risk differential between the normal (current) pattern of flow and the potential flow that results after introduction of the proposed restriction (route designation).

The Boston Report used a good range of sources to try to determine the types and quantities of hazardous materials traveling through the study area. It is unfortunately quite common for there to be no usable hazmat commodity flow data available. A brief discussion of each source the Boston Report considered and the approach to utilize it follows.

> *US DOT-reportable spills*. While it is true that most of the reports in this database involve unintentional releases, there is a requirement for reporting any incident in which (a) any specification cargo tank with a capacity of 1,000 gallons or more has structural damage or (b) an undeclared hazmat is discovered—even if there is no release. It is not clear whether any en-route reportable non-releases occurred in the Boston Report's study area . If so, they would provide some additional context for the materials that should be considered in the analysis.
>
> While it is informative to explore the distribution of hazmat incidents across the five counties, it is more important to consider the aggregate totals for the entire area. Obviously, any changes to the routing designations have the potential to alter commercial and product distribution patterns. Also, while the magnitude of past releases is informative, they should not drive the selection of materials to include in the analysis. Any effects of release quantity would be captured in the risk analysis. It is notable that, although the Boston Report states the bias toward over-representing Class 3 (and Class 9) materials, they only account for one-half of the reported incidents. The Boston Report shows Class 2 and Class 8 materials account for 5 and 33 percent of en-route incidents, respectively. However, they are not included in the analysis.

Note that Table 2 in the Boston Report, "In Route Incidents Reported to HMIRS by Carriers for Years 2005 through 2009," contains errors in the information provided. If the percent by hazard class values are correct, then the "Total Releases" summary row values cannot be correct. For example, in Suffolk, if one release is equal to "7.69%," then the "Total Releases" would equal 13, not 5 as presented in the table. If the "Total Releases" summary row values are correct, then the percent by hazard class values are incorrect. Partial releases in this context are not possible.

Boston Hazmat Inspections. While the Boston Report acknowledges the biases in the data, it shows that, in addition to Class 3, Classes 2, 8, and 9 have presence in the region.

Permit Applications. The approach to estimate the total number of shipments and the distribution seems appropriate, understanding that not all hazmat shipments require a permit.[3] Again, Class 2 shipments have a significant share of the total estimated by this method, at 9 percent.

Survey Results. While the approximate 10 percent survey response rate is fairly low, it can be appropriately used in this context to gain a general understanding of the types of materials that are being shipped by entities within a close proximity to the Boston area. The response rate would result in a wide confidence interval, but it is clear that there are regular shipments of Class 2 and Class 8 materials.

Commodity Flow Survey. The suppression of values in the Census data (as shown in Table 5 in the Boston Report) are not due to lack of "significance" as stated, but due to privacy constraints. The Boston Report is correct in pointing out that shipments of flammable liquids would be expected to be disproportionally heavier than those of many other hazard classes because of package size, but the product weight itself would skew the data measured in ton miles.

Based on the Boston Report's analysis on commodities moved through the Boston area, it is fair to assume that Class 3 materials will make up the majority of the shipments on the highways. However, it is inappropriate to exclude all other US DOT Hazard Classes from the analyses. The PHMSA data clearly show that Class 3 is underrepresented in the number of incidents if they account for 70 to 90 percent of all shipments. Class 3 en-route incidents shown in Table 2 in the Boston Report only account for 50 percent of the total. This indicates that half of all incidents will involve a hazardous material *other* than Class 3 flammable liquids. Again, the Boston Report only considers the release of a Class 3 flammable liquid in any of the risk analyses that they perform. In their conclusions, they state that "[t]here is nothing in the analysis that would result in a different finding had another Class or Division of Hazardous Material been chosen for [sic] as the reference shipment in the risk assessment." There is no justification presented in the report that can substantiate this claim. Without performing any analyses based on other materials or even discussing how the impacts of using other materials would not alter the calculations at each step in the risk equation or as part of the consideration of the subjective factors, that claim cannot be accepted at face value.

Clearly from the sources cited in the Boston Report, shipments involving Classes 2, 3, 8, and 9 materials are moving regularly within the Boston region (Route Incident Reports involving these hazard classes are irrefutable). Different commodities (i.e., US DOT hazard classes) have different associated areas of

[3] http://www.cityofboston.gov/Images_Documents/Application%20for%20Permit%20for%20Transport%20Certain%20Hazardous%20Materials_tcm3-17928.pdf

impact should an incident occur. A route's risk profile when considering one commodity (hazard class) maybe different when considering another; they cannot be assumed to be the same. As required by 49 CFR 397.71(9)(iii), "An examination shall be made of the type and quantity of NRHM normally transported along highway routes which are included in a proposed NRHM routing designation, and consideration shall be given to the *relative impact zone and risks of each type and quantity*." (emphasis added)

A key benefit of a risk analysis, such as that required to support new routing designations, is to measure and allow consideration of the full range of scenarios. These include the high-probability, low-consequence events; the low-probability, high-consequence events; and those events in-between. In the Boston Report, no consideration was given to identifying the potentially high-consequence events. Given the ease that analyses can be performed with current computer software, including geographic information systems, and adjusting parameters such as the appropriate impact range for consequence analysis for varying materials, one would expect this to be considered.

2.4. Applying the Risk Equation

In broad terms, risk can be defined as the "likelihood that something will happen" times the "consequences" of that something happening. This simple understanding of risk is utilized across many disciplines (financial, medical, transportation, etc.) and industries. It is the responsibility of the risk assessment practitioner to determine the most appropriate manner by which to model (express) the risk definition so that it is relevant to the issue being investigated. Often in a hazardous materials route risk assessment, the potential for a hazmat release represents the "something" in the "likelihood that something will happen" statement and a measure of population exposure represents the "consequence".

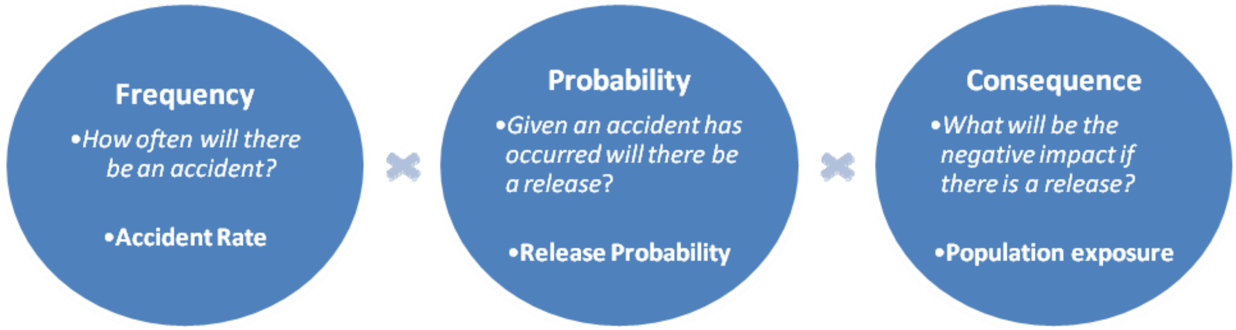
Typically, the "how likely is it that there will be a transportation hazmat release" is modeled in terms of frequency and probability. Frequency addresses the question of "how often will an accident occur" and is typically based on accident rates, while probability (release probability) predicts the likelihood of a hazmat release given that the accident has occurred. The release probability component is an important consideration as an accident involving a hazmat truck will not always result in a release of product. Within the Boston Report (p. 81), the risk equation utilized only contained two components:

Risk = Accident Rate × Number of People Adjacent to Route

The study utilized a very conservative approach and did not consider a release probability component. Effectively this means the risk equation modeled that all accidents would cause a release of product that would totally impact the population within ½-mile of the road segment on which the accident occurred, an unlikely probability both in release and distance.

Typically, a three-parameter risk model is used for transportation risk assessments, where the parameters are frequency, probability, and consequence. Within this model, the frequency component is expressed in terms of accident rate, the probability is often container release probability, and consequence is a measure of population exposure. This three-parameter risk model addresses the statement:

> *"What is the rate at which an accident is to be expected; given that an accident has occurred, what are the chances of a release; and if there is a release, what is the negative impact?"*



Given the analysis framework of the Boston Report (i.e., only evaluating one hazard class with a single associated exposure bandwidth), it could be argued that the use of a release probability component would have no net effect on the risk comparison outcome. This would be true because the same release probability value would be consistently applied across all road segments in all route alternatives and thus would effectively factor out as it would uniformly decrease the individual road segment risk values.

The premise is that the through-route analysis should have considered more than just Class 3 flammable liquids. When an analysis is considering multiple commodity combinations, the use of associated release probabilities is relevant and important. Note that the 1996 Routing Guide discusses the use of conditional release probabilities[4] as a function of roadway functional class, which, among other things, is closely tied to speed.

2.4.1. Computing the Risk Measure

For route risk assessments such as those discussed here, the commonly accepted approach is to perform the risk calculation on a segment-by-segment basis. In this approach, the risk for a segment is the product of the accident likelihood for the segment, the conditional release probability (if used), and the consequence measure. The overall route safety risk is the sum of all the segment risks. From the description in the Boston Report, it is not clear that this approach was taken. For example, the discussion beginning at the bottom of page 80 in the Boston Report mentions the approach used for estimating route risk as: "Using the second method, the average density of people within a selected distance of the route is calculated, multiplied by the accident rate and distance to obtain risk." The equation on the next page of this report does not show the calculation as a summation of the values computed at the segment level. The calculation of risk at the segment level should be verified with the Boston Report's authors.

The segment-based approach is very important because it connects the potential consequences at a particular location to the likelihood of an accident (or a release) at that location. Two routes with the same accident rates and same total population exposure could have significantly different risk scores based on where the population was distributed. A segment-based approach to calculating route risk is important for determining why two routes' risk values differ and which portions of the routes are the key contributors.

[4] Page 19

2.4.2. Accident Rates and Conditional Release Probabilities

2.4.2.1. Accident Rates

The Boston Report determined accident rates for each roadway segment based on roadway functional class. Given the available data, we believe that their approach was appropriate. This assumes the data that Battelle received from UMass was correctly prepared. Of course, roadway-specific accident rates would be highly preferred, but such data are usually not available with a reasonable level of statistical confidence. Typically, there are too few accidents occurring on a specific section of roadway to compute a meaningful rate per million miles traveled. Note that where specific local knowledge of high-accident locations exists, it is appropriate for a risk analysis to subjectively consider that knowledge when evaluating the use of these roadways.

Another accident rate-related statement in the Boston Report needs clarification. The report states on p. 49 that "The accident rate was obtained by dividing the total crashes by the annual truck miles traveled, column 5 divided by column 6" in reference to the report's Table 1: "Estimated Annual Truck Accident Rates by Functional Class Applicable to the City of Boston, Massachusetts." In the Boston Report's Table 1, column 5's title is "Total Truck Crashes (2007 thru 2009) and column 6's title is "Annual Truck Miles Traveled." If column 5's truck crash values are divided by column 6's annual truck miles traveled values, the "Accident Rate / 10^6 Miles" value presented in Table 1 is not the resulting quotient. For example, for Interstates, the value of 0.90 is achieved vs. the reported 0.30 value; for Urban Principal Arterials it is 3.09 vs. 1.03. We believe the difference is attributed to the fact that the Total Truck Crashes is reported for 2007 thru 2009 while the truck miles traveled is presented for a single year and thus the factor of 3 difference. It would be prudent to verify this and ensure that it is simply an error in documentation and not an error in the calculated accident rate.

Within Battelle's response to a question related to accident rate calculations,[5] the number of Interstate and Urban Principal Arterial miles for RA1 and RA3 were provided. Given this information, the Weighted Average Accident Rate may be computed for the two routes utilizing the following equation.

