FINAL REPORT

Risk Analysis Study of Hazardous Materials Trucks through Eisenhower/Johnson Memorial Tunnels

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for
Colorado Department of Transportation

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Executive Summary

The Eisenhower/Johnson Memorial Tunnels (EJMT) are located approximately 70 miles west of Denver, Colorado on Interstate I-70. Each tunnel consists of two lanes and carries one-way traffic. The tunnels are approximately 9,000 feet long at an elevation of 11,000 feet above sea level. The tunnels are horseshoe-shaped with asphalt pavement road, concrete-lined sidewalls with wall panels, and concrete slab ceiling with ceiling panels. There are ventilation buildings at both ends of the tunnels with a fully transverse ventilation system. Both fresh air and exhaust ducts are located side-by-side above the ceiling.

At present, hazardous materials (Hazmat) trucks, such as gas tankers, are not allowed passage through EJMT and are routed over Loveland Pass via U.S. 6. U.S. 6 is a mountain pass with tight switchbacks and steep grades. Hazmat vehicles are currently only allowed through EJMT when U.S. 6 is closed and then only allowed once an hour when the tunnels are closed to normal traffic.

The Colorado Deportment of Transportation (CDOT) asked Parsons Brinckerhoff Quade & Douglas (PB team) to conduct a study to determine the risk involved in allowing Hazmat vehicles through EJMT on a regular basis throughout the year and compare it the risk of the vehicles traveling over Loveland Pass. The team was also asked to review and summarize Hazmat transport policies at tunnels in other locations in the U.S. and worldwide, as well as develop mitigation options for the EJMT to help minimize the consequences of a Hazmat incident in the tunnel.

To carry out the study, the PB team conducted a site visit of the EJMT and Loveland Pass; collected all relevant route information, traffic data, accident data, population exposure, tunnel design information, and Hazmat truck transport data; conducted a comparative risk assessment of the two routes using the industry-standard PIARC/OECD QRAM[1] model; and obtained input from the Colorado State Patrol and Colorado Motor Carriers Association. The results of the risk comparison – comparing the U.S. 6 route with its current rate of Hazmat truck transport to the I-70 route through EJMT with a changed policy to allow unrestricted Hazmat truck transport – are summarized as follows.

Casualty Risk: On an annual expected value basis, the number of casualties on the I-70 route is higher than on the U.S. 6 route for all scenarios together. Tunnels are usually designed for 20MW fires as per National Fire Protection Association (NFPA) Guidelines. A significantly higher fire, such as 100MW, is possible with gasoline trucks. The 20MW and 100MW fires dominate the results for both routes. If one of the non-fire scenarios were to occur in the tunnel causing an explosion during a peak travel time, the consequences could be catastrophic in terms of loss of life.

Environmental Impact: The U.S. 6 and I-70 routes have a similar significant potential for environmental impact from a Hazmat incident. Sensitive wildlife habitat, forest and

[1] World Road Association / Organization for Economic Cooperation and Development Quantified Risk Assessment Model

vegetation, and water supply sources could all be adversely affected by a Hazmat spill, explosion, or fire. For the U.S. 6 route, the Snake River and Dillon Reservoirs are at risk, and for the I-70 route, the Clear Creek and Straight Creek are at risk.

Infrastructure Damage: A Hazmat incident on each route (outside of the EJMT on the I-70 route) would result in similar damage to the roadway on both routes, with a replacement cost of approximately $5.5M/mile. Along the U.S. 6 route, there is also the possibility that adjacent buildings and other infrastructure in Keystone, the A-Basin ski area, and Dillon could be damaged in an explosion or spreading fire caused by a Hazmat incident. The greatest risk to infrastructure is the EJMT on the I-70 route. The QRAM model results show that the worst Hazmat incident would cause damages with a repair cost of 12.5% of the replacement value of the tunnel. It is highly unlikely that the tunnel structure would collapse; however, there would be severe damage to the tunnel ceiling, as well as the electrical and mechanical systems.

Local Economic Impact: The local economy of the region is highly dependent on tourism, not only skiing in the winter months, but also other outdoor recreation in the summer months. For the U.S. 6 route, the local economies of Keystone, Dillon, and the A-Basin ski area are all dependent on the proper function of the U.S. 6 route, and would be severely impacted if a Hazmat incident were to occur on the U.S. 6 route and cause a soil or water contamination problem in these locations. In a similar manner, the local economies of Silverthorne and Dillon depend on the proper function of the I-70 route and would be similarly impacted by a nearby Hazmat incident on the I-70 route. The criticality of the I-70 route extends beyond the local economy in the area. This route serves as a major east-west corridor for the state, as well as for the United States. Closure of the EJMT for a significant period of time, even one tube with the other operating with bi-directional traffic, would significantly disrupt traffic flow between the Denver metropolitan area and the western slope of the Rocky Mountains causing a severe economic impact to areas such as Vail and Aspen.