Weighted Avg Accident Rate = ([((Number of @Interstate Miles)) * ((Interstate @Accident Rate))] + [((Number

Table 1 presents the calculated Weighted Average Accident Rate for these two routes. Notice the accident rate associated with RA1 is double that of RA3 due to RA1's heavier use of Urban Principal Arterials which have an estimated 1.03 accidents per million miles versus the Interstate rate of 0.30 per million miles. If on the other hand, we look at the route's accident expectancy, we will find that RA3 is expected to have more than double the number of accidents that are expected to occur on RA1. Expectancy is based on frequency of use. RA3 is over 4 times longer in trip miles that RA1. While RA3 has a lower per-mile accident rate, the increase in trip distance means that if an equal number of trips where to traverse RA3 and RA1, we would expect to have double the number of accidents on RA3 than on RA1. The following equation was utilized to calculate Accident Expectancy.

Accident Expectancy = [((Number of @Interstate Miles)) * ((Interstate @Accident Rate))] + [((Number of Urban @Pr

[5] "Response to MassDOT Questions 8/02/2011" – available from http://www.massdot.state.ma.us/highway/ProposedHazmatRoute.aspx

Table 1. Accident Expectancy

Route	Total (miles)	Interstate (miles)	Urban Principal Arterial (miles)	Weighted Average Accident Rate (per 10^{-6} miles)	Expected Accidents per Million miles
Route Alternative 1 – Through Boston	10.7	4.85	5.85	0.6991	7.48
Route Alternative 3 – I-93S to I-95N to I-93S	47	45.6	1.3	0.3202	15.02

With the weighted average accident rate calculated for the route, the number of years between expected truck hazmat accidents can statistically be predicted. Table 3 presents this information for each route for various annual shipment levels. For example, if there are 25,000 shipments per year, we would expect an accident to occur every 5.35 years on RA1 and every 2.66 years on RA3.

Table 2. Expected Number of Years between Hazmat Truck Accidents

Number of Annual Hazmat Shipments	Number of Years Between Accidents	
	RA1 Through Route	RA3 – I-93S to I-95N to I-93S
10,000	13.37	6.64
25,000	5.35	2.66
50,000	2.67	1.33
75,000	1.78	0.89

In our opinion, the Boston Report was deficient by not presenting information related to a route's average accident rate and accident expectancy. While these factors can be derived from the information provided in the report, one would need subject matter expertise to be able to do so.

As discussed earlier, risk calculations should be evaluated at a road segment level to capture the potential consequences in relation to the likelihood of an accident. Often, summations of the individual components of the route risk are reviewed to ensure that no one factor is extremely out of bounds. Typically, route mileage, population exposure, average accident rate, and risk are presented to help decision makers understand the characteristics of the route and understand the key risk drivers. The Boston Report does not follow this format.

2.4.2.2. Conditional Release Probabilities

As stated earlier, the "through route risk analysis" should have considered additional commodities (based on the appropriate mix of commodities moving through the area) . The Battelle-cited incident reports in HMIRS indicate that non-Class 3 commodities are being transported within the region. Table 3 presents a sample of the type of containers that could be used to transport Hazard Class 2.1, 2.2, 3, and 8 commodities (which have reported HMIRS accidents in the Boston region).

Table 3. Commonly Used Cargo Tanks

Container Description		Used to Transport	Used with
MC-306	Non-pressure liquid tanks	Motor fuels	Hazard Class 3
MC-312	Corrosive liquid tanks	Corrosives and other high density liquids	Hazard Class 8

MC-331	High-pressure tanks	Compressed gases Anhydrous Ammonia, UN1005 Liquefied petroleum gas, UN1075	 Hazard Class 2.2 Hazard Class 2.1

Different container types have different failure rates (i.e., release probabilities) associated with them. Container-specific conditional release probabilities are determined based on the container composition, structure, understanding of the forces involved in accidents as well as previous accident/release history. Table 4 presents published container-specific conditional release probability estimates determined by Brown et al (2001).[6] Based on this data presented, if a shipment of motor fuel transported in a MC-306 were to be in an accident, there is a 93.5 percent chance that a release would not occur. An accident involving a truck with hazmat cargo cannot lead to potentially catastrophic consequences unless the hazmat cargo being transported is released. Consideration of release probability could have a significant effect on the results stated in the Boston Report.

Table 4. Release Probabilities, Given an Accident, by Container Type

Container Type	Shell characteristics	Release probability (%)
MC-331	0.187 stainless	2.5
MC-331	0.625 standard, 0.3 stainless	1.0
MC-306	All	6.5
MC-312	0.25 standard	4.0
MC-312	0.25 stainless	1.5

Additionally, experts acknowledge that the magnitude of an accident (i.e., forces involved) will have an effect on the likelihood that the container will breach. As an extreme example to illustrate the point, consider a flatbed truck hauling bales of hay vs. a high-pressure cargo tank hauling a compressed gas. If the flatbed truck were in an accident, one would expect with high certainty that there would be a spill of hay without even considering asking additional questions about the nature of the accident. If on the other hand, a high-pressure cargo tank were in an accident, one would want additional information before predicting whether or not there would be a release of product. For example, the speed at which the accident occurred, the nature of the accident (e.g., was it side-swiped or rear-ended while at a traffic signal). The reason we need more information is because we intuitively know that high-pressure cargo tanks have more structural stability than a flatbed truck. Not all accidents involving a high-pressure cargo tank will result in a release.

Some transportation risk analyses use speed adjustment factors to augment the conditional release probabilities. These speed adjustment factors are applied to help account for the fact that lower-speed accidents involve smaller forces and are less likely to result in a breaching of hazmat containers. In some cases, the application of a speed adjustment factor is quantified in the risk equation and, in other cases, it is more of a subjective factor. Given the known speed differentials between the route alternatives, it would be appropriate to consider roadway travel speeds in the analysis.

[6] Brown, D.F., W.E. Dunn, and A.J. Policastro. (2001) "A Risk Assessment for National Transportation of Selected Hazardous Materials". Transportation Research Record. Vol. 1763. pp. 114-121.

Based on the findings of the Boston Report, the recommended route (RA3) has an accident expectancy double that of the through-route alternative. If we consider that release probability has some dependency on speed, and accept that an accident occurring 15 mph will be less likely to cause a release that one occurring at 60 mph, then we can make the following observation. **By utilizing RA3, one would expect to have at least twice the number of accidents as that of the through route and when those accidents occur, one would expect more of them to cause a release than if the accident occurred on the through route.**

2.4.3. Consequence Measures

2.4.3.1. Impact Area

As previously mentioned, the Boston Report's analysis is solely based on Class 3 flammable liquids, and we believe this approach is not sufficient to properly characterize the commodity flow or route risks in the study area. This insufficiency notwithstanding, the analysis to calculate the potential consequences for Class 3 flammable liquids uses a ½-mile impact area. It is not clear why that impact range was selected, given the discussion in the report about the remoteness of an impact from a release of a flammable liquid extending to ½ mile. The Boston Report indicates that the likely impacts from a release would mostly affect the occupants of other vehicles on the road. If this is the case, then a much narrower impact area would be appropriate, such as those mentioned in the report.

In the guidance document, *Hazardous Materials Routing Using Safety and Security Criteria,* March 19, 2008 (and published in 2009), Battelle makes several statements to suggest that the ½ mile impact area would be inappropriate for use with Class 3 Flammable Liquids:

> "In addition, the fireball from a release involving a gasoline tanker would not be expected to have consequences beyond 100 meters." (Page 12)
>
> "One of the important parameters that can be considered when designating a hazardous material route or determining the extent of a restricted zone is the amount of damage that would result should the hazardous material be suddenly released during an incident. This damage zone or distance from the highway within which population could be affected by a HM release is an important parameter to consider when evaluating proposed hazardous material routes." (page 30)
>
> "As long as a person is not trapped in their vehicle, the heat from a pool fire following the release of gasoline, diesel, or jet fuel would not cause serious damage 50 meters from the fire assuming the individual moved back within a few minutes."(page 30)
>
> "3.6.4 Flammable Liquids. The danger from flammable liquids is that they will form a pool and ignite or that the residual liquid in the cargo tank will form a fireball. Because the cargo tank fails at a low pressure, BLEVEs that occur with compressed liquefied flammable gases will not occur with flammable liquids. The damage zone from flammable liquids pool fires or fireballs is almost always less than 50 meters."(Page 32)

Based on citations from Battelle's own assertions in the guidance document, we do understand why Battelle would knowingly use a ½-mile impact area to perform the analysis for the Boston area. If the extreme ½-mile case were appropriate for use, it would still require the use of a probability-based component to reflect the remote likelihood of a release given an accident.

If the through-route analysis considered multiple hazard classes, then their associated impact areas would need to be considered. It is acceptable for an analysis to utilize multiple impact distances—a single "surrogate" impact range is not necessary. Furthermore, while it can be a tedious process if not automated, GIS software can greatly simplify the process of examining the impacts from several impact ranges around the same roadway segments.

2.4.3.2. Population Data

The Boston Report indicated that their estimate of population was based on "[c]ensus track [sic] data …. using traffic analysis zones (TAZs)"[7] and population related to selected facilities (schools, hospitals, nursing homes, hotels, and park visitors). Figure 5 below summarizes the population data source, population type, and calculation formula as documented in the report.

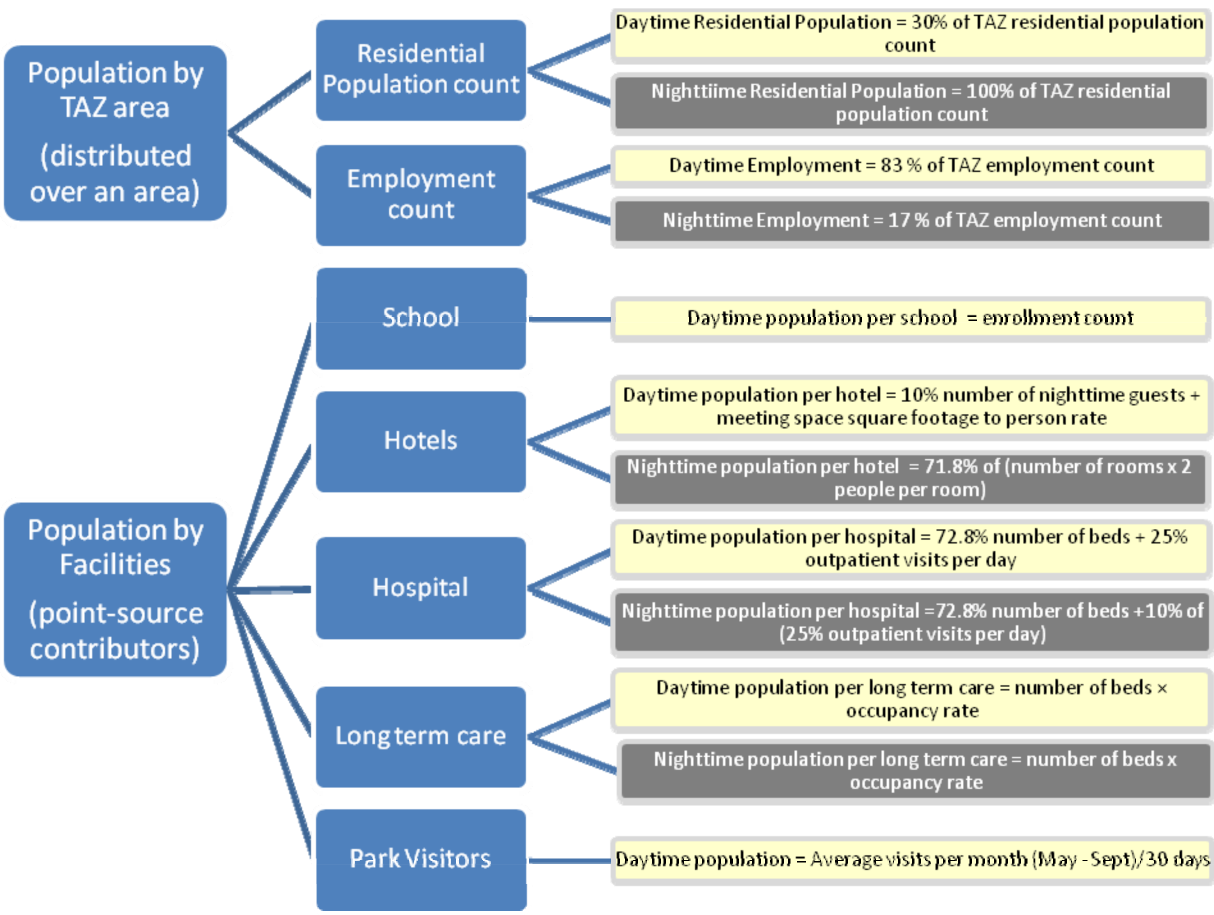


Figure 5. Population Data in the Boston Report

While not organized this way in the Boston Report, these data sources can be categorized into two groups (as organized in Figure 5) based on how each was ultimately used to estimate population. One group containing population related to select facilities (e.g., schools, hospitals, etc.) can be considered point-source population contributors. This means that the entire population associated with a specific

[7] Boston Report p. 65., Section: Estimating the Population Living Near Alternative Hazmat Routes. TAZ data supplied by CTPS 2010.

facility (e.g., O'Bryant School Math/Science – day population reported as 1,212 people) would be allocated to a road segment (and, therefore, ultimately a route) if the location of the facility, based on its latitude/longitude coordinates, was within the road segment's impact zone.

The other manner by which population was estimated along the routes utilizes area boundaries and associated population densities. In the study, traffic analysis zones (TAZs) were used as area boundaries. The population associated with each TAZ was then assumed to be equally distributed over the area of the TAZ, allowing a population density for the TAZ to be calculated. If a portion of a TAZ was within a road segment's impact zone, that impacted area was multiplied by the TAZ's population density and the resultant population was allocated to the road segment's population count.

Both of the population estimation methods used in the Boston Report—facility point-source population and population density over an area—are valid and commonly used methods in population consequence estimation. Our key concern deals with the specific data sources Battelle used in the study.

2.4.3.3. Why were Traffic Analysis Zone Areas used for Population Estimation?

The study utilized TAZ boundaries to estimate residential population along a route; it is not clear why the readily available and more granular Census block boundaries were not used instead (at least for residential population). As background, the following can be said about each of these two area boundary types:

- Traffic analysis zones (TAZs) are generally created for and used in transportation planning models to help depict the number of trips that will be produced and attracted within a zone. Typically, the TAZs are attributed with information derived/aggregated from underlying Census block information (e.g., household income, number of automobiles per household, employment).

- Census blocks represent the smallest geographic unit for which the US Census Bureau provides population data. Census block boundaries are established by the US Census Bureau and typically use natural boundaries such as roads, railroads, and water bodies in their makeup. In highly populated urban areas, a Census block is often equivalent to a city block; whereas, in rural areas, a Census block may span a more disperse geographic area.

TAZs are established with the intent of modeling traffic flow between areas while Census blocks are established specifically to capture population demographics. Figure 6 presents a graphic of TAZ[8] areas and Census block boundaries within an approximate 100 square mile area in the Boston region.

[8] VRT requested and received the geographic data file, taz2727.shp, from CTPS on 09/22/11 depicting the Boston Region TAZs reported to be used in the Battelle Study.

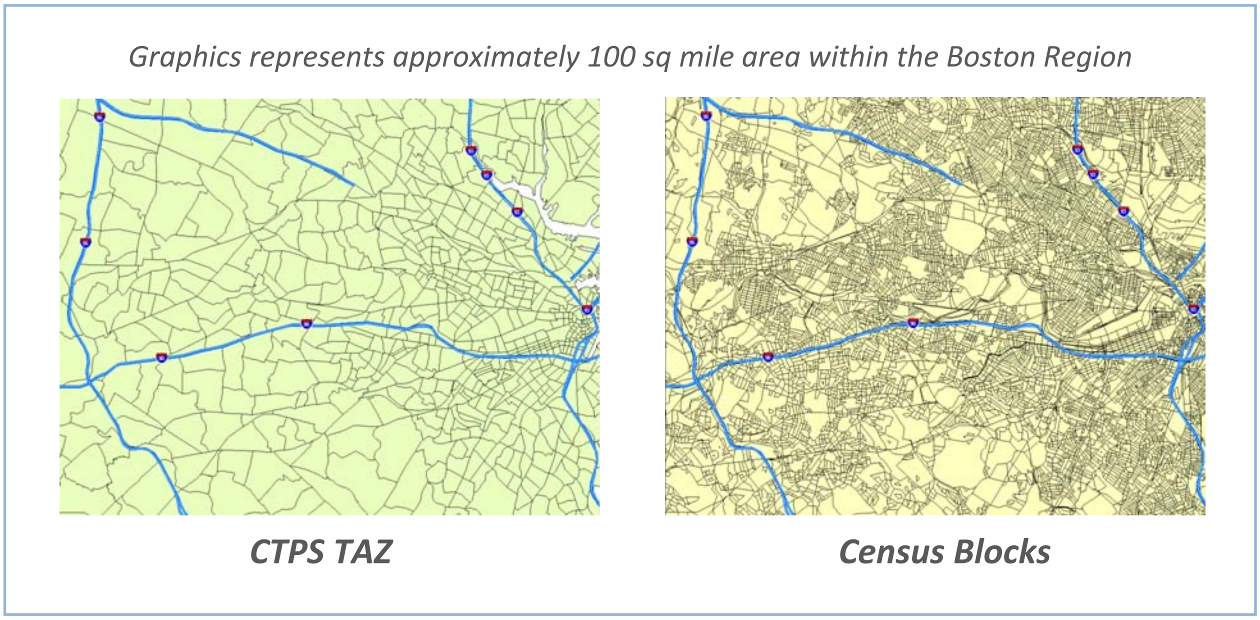


Figure 6. Comparison of Population Boundary Areas: TAZ vs. Census Blocks

Clearly the TAZ areas are significantly larger in size as compared to Census block areas. The average TAZ size (0.30 mi^2) for those TAZs along routes RA1, RA2, and RA3 are 15 times as large as the average Census block size (0.02 mi^2). This size differential is significant because each area has an associated population density that will be used to estimate the population within a route's impact zone. The smaller the area, the more granular and precise the population estimation can be. The larger the area the more susceptible the resultant population estimates are to geographic dilution. To illustrate this point, Figure 7 displays the components utilized to estimate population exposure for a single road segment of I-93[9] based on TAZ vs. Census block areas. Note that in this example, raw residential population values were used.

[9] Road segment is located south of Middlesex Fells Reservation at the intersection of I-93 and SR-28.

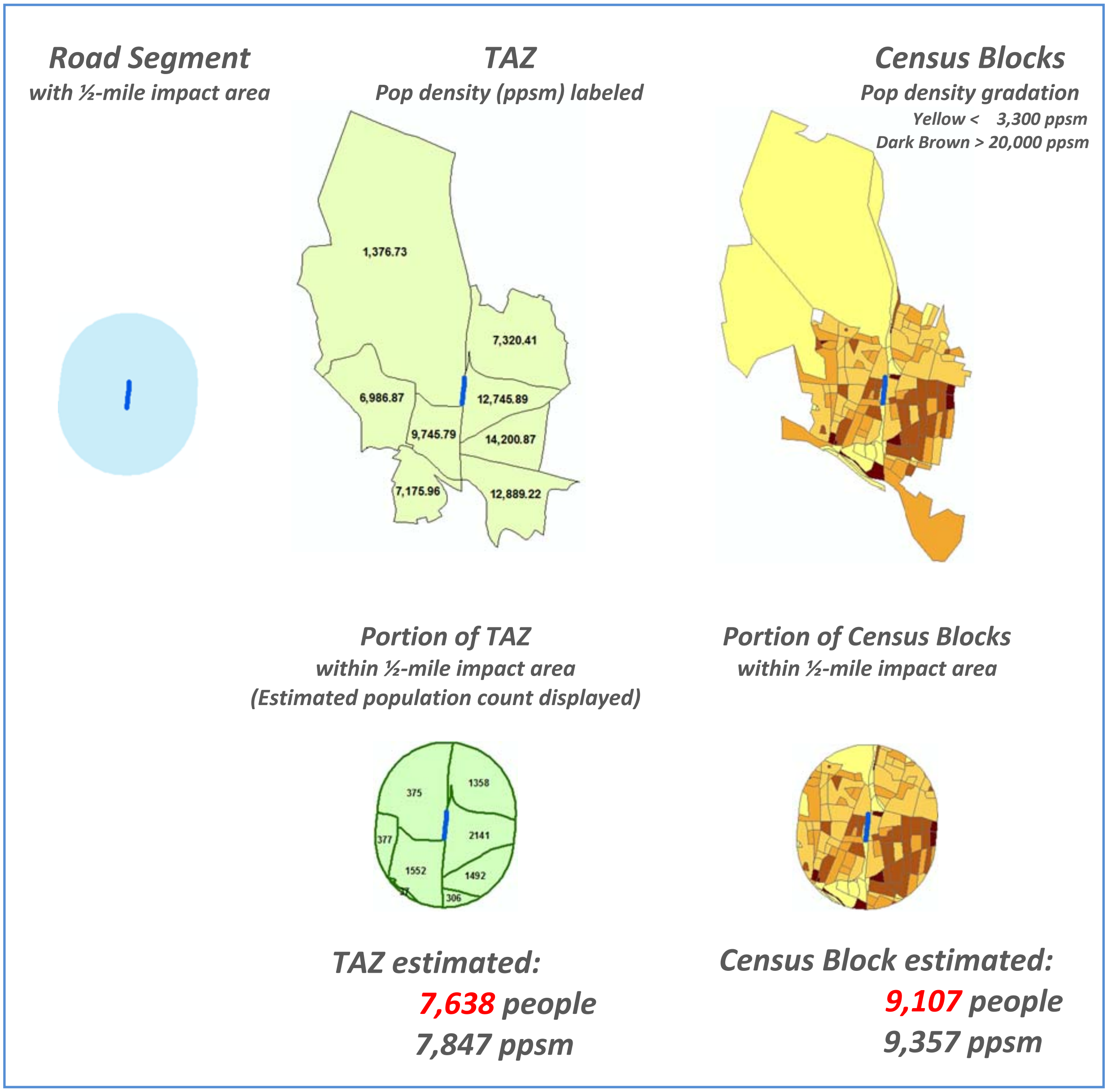


Figure 7. Comparison of Population Estimation using TAZ vs. Census Block Areas

Within Figure 7, on the first row, moving left to right, the graphic displays:

- Road Segment – a single 0.23-mile road segment (blue line) with a ½-mile buffer (impact area) surrounding it.
- TAZ – display of those TAZs that are intersected by the road segment's ½-mile impact area. The associated population density in people per square mile (ppsm) is displayed for each TAZ.
- Census Blocks – display of those Census blocks that are intersected by the road segment's ½-mile impact area. The Census blocks are color-gradated based on population density, moving in ascending order from yellow (< 3,300 ppsm) to dark brown (> 20,000 ppsm).