Based on these results and the information gathered in the study, the PB team recommends the following:

1. The current policy of routing Hazmat trucks on the U.S. 6 route over Loveland Pass should be maintained. The risk of Hazmat truck transport through the EJMT is too great in terms of potential for catastrophic loss of life, extensive infrastructure damage, environmental impact to Clear Creek, and economic impact to the areas on the western slope to warrant a change in the current policy. In addition, if Hazmat truck transport were allowed through the EJMT, the attractiveness of this asset as a target for terrorism utilizing a Hazmat vehicle as the weapon, would significantly increase. Hazmat truck travel on the I-70 route, including through the EJMT, should be allowed only when Loveland Pass is closed and then only under convoy with the tunnel closed to regular traffic, as is the current policy.
2. The current procedures for convoying Hazmat trucks through the EJMT should be revised to limit the speed of the trucks through the tunnel to 30 mph, using CCTV at tunnel exits and Colorado State Patrol personnel to help enforce this speed limit. In addition, the dangerous traffic condition related to the mixing of passenger cars and Hazmat truck traffic (cars at high speed attempting to overtake the trucks on the

stretch of I-70 following the exit of the tunnel after the Hazmat truck convoy has ended) should be examined.

3. Improvements should be made to the U.S. 6 route at Loveland Pass to accommodate the parking and pedestrian demands associated with the increased recreational use, especially during the nighttime hours when Hazmat truck travel through the area is common.
4. The U.S. 6 route should undergo evaluation to determine if mitigations to the route geometry and roadway conditions could be done to help reduce the problems faced by Hazmat truck drivers with side-to-side sloshing of liquid cargo in bulk containers while traveling over Loveland Pass.
5. A truck runaway ramp should be installed in the westbound direction on the U.S. 6 route near Milepost 220, and it should be designed to contain a possible Hazmat spill. In addition, the current truck runaway ramps on the I-70 route outside of the EJMT should be modified to contain a possible Hazmat spill, and the regular use of these ramps should be evaluated to determine if additional ramps are needed for exit from the left side of the road.
6. The Colorado DOT should evaluate the CMCA "Proposal for Pilot Program for Movement of Hazardous Materials through the Eisenhower Tunnel".

1. Introduction

The Eisenhower/Johnson Memorial Tunnels (EJMT) are located on Route I-70, approximately 70 miles west of Denver. At present, hazardous materials (Hazmat) trucks, such as gasoline tankers, are not allowed passage on I-70 through the EJMT and are routed instead over Loveland Pass via U.S. 6, which is a mountain pass with tight switchbacks and steep grades. Hazmat vehicles are currently only allowed through EJMT when U.S. 6 is closed and then only on the hour if the tunnels can be closed to normal traffic. The focus of this study is to determine the risks involved in allowing Hazmat vehicles through EJMT on a normal basis and to compare them to the risks that would arise were those same vehicles to travel over Loveland Pass. It should be noted that at present, there are no restrictions at Hanging Lakes Tunnels, located further west on I-70[2].

Key work elements of this study include:

- The collection of relevant data (i.e., geometric, traffic, etc.) for each of the alternative routes
- An investigation of policies and procedures followed at other tunnels
- An identification of appropriate accident scenarios for analysis
- A comparative risk analysis which considers the estimated consequences and frequency of an incident involving a Hazmat vehicle for both routes.

The study excludes the impact to national economy, convoy effect, and the effect of mixing of cars and trucks.

The consequence portion of the analysis estimates the effect of a catastrophic fire occurring in the tunnel and includes the benefit of ventilation system operation on mitigating the effects. The potential for an explosion has also been examined.

The risk, accident potential, and possible catastrophic effects due to trucks using the U.S. 6 alternate route and while traveling through local communities along the route were evaluated using scenarios identified earlier. Mitigation factors were taken into account following evaluation of the firefighting capabilities of the current maintenance forces and the facility related to a potential major tunnel fire. The types of Hazmat vehicles included in the analysis primarily addresses gasoline, explosive, and chemical.

This study report provides a clear evaluation of the relative risks involved in allowing Hazmat vehicles through EJMT and includes a comparison with the current risks of Hazmat vehicles passing over Loveland Pass. The report includes the results of a survey of existing conditions with a brief comparison to other tunnels throughout the world.

The work has been accomplished in two phases: Phase 1 – Problem Definition that culminated in a letter report submitted at the end of September 2005 and Phase 2 – Risk Analysis and Recommendations, which is documented