On the second row moving left to right:

- TAZ areas clipped by the route segment's ½-mile impact zone – based on the portions of each TAZ area within the road segments impact zone, the associated estimated number of people is displayed. Population is estimated by multiplying the area within the impact zone by the underlying TAZ population density.
- Census block areas clipped by the route segment's ½-mile impact zone – the resulting Census block portions are color-gradated based on population density, moving in ascending order from yellow (< 3,300 ppsm) to dark brown (> 20,000 ppsm). Although not displayed in the graphic, the number of people associated with each Census block portion within the impact zone was calculated.

Finally, with the population associated with each portion (within the impact zone) of a TAZ or Census block determined, the population values can be summed to derive the total estimated population within ½-mile of the road segment. In this example, the TAZ method estimates 7,638 people, while the Census block method estimates 9,107 people. This results in an approximately 19 percent difference in the population values in this case, a 19 percent underestimation.

Figure 8 below presents another population estimation example comparing the use of TAZ vs. Census block areas. In this example, there is an apparent 40 percent overestimation of the resultant population count attributed to the use of the TAZ area boundaries and their associated population density (TAZ's 1,722 people vs. Census block's 1,019). More importantly, this example is presented to illustrate why the Census block areas, which were specifically created to facilitate the capture of population demographic information, are a much better source for defining the area over which population should be equally distributed.[10] Specifically, Census block boundaries were established to take into account local area topology elements such as parks, water bodies, and transportation infrastructure.

[10] See Section 2.4.3.2 for discussion of which source of population values should be used to associate with each area.

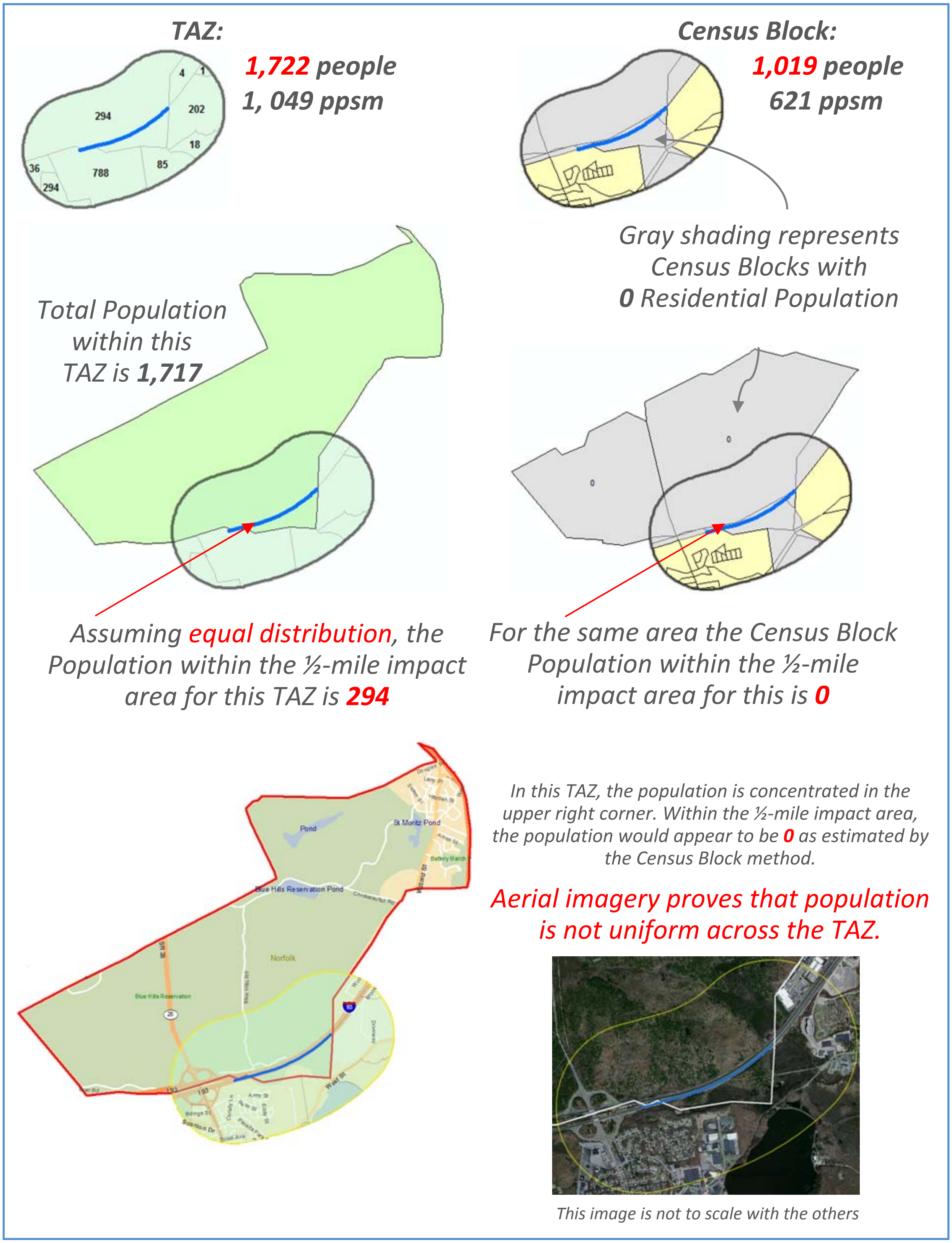


Figure 8. Example of Population Overestimation: TAZ vs. Census Blocks

In Figure 8, moving left to right, the first row graphics depict the portion of TAZ and Census blocks that are within the ½-mile impact zone of this road segment. For the TAZ portions, the associated population values are displayed. For the Census blocks, those portions found to have zero population are displayed in gray. The leftmost graphic on the second row focuses on the display of one of the impacted TAZs in its entirety. This TAZ is reported to contain a total of 1,717 people. Given that the methodology used assumes equal distribution of population within an area, the portion of the TAZ within the road segment's ½-mile impact zone would yield an estimate of 294 people. Conversely, the Census blocks for the same vicinity are found to contain zero population.

Row three provides a map of this specific TAZ area (outlined in red) and shows that the majority of this TAZ falls within the Blue Hills Reservation (green fill). Only the northeast portion of this TAZ contains local streets and residential neighborhoods. Aerial imagery of the road segment's ½-mile impact zone confirms that the north central portion of the impact area would indeed have zero residential population as it is vacant land. Similarly, notice the south central portion of the road segment's impact zone, which displays a water body (Great Pond). Again, the Census block reflects a zero population count for this area, while the TAZ method predicts 85 people.

The take away point from these two examples is that Census block areas are more accurately estimate population exposure along road segments. We recognize that population counts based on census block areas are only estimates of population as opposed to an absolute, quantifiably correct value. Any method used for estimation will have inherent error associated with it, but the objective is to minimize the error. Equally distributing population across large areas (such as TAZs) produces estimation errors when trying to assess the population within a small area. A more accurate method would be to use small areas over which to distribute population density (i.e., utilize Census blocks, as they are structured to better represent localized population demographics). Given the large size of the TAZ areas, there is greater potential to have instances of both over- and under-estimates of population as compared to the use of Census block areas.

2.4.3.4. Impact on the Risk Analysis Results

The use of Census block areas as opposed to TAZ areas would definitely have an impact on the route risk analysis results. However, the specific (quantified) impact cannot be determined without further analysis. We can, however, discuss known patterns that would influence the risk calculation and, therefore, alter the comparison of the through-route analysis.

As the previous examples illustrated, errors in estimation are more prevalent when large TAZ areas are utilized versus the more granular Census block areas. Figure 9 below illustrates that the average size of the TAZs along the "Through Route" are significantly smaller in size than those utilized by the two route alternatives. This implies that the error in population estimation (both over- and under-counting) will be more pronounced on the two alternative routes (with generally larger TAZs) as compared to the "Through Route" (with smaller TAZs). Additionally, it should be noted that the estimation error would likely be more dramatic if a smaller impact zone buffer distance were used (i.e., a 0.1-mile buffer vs. a ½-mile buffer).

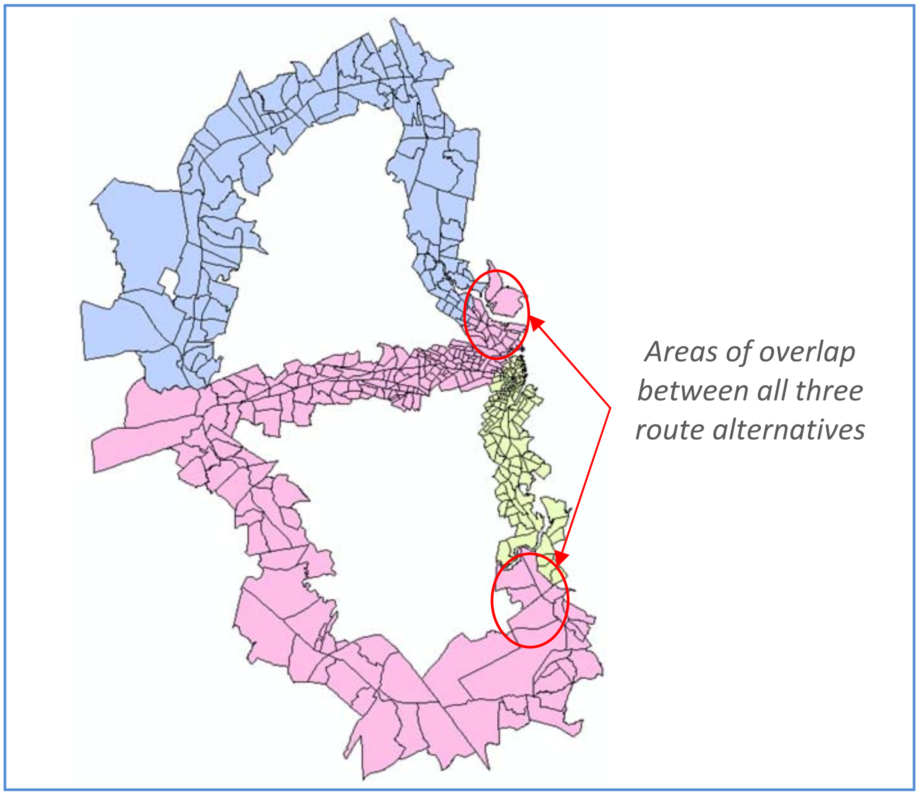


Figure 9. TAZ Areas within a ½-mile of the Route Alternatives

Given that the Boston Report utilizes population exposure as the only quantified consequence metric in the risk formula, any changes in how population is estimated would have an effect on the segment-based risk value and thus on the cumulative route risk score. Since the TAZ estimation error is not uniform in its effect on a road segment's population estimate (meaning estimated population could be either greater or less than currently modeled, based on the specific topology of that road segment, and its surrounding TAZ areas), the net result (and magnitude) of impact within the overall risk analysis cannot be known - although it is safe to conclude there would be differences.

2.4.3.5. Other Considerations related to Population Estimation

It is possible that the Boston Report authors chose to utilize the CTPS TAZ areas and their associated population values because these areas may have been reported to provide updated residential population estimates and a source of employment data. Without specific knowledge about the content, history, and derivation of the CTPS population and employment values (i.e., data vintage; whether the values were estimated, projected, or aggregated up for 2010 Census blocks statistics; etc.), we are hesitant to comment on the validity of these values.

It is important to recognize that the previous discussion about TAZ areas vs. Census block areas is still applicable. While the previous examples did utilize specific population values, the source of the error has more to do more with how the population was distributed across larger areas versus smaller areas. If the CTPS population values were found to represent the most current population vintage, then there are GIS methodologies that could be used to apportion the TAZ population back to Census block areas while still maintaining the granularity of population distribution across the Census blocks. Note that with the release of the block-level population data from the 2010 US Census in the spring of 2011, it is highly likely that the Census block data is the most current representation of population distribution.

Given that large TAZ areas were used to estimate population distribution, the significant effort exerted in the study to estimate the point-source population contributors seems unbalanced. For example, in order to estimate the number of people to be associated with the daytime population of a specific hotel, measurement of meeting space square footage and the number of rooms was acquired and manipulated. The benefit of this effort is lost when you consider the magnitude of the population estimation differences (inaccuracy) illuminated in the examples previously discussed for TAZ areas vs. Census block areas. For instance, the first example was found to have an estimation difference of 1,469 people for a single 0.23-mile road segment. In the case of hotels, the largest single contributing hotel had an estimated daytime population of 1,696, with the average number of people per hotel being 284 people. Whether or not hotel population is considered in the road segments' population estimate is insignificant relative to potential inaccuracy resulting from the underlying residential population estimation utilizing TAZs.

Another population data source commonly used by the transportation risk assessment community is found in HAZUS-MH.[11] HAZUS-MH, developed by FEMA to serve as its tool for estimating the potential losses from disasters, utilizes GIS data to estimate physical, economic, and social impacts. In order to support this mission, HAZUS-MH has developed enhanced Census block population statistics. Specifically, the base US Census block statistics were augmented with employment data and modeling by Dun & Bradstreet. The result of this effort is the reporting of daytime and nighttime population estimates at the Census block level that are inclusive of an area's employment profile. Additional HAZUS-MH data available at the block level include hotel, visitor, school, college, and commuter populations. This enhanced Census block population data is available nationwide in GIS format and is included in the HAZUS-MH product release for public use. Many government-sponsored risk assessment efforts utilize the HAZUS-MH Census block population data in their consequence modeling.

2.4.3.6. Potential Issues with Calculating Population Estimates

As discussed, the comparative risk analysis of the through-route alternatives should have included the current legal hazmat route restriction. Within the Boston Report, one alternative route (RA9 Commercial/North Washington) did at least cover the downtown Boston portions of the current hazardous material route restriction (see route directions in Table 5). Figure 10 provides an image of the northbound path of route "RA1 – Through Boston" (in pink) and route "RA9 – Commercial/North Washington" (in green).

[11] http://www.fema.gov/plan/prevent/hazus/

Table 5. Route Directions

MassDOT[12]	Boston Report (p. 23)
Northbound I-93 Boston Hazardous Cargo/Material Tunnel Detour ▪ Take I-93 Northbound to exit 18 (Mass. Ave) ▪ From exit 18 continue north on Frontage Rd. to the intersection of Frontage and Broadway. ▪ Proceed north onto the South Station/Downtown on ramp. ▪ At the end of the ramp proceed straight onto Atlantic Ave northbound. ▪ Follow Atlantic Ave northbound, at Christopher Columbus Park turn right onto Commercial Street. ▪ Follow Commercial Street around and turn Right onto No Washington Street ▪ Stay Straight on No. Washington Street through Charlestown-No. Washington Turns into Rutherford Avenue. ▪ Continue straight onto Rutherford Avenue towards Sullivan Square. ▪ At the Sullivan Square follow the signs around to I-93 (this is Mystic Avenue) ▪ Follow Mystic Avenue northbound to the I-93 North on ramp at Assembly Square (Home Depot). ▪ Proceed onto I-93 Northbound adjacent to the Assembly Square on-ramp in Somerville.	***2.2.9A: Commercial/North Washington NB (Route Alternative 9) [RA9]*** This route runs northward through the cities of Boston and Somerville in Massachusetts. The route runs north along Atlantic Avenue and Commercial Street to MA-99 in Boston and MA-38 in Somerville. Specifically, the route starts on I-93 Frontage Road at Exit 16 and continues as follows: **Start on I-93 at Exit 16** North on I-93 Frontage Road Continue north onto Atlantic Avenue Northeast onto Commercial Street Northwest on North Washington Street Continue northwest onto Rutherford Avenue At Rutherford Avenue, there are two destination points. The two routes continue from the above directions as follows: **Destination 1: (used when comparing alternative routing)** Northeast on Alford Street/MA-99 End on Alford Street/MA-99 Bridge just before Everett

Since RA9's origin is not the same as RA1's (or RA2's or RA3's), the risk analysis results among the routes cannot be compared. Notwithstanding this finding, several issues are apparent after reviewing the risk results tables in the Boston Report for routes RA1 and RA9. For convenience, the relevant information has been transcribed and presented in Table 6 below. Looking at the reported population statistics, the population differential between these two route alternatives seems suspect. The shorter route, RA9 (5.1 miles) is reported to have higher daytime and nighttime population values than those found on RA1 (10.7 miles). Given that route RA9 is half the length of RA1 and that approximately 85 percent of route RA9 uses road segments in common with route RA1, an investigation into this issue was warranted. Could RA9 really have higher population exposure than RA1?

[12] http://www.massdot.state.ma.us/highway/DoingBusinessWithUs/PermitsRoadAccessPrograms/CommercialTransport.aspx

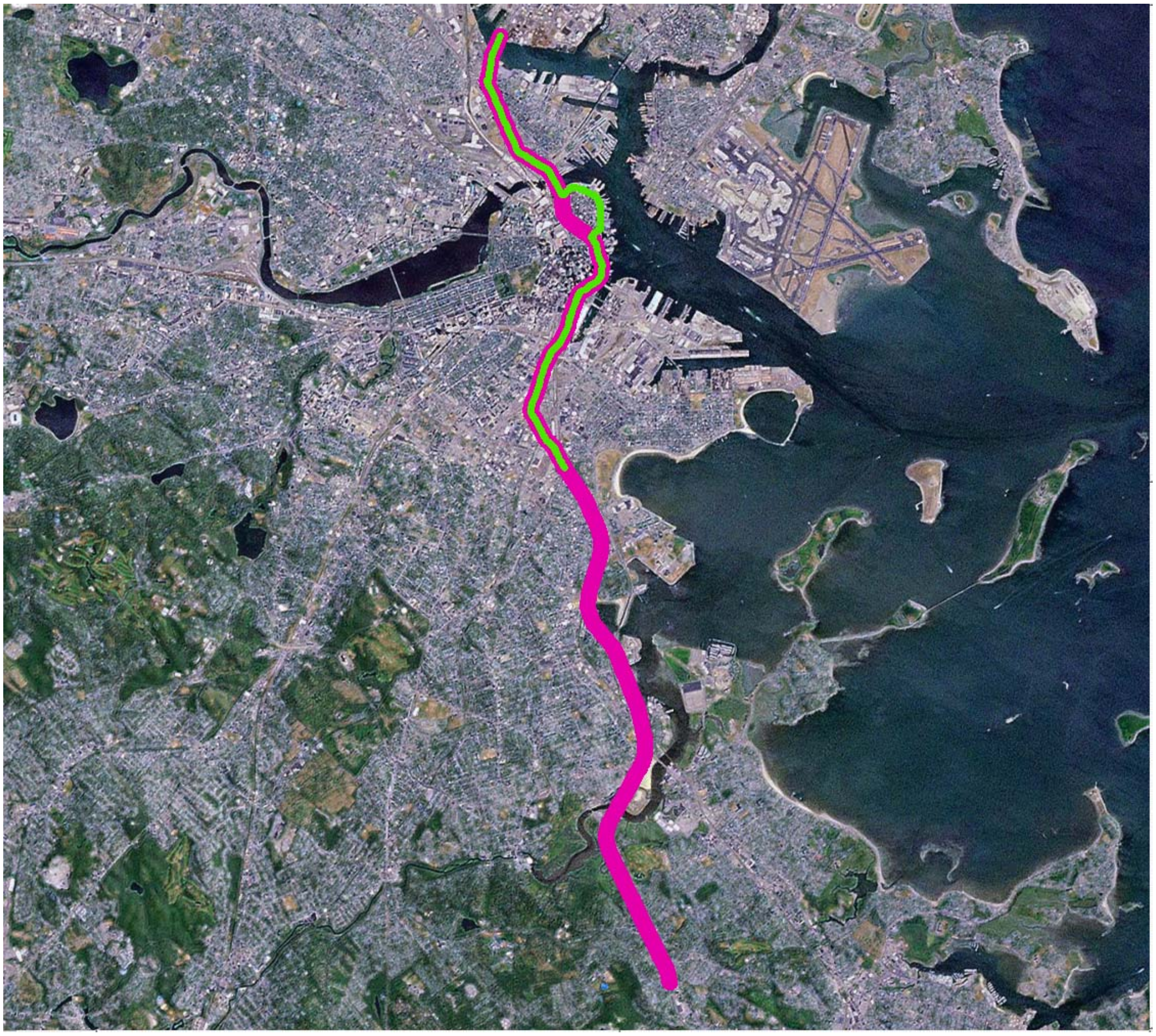


Figure 10. Routes RA1 and RA9 Northbound

Table 6. Population Statistics Reported in the Boston Report

Route Description	Distance Miles	Daytime Population	Nighttime Population	Daytime Pop Density (people/mi^2)	Nighttime Pop Density (people/mi^2)	Boston Report Reference
Route RA1 – (Northbound) Through Boston	10.7	309,000	173,000	28,900	16,200	Table 8
Route RA9 – (Northbound) Commercial/North Washington	5.1	321,000	139,000	62,900	27,300	Table 10

Reviewing the route paths for RA1 and RA9, we find that there are two differences between them. One variance occurs in downtown Boston; RA1 utilizes Cross Street, while RA9 traverses Commercial Street. The other variance occurs on RA1, which incurs additional mileage between Exit 9 and Exit 16 on I-93

If we focus on the daytime population reported for these two routes (309,000 for RA1 and 321,000 for RA9) we find that the difference in daytime population is 12,000. That is, RA9 is reported to impact 12,000 more people than RA1. Given that RA1 is 5.6 miles longer than RA9, and we know that there are densely populated areas located within a ½-mile buffer of I-93 between Exit 9 and Exit 16 (see Figure 10), then the only way (theoretically) that RA9 could have a higher population than RA1 would be if the difference in the routing in downtown Boston (i.e., Cross Street vs. Commercial Street) was of such significance that it offset (and extended 12,000 people beyond) the population contribution from the 5.6-mile section of I-93 Exit 9 to Exit 16. This is highly improbable. We would intuitively expect the two route path patterns in downtown Boston (Cross Street vs. Commercial Street) to have similar population characteristics within ½ mile. Both paths are of similar length, they occur in close proximity to each other, and thus they will likely impact the same population concentrations. However, the closer proximity of Commercial Street to the water may have a noticeable effect on the population estimates.

The route population data presented in the Boston Report appears to contain flaws. To support this statement, the following discussion is presented. The premise to be proven is that the difference in routing in downtown Boston (i.e., Cross Street vs. Commercial Street) is not of such significance as to offset the population contribution that would be received from the addition of 5.6 miles on I-93 between Exit 9 to Exit 16.

Figure 11 diagrams the difference in route path between northbound RA1 and RA9. The horizontal gray dotted lines reference locations along the route path profiles where the routes are at a point of convergence or divergence. The “Route Difference” column presents the two variances between RA1 and RA9.

The line labeled as Reference Point:

1 represents Alford Street/MA-99 Bridge just before Everett.

2 represents I-93 Exit 16

3 represents I-93 Exit 9.

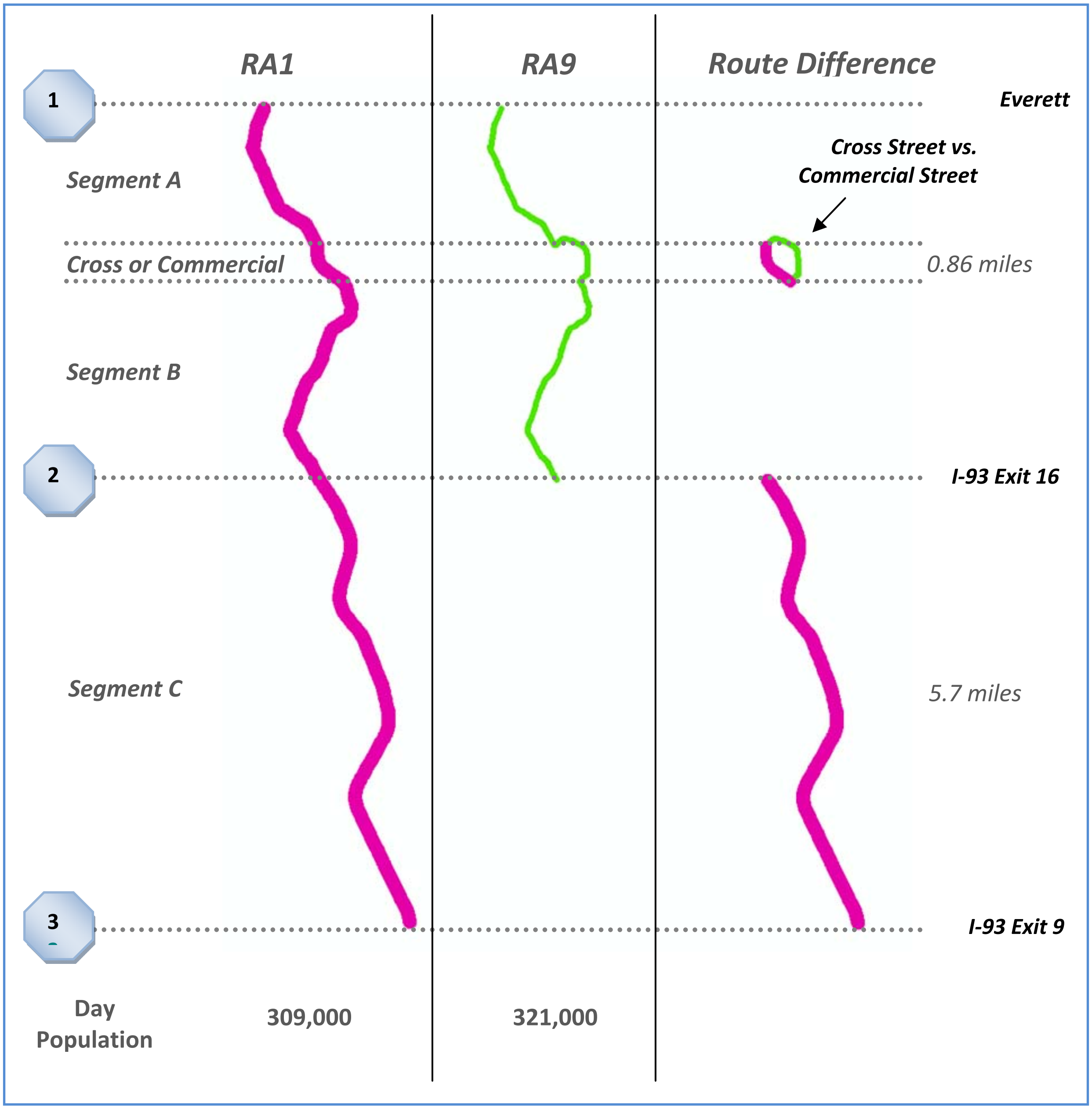


Figure 11. Route Path Comparison

Figure 12 contains a series of graphics illustrating a GIS spatial analysis to evaluate population associated with the differing routings in downtown Boston. This analysis is focused on only the difference in routing, not the entire RA1 and RA9 routings. Both route paths presented utilize the same origin and destination locations, located at the point where RA1 and RA9 diverge and converge with each other.

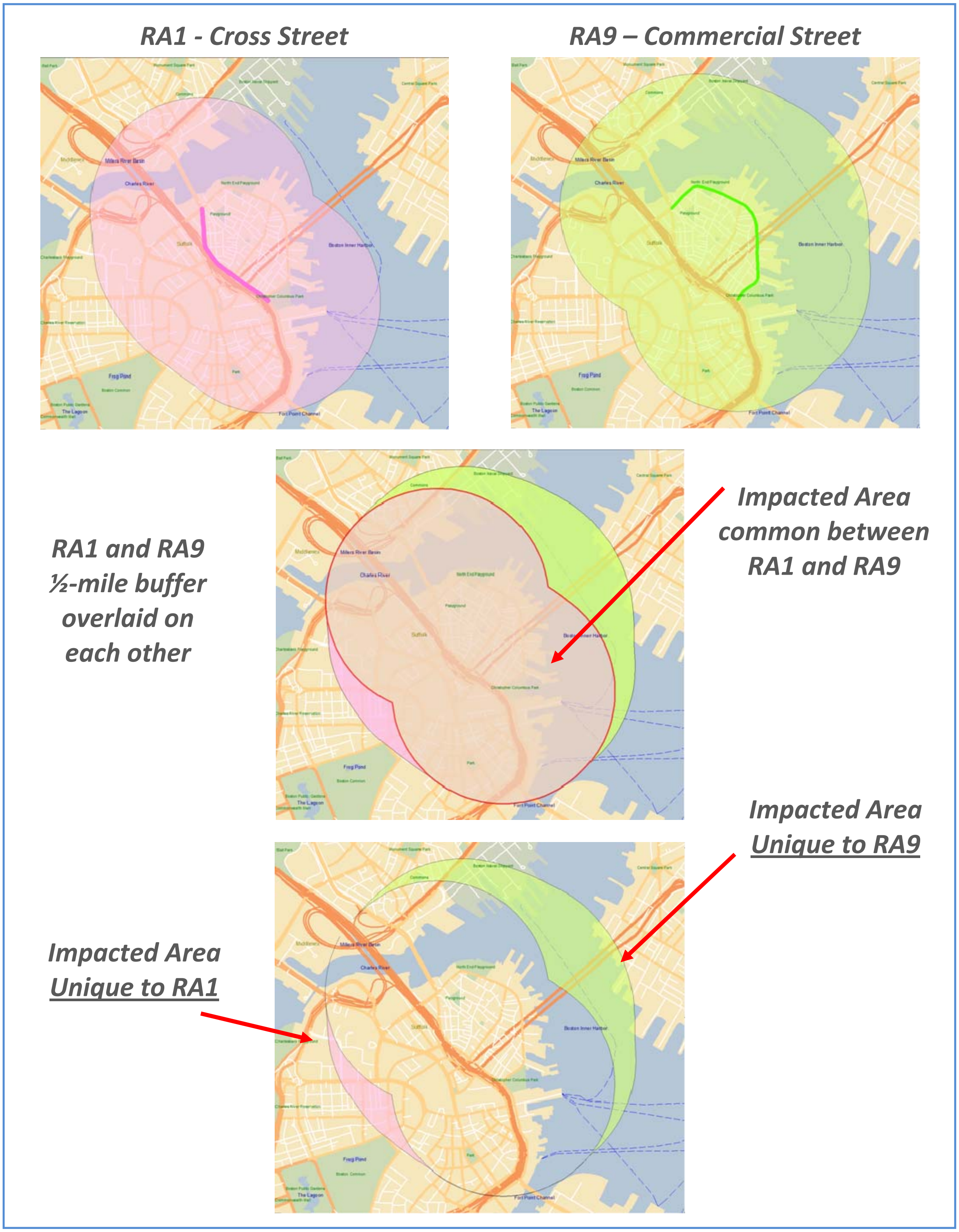


Figure 12. Impact Areas – ½-mile Buffer around Downtown Route Differences

The first row presents the Cross Street and Commercial Street route paths with their respective ½-mile impact zones displayed. As expected, there is a large amount of impact area overlap between the two paths. The graphic on the second row depicts those areas in common (middle section outlined in red) as well as those areas unique to each route path. The final graphic presents the resulting differences in impact area exposure. For example, the pink shading indicates an area that will only be affected by RA1. We've termed this area "Unique to RA1." Similarly, the green shading represents the "Unique to RA9" impact area.

Again, the premise/goal of this analysis is to determine the difference in population exposure achieved by these two downtown routing alternatives. By focusing only on the impact areas unique to each route path, we will be able to determine the net change in population.

Now that the route specific unique impact areas have been identified, the associated underlying TAZ areas can be determined. Figure 13 presents a graphic that displays the TAZ areas in yellow with the unique impact areas overlaid. The second graphic shows the apportioning of the unique impact areas into their underlying TAZ areas. Based on the portion of the TAZ utilized, we then calculated the daytime residential, daytime employment, nighttime residential, and nighttime employment populations as prescribed in the Boston Report for the unique impact areas.

Figure 13. Unique Impact Areas – TAZ Areas and Facility Locations

Additionally, utilizing the information contained in the Boston Report's Appendix D, we were able to create GIS data layers representing the locations of hospitals, hotels, long term care facilities and schools (see second graphic in Figure 13). Based on the longitude and latitude values provided in the report, we found that within the "Unique to RA1" impact area there were two hotels. No other facilities (e.g., hospitals, long-term care, schools) were identified in either unique impact area. Note the ½-mile impact area for both the downtown route paths is known to include visitor population related to the Boston National Historic Park. We believe most of the park site locations fall within the common impact area between the two routes (see Figure 12, row 2). Geographic coordinates for the Boston National Historical Park sites where not provided in the study report so we were unable to determine if any of the sites were only impacted by a single route in the Battelle analysis. Whether or not there is a difference in the visitor population between these two routes is insignificant in our analysis; even if all 8,849 people were attributed to a single route, it would not alter/affect our findings about the significance of the difference between RA1 and RA9.

Table 7 below presents our findings related to the population within each of the unique-to-impact areas. As predicted, the net difference in population exposure between these two downtown routings is negligible. The use of RA1's Cross Street routing does not drastically reduce the population that would have been exposed if RA9's Commercial Street was used. By these analysis results, the use of Cross Street would actually have a slight increase in population exposure.

Table 7. Population Comparison

Impact Area is Unique to	Daytime Population				Nighttime Population			
	Residential	Employment	Hotel	Total	Residential	Employment	Hotel	Total
RA1 - Cross Street	743	5,867	196	**6,806**	2,478	1,202	523	**4,203**
RA9 - Commercial	621	663	-	**1,284**	2,071	136	-	**2,207**

Based on intuition and supported by the results of the analysis above, it is apparent that there are errors in the reporting of population totals for at least some of the routes. Without re-performing the Boston Report population estimation process in its entirety, we cannot specifically identify how many or which routes contain this error. If numerous errors in the estimation of route population totals are found, the accuracy of the prescribed population estimation method at the road segment could be far worse. The northbound and southbound route paths of RA1, RA2, and RA3 alone are comprised of over 650 individual road segments from the 2010 Massachusetts Road Inventory geodatabase[13].

In the Boston Report, population exposure is the consequence component in the risk equation. It is one of only two factors used to determine a road segment's (and ultimately a route's) risk value. Any errors or changes in how population was estimated (i.e., our recommendation to utilize Census block areas) would alter the risk results.

[13] RoadInv2010_pGDB.zip obtained from http://www.eot.state.ma.us/default.asp?pgid=content/plan02&sid=about

2.4.4. Considering Subjective and Secondary Factors

2.4.4.1. Emergency Response Times

As emphasized in the 1996 Routing Guide, "[e]mergency response capabilities can be a critical consideration in evaluating the consequences of a highway accident involving the release of hazardous materials." The Guide recommends that "the number of properly trained and equipped firefighting units *within a 10-minute response window* from any point along a highway route under analysis" (emphasis added) is the proper measure to use when considering the mitigating effects of emergency response. The Guide also recommends "the level of planning and preparedness at the local level as an important indicator of the vulnerability of a community to the consequences of a hazardous materials incident."

The Boston Report clearly highlights the difference in preparedness between the response capability in the City of Boston and the rest of the region. Boston-based response units can respond within 5 to 10 minutes; whereas, getting an operational team on-scene in other areas can take up to 30-60 minutes. Even at this conservative estimate, this is a significant difference. In locations where significant congestion might occur, the ability for adequate response to arrive on the scene of an accident would further increase these times. The Boston Report states that emergency response capabilities are adequate and could not be used to differentiate between different routes. Again, the 1996 Routing Guide instructs analysts to use a 10-minute response time to determine adequate emergency response coverage from adequately capable teams. Response times greater than the 10-minute window are, therefore, not meeting the defined adequacy.

Although the Boston Report focused on Class 3 flammable liquids, they did not mention the growing national trend toward increased use of ethanol. This may be an important emergency response-related issue due to the specialized fire suppression foam required to fight ethanol fires. The availability of this specific foam to response units throughout the area would be an appropriate item to address.

2.4.4.2. Climate

We concur with the Boston Report's conclusion that there are no relevant differences in the routes due to climactic conditions. If there were such differences between the routes, one would expect them to be captured by the accident rates for the different types of roadways, which were based on regional data and not national averages.

2.4.4.3. Environmental Exposure

The many data types and sources cited in the Battelle study related to environmental exposure appear to be appropriate. There are, however, questions concerning the information presented about the acreage of environmental exposure along a route, which may indicate that there are problems with underlying calculations. For convenience, Table 8 is a reproduction of the Boston Report's "Table 22. Environmental Risk Results for the Alternative Routes RA1 through RA6."

Table 8. Reproduction of Boston Report Table 22

Route	Distance	Acres	Environmental Risk $*10^6$
Everett to Quincy (Exit 9 on I-93)			
Route Alternative 1 – Through Boston	10.7	920	0.47
Route Alternative 2 – Through Cambridge	33.2	4,583	2.9
Route Alternative 3 – I-93S to I-95N to I-93S	47	14,500	6.8
Everett to Quincy (Exit 12 on I-93)			
Route Alternative 4– Through Boston	19.5	6,969	2.2
Route Alternative 5 – Through Cambridge	24.4	2,606	1.3
Route Alternative 6 – I-93S to I-95N to I-93S	38.2	10,898	5.1

With the exception of the route segments between I-93 Exit 9 and I-95 Exit 12, RA1 is identical to RA4, RA2 is identical to RA5, and RA3 is identical to RA6. Therefore, one would expect that certain metrics would be identical among counterparts plus or minus the constant contribution of the 8.8-mile path between I-93 Exit 9 and I-95 exit 12.

Combining roadway GIS data with the sensitive environmental area information in Appendix E of the Boston Report allows one to sum the distance and environmental exposure metrics for all six of these routes and compute pairwise differences. Figure 14 shows the common stretch of roadway between these routes. Table 9 demonstrates expected results for distance differentials but not for environmental exposure acreage. The 8.8-mile path's contribution to the acreage of environmental exposure is different for each pair of routes (6,049 vs. 1,977 vs. 3,602). Given a consistent measurement technique, the value should be the same in each case; therefore, there appear to be calculation errors in the estimation of environmental exposure.

Table 9. Discrepancy in Environmental Exposure

Comparing	Absolute Differences between I-93 Exit 9 and I-95 Exit 12 Routes	
	Distance	Acres
RA1 to RA4 – Through Boston	8.8	6,049
RA2 to RA5 – Through Cambridge	8.8	1,977
RA3 to RA6 – I-93S to I-95N to I-93S	8.8	3,602

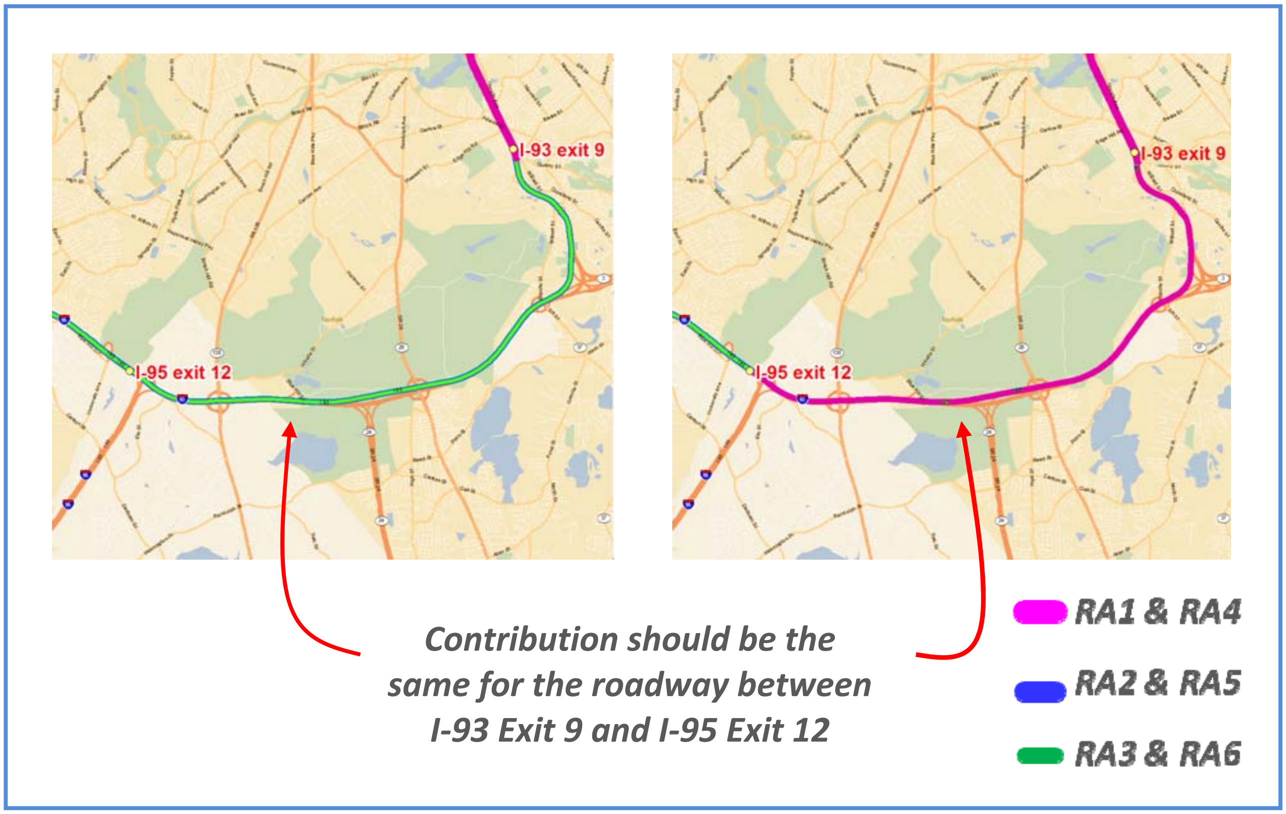


Figure 14. Common Roadway Segments with Environmental Exposure Discrepancies

The Boston Report states that a 140 percent difference between two routes' environmental exposure values is not significant. This statement referenced RA4 and RA5; however, the difference is 1,350 percent when comparing RA1 and RA3. As the speeds on the highway alternatives are generally greater than those through the city, one would expect the conditional release probabilities, if they were used, to create an even larger difference between the routes. As it is, the accident expectancy on the recommended route (RA3) is more than double that of the through route.

Finally, page 98 of the Boston Report uses the argument that US DOT regulations adequately protect the population and the environment, so there is no need to consider the increased environmental risk. If this were a valid argument, which it is not, then by inference, it could also be applied to population-based risk, eliminating the need to do any comparative route risk assessment at all.

2.4.4.4. Other Considerations related to Environmental Exposure

In the Boston Report, a ½-mile impact distance was used for both population and environmental consequence measurement. In route risk assessments, the impact distance used to measure environmental exposure often does not match that used to measure population exposure. A 0.1-mile impact distance is commonly used for measuring environmental exposure. The rationale behind this approach is that it more realistically assesses the potential environmental exposure from a release. Considering water bodies for example, often the negative impact of exposure only occurs if the product makes its way into the water source. If an accident occurs on a roadway, would we expect a released liquid or solid to be either dispersed in the air (with no major environmental effects). Much more unlikely is the case presented in the Boston Report that product would flow along the ground for a distance of almost ½ mile before reaching the edge of a water source. Utilizing a 0.1-mile buffer along the road segment, therefore, better captures the environmental exposure that is present along the roadway corridor. If the route crossed or ran parallel to a water body, exposure to it would be captured with the 0.1-mile buffer. By reducing the impact distance, exposure that is unlikely to occur is not counted.

2.4.5. Uncertainty and Sensitivity Analysis

2.4.5.1. Uncertainty

The Boston Report computes uncertainty estimates for the daytime and nighttime risk at 0.14 (14 percent). These estimates consider the uncertainty in the accident rates as well as in the population estimates. The Boston Report states that at the 95-percent confidence level, the only statistically significant difference in risk values identified in the report is between RA1 and RA3.

One area of confusion is the basis for the coefficient of variation for employment population and how it was converted into a standard deviation. The coefficient of variation is the standard deviation divided by the mean, yet Appendix F of the Boston Report states that “the coefficient of variation of the employment numbers is estimated to be about 1 percent.” The reference cited is specific to government employment estimates only (not commercial) and does not provide specific values.

2.4.5.2. Sensitivity Analysis

Sensitivity analysis in the Boston Report is limited to the following:

- To determine whether any roads, if evaluated, with a functional classification of “Local” or “Urban Collector” have some influence on the route selections, since there is a lot of uncertainty in the accident rates for them
- Examination of other transient populations that could be present along the potential routes
- Using an alternate endpoint for the through-route analyses
- Changing the fraction of the residential population that is present during the day
- Changing the fraction of employment population that works at night

While the Boston Report characterizes the uncertainty analysis in Appendix F as a sensitivity analysis, it does not examine the effects of altering the values of any of the parameters in the risk equation. The selection of an alternate endpoint to investigate the sensitivity of the through-route analysis is inappropriate and does not constitute a sensitivity analysis. If the data or collected information (through the surveys or interviews) indicates that through transportation of hazardous materials follow that route, then it should be considered as part of the base analysis framework. That analysis should consider a range of primary through movements to identify an appropriate route-based risk mitigation strategy; adding more variance in the origin-destination pairs analyzed would reflect the variety of movements through the region. The selection of origins and destinations is discussed further in Section 2.1.

Given the dominance of the residential plus employment population to the total population (versus the contribution of selected facilities), it would be expected that adjusting the fractions that stay home during the day or that work at night would not alter the results. The Boston Report states that “the downtown Boston employment is predominately financial…”, which might suggest a low work-at-home ratio. Conversely, the Boston suburbs might be expected to have a larger percentage of at-home workers.

Other sensitivity analyses that the Boston Report identifies but does not perform are:

- Varying the accident rate
- Counting additional hospital visitors
- Adjusting the Census-based population counts to account for changes since the data were collected
- Adjusting the visitor population and accounting for the tour bus population

The assumption that any underreporting would be systemic and equal across all roadway functional classifications is unlikely to be true. Assuming that all fatal and personal injury accidents will be reported, it is less likely that all property damage accidents would be reported. Given that speed is a key factor in accident severity, roadway functional classification would be correlated with the lower-speed accidents and, therefore, affected.

With the relatively low hospital population counts, it is reasonable to ignore the potential undercounting of hospital visitors, changes in the visitor population, and including the tour bus population. Similarly, we agree that it would not be worthwhile to adjust for the time since the Census data were collected.

With the exclusive focus on Class 3 flammable liquids, an important analysis that was not performed would be to vary the impact ranges used to measure population exposure. Such an analysis would be relatively easy to do as long as the current analysis was conducted using a GIS, which appears to be the case. This would reduce the concern about the commodity flow analysis.

2.4.6. Burden on Commerce

The analysis of the burden on commerce in the Boston Report is exclusively focused on the local transportation of petroleum products and particularly those that are moved in the greater Boston area. The report also makes some assumptions about the movement of petroleum products in the greater Boston area that are not supported by any data. There are other product movements that should be considered as well, including long-haul shipments moving longer distances than those analyzed.

Travel time estimates from CTPS used in the Boston Report are based on mid-day field observations rather than averages, which would include peak congestion time periods. The effects of the significant congestion in the Boston region do not appear to be captured by these estimates. To the extent that the shipments along the alternate routes may have even longer travel times than the through routes due to congestion has not been evaluated and may underestimate the burden on commerce.

Finally, the burden on commerce analysis did not consider that the additional travel time required to use the alternate routes has the potential to extend the workday for each of the drivers. The Boston Report assumes that each driver has only sufficient time to complete two round trips per day in a normal workweek. The current federal hours of service rules include both driving and non-driving work time and this would result in a reduction of 50 percent over current delivery expectations. [14]

[14] http://www.fmcsa.dot.gov/rules-regulations/topics/hos/index.htm

2.4.7. Recommended Routes and Potential Restrictions

The Boston Report recommends that there is a strong basis for prohibiting through shipments of hazardous materials from Boston during the day. They do not make a similar claim for through shipments at night.

The Boston Report makes no attempt to establish an absolute threshold for acceptable risk. Their analysis can only support the relative risk between two or more route options with identical origins and destinations.

The Boston Report states that using other chemicals in their analysis would not alter their results. This claim is not substantiated in the report.

3. Findings

After a thorough assessment of the Boston Report and the methods and data utilized to form conclusions, several key issues were found. In addition, a variety of cases in which there were irreproducible results were evident. The following issues should be addressed before decisions concerning hazmat route designations are finalized.

3.1. Key Findings

- The Boston Report does <u>not</u> evaluate the legally designated hazmat route currently in effect. This is a critical procedural error given that any analysis performed under 49 CFR 397.71 must evaluate the relative safety of any alternatives as compared to the current routing (49 CFR 397.71 (9)(ix)).

- The Boston Report lacks discussion of the specific hazmat movements that are under consideration before the alternative selection process is described. The specific origins and destinations used to define the route alternatives are selected without description of the rationale for why they were chosen. Therefore, we must assume they were chosen arbitrarily or out of analytical convenience. Further, the Boston Report does not consider sufficient origin-destination pairs to evaluate the selection of through routes. One analysis endpoint, for example, is more suitable for routing to or from local establishments than through routing.

- The Boston Report only considers Class 3 flammable liquids, suggesting that all other US DOT hazard classes of products would result in identical routing analysis results. Based on the report, these materials only account for 50 percent of the hazardous materials accidents that occur in the area. From the sources cited in the Boston Report, shipments involving Classes 2, 3, 8, and 9 materials are moving regularly within the Boston region. Based on the high degree of variability for exposure distances among US DOT hazard classes, a "one size fits all" conclusion cannot be assumed. As such, a formal analytical validation is required. US DOT regulations require that consideration be "given to the relative impact zone and risks of <u>each</u> type and quantity … of NRHM normally transported along highway routes which are included in a proposed NRHM routing designation."

- It is not clear why a ½-mile impact range was selected, given the discussion in the Boston Report about the remoteness of an impact from a release of a flammable liquid extending to ½ mile.

The report indicates that the likely impacts from a release would mostly affect the occupants of other vehicles on the road. If this is the case, then a much narrower impact area would be appropriate. The guidance document, *Hazardous Materials Routing Using Safety and Security Criteria,* March 19, 2008, Battelle provides two potentially appropriate impact ranges for flammable liquids: 50 meters and 100 meters, both of which are less than 0.1-mile. If the extreme ½-mile case were appropriate for use, it would still require the use of a probability-based component to reflect the remote likelihood of a release given an accident.

- The study utilized TAZ boundaries to facilitate the estimation of residential and employment population along a route; it is not clear why the readily available and more granular Census block boundaries were not used instead. Given the large size of the TAZ areas, there is greater potential to have instances of both over- and under-estimates of population as compared to the use of Census block areas. Because the Boston Report utilizes population exposure as the only quantified consequence metric in the risk formula, any changes in how population is estimated would have an effect on segment-based risk values and thus on the cumulative route risk values. Utilizing Census block areas with population data sourced from either CTPS, Census Bureau, or HAZUS-MH data would help to mitigate these issues and provide a significantly more accurate assessment of risk.

- Reviewing the data included or cited in the Boston Report, we identified errors in the results of consequence estimates for population and environment exposure. For example,

    - Examination of specific routes uncovered some apparent population-related calculation errors.
    - Information presented about the acreage of environmental exposure along a route indicates that there are problems with underlying exposure calculations.

3.2. Other Findings

- Security issues are not addressed in any way even though the Boston Report analysts were the authors of the most recent federal hazmat routing guidance document, which was specifically written to incorporate security components into the safety-based approach. Instead, the Boston Report relies on a pre-9/11 document from 1996.

- The Boston Report does not consider any low-probability, high-consequence events, even to address why they were not included. For example, a release from a cargo tank carrying anhydrous ammonia.

- The study utilized a very conservative approach and did not consider a release probability component in the risk evaluation. Conditional release probabilities can be appropriate to reflect different impact velocities (which can be tied to roadway functional classification) and container integrity (only useful if multiple commodity types are considered). For example, the BLEVE assessment in the Boston Report utilizes a rail car, not a cargo tank, which presents very different protections against a BLEVE. The 1996 Route Guidance (p. 19) discusses the potential use of conditional release probabilities.

- The Boston Report was remiss in not presenting information related to a route's average accident rate and accident expectancy. While these factors can be derived from the information provided in the report, one would need subject matter expertise to be able to do so. Based on the findings of the Boston Report, the recommended route (RA3) has an accident expectancy double that of the through-route alternative. Acceptance of the recommended route implies a willingness to accept twice as many accidents occurring due to increased speed and trip distance.

- There is an inconsistency in the Battelle Report between the text and Table 1 showing the accident rates. The calculations are likely correct but the text is incorrect and that should be verified.

- The Boston Report clearly highlights the difference in preparedness between the response capability in the City of Boston and the rest of the region. Boston-based response units can respond within 5 to 10 minutes; whereas, getting an operational team on-scene in other areas can take up to 30-60 minutes. Even at this conservative estimate, this is a significant difference. In locations where significant congestion might occur, the ability for adequate response to arrive on the scene of an accident would further increase these times. The 1996 Routing Guide instructs analysts to use a 10-minute response time to determine adequate emergency response coverage from adequately capable teams. Response times greater than the 10-minute window are, therefore, not meeting the defined adequacy.

- Although the Boston Report focused on Class 3 flammable liquids, they did not mention the growing national trend toward increased use of ethanol. This may be an important emergency response-related issue due to the specialized fire suppression foam required to fight ethanol fires and which is different and more expensive than the foam used to fight oil and gasoline fires.[15] The availability of this foam to response units throughout the area would be an appropriate item to address.

- The Boston Report states that a 140 percent difference between two routes' environmental exposure values is not significant. This statement referred to RA4 and RA5; however, the difference is 1,350 percent when comparing RA1 and RA3. As the speeds on the routes around downtown Boston are generally greater than those through the city, one would expect the conditional release probabilities, if they were used, to create an even larger difference between the routes.

- The Boston Report uses the argument that US DOT regulations adequately protect the population and the environment, so there is no need to consider the increased environmental risk. If this were a valid argument, which it is not, then by inference, it could also be applied to population-based risk, eliminating the need to do any comparative route risk assessment at all.

- In the Boston Report, a ½-mile impact distance was used for both population and environmental consequence measurement. In route risk assessments, the impact distance used to measure environmental exposure often does not match that used to measure population exposure. A 0.1-mile impact distance is commonly used for measuring environmental exposure. 49 CFR 397.71(9)(vi) states that "The distance to sensitive areas shall be considered."

[15] http://www.iafc.org/files/1HAZ/haz_Advisory_Guidance_Ethanol_Gas_Mixtures.pdf; http://www.usatoday.com/news/nation/2008-02-26-2111231703_x.htm

- One area of confusion is the basis for the coefficient of variation for employment population and how it was converted into a standard deviation. The coefficient of variation is the standard deviation divided by the mean, yet Appendix F of the Boston Report states that "the coefficient of variation of the employment numbers is estimated to be about 1 percent." The reference cited is specific to government employment estimates only (not commercial) and does not provide specific values.

- The selection of an alternate endpoint to investigate the sensitivity of the through route analysis is inappropriate and does not constitute a sensitivity analysis. If the data or collected information (through the surveys or interviews) indicates that through transportation of hazardous materials follow that route, then it should be considered as part of the base analysis framework.

- With the exclusive focus on Class 3 flammable liquids, an important sensitivity analysis that was not performed would be to vary the impact ranges used to measure population exposure associated with Class 3 flammable liquids.

- Another useful sensitivity analysis would have been to utilize multiple impact ranges, which model the varying potential impacts of different commodities. This would help to reduce the concern about the limited commodity flow analysis and is more in line with regulatory expectations.

- The analysis of the burden on commerce in the Boston Report is exclusively focused on the local transportation of petroleum products and particularly those that are moved in the greater Boston area. The report also makes some assumptions about the movement of petroleum products in the greater Boston area that are not supported by any data. There are other product movements that should be considered as well, including long-haul shipments moving longer distances than those analyzed, specifically to communities in other areas that will be impacted by reduced product delivery and by increased cost.

- Travel time estimates from CTPS used in the Boston Report are based on mid-day field observations rather than averages, which would include peak congestion time periods. The effects of the significant congestion in the Boston region do not appear to be captured by these estimates. To the extent that the shipments along the alternate routes may have even longer travel times than the through routes due to congestion has not been evaluated. Not only does this impact emergency response time, it may underestimate the burden on commerce, particularly during the 6-10 am and 3-7 pm rush hour periods.

- Finally, the burden on commerce analysis did not consider that the additional travel time required to use the alternate routes has the potential to extend the workday for each of the drivers. The Boston Report assumes that each driver has only sufficient time to complete two round trips per day in a normal workweek. The current federal hours of service rules include both driving and non-driving work time and this would result in a reduction of 50 percent over current delivery expectations.

4. Conclusions

- As currently written, the Boston Report is too narrow in scope to serve as the only justification for a change in hazmat route restrictions.
    - The current legal hazmat routing restriction is not evaluated and did not serve as the basis of comparison.
    - A single DOT Hazard Class was evaluated instead of a mix of representative commodities (hazard classes).

- The presence of apparent calculation errors in the consequence estimates:
    - Requires verification and validation of all data and calculations, and
    - Reduces confidence in the results for the analysis conducted.

- If the issues raised in this review were addressed, the resulting relative risk values would not be as presented in the Boston Report. This may affect whether the risk ratios exceed the threshold at which the deviation from the current routing (in miles or percentage increase in miles) is subject to the 25-percent/25-mile limitation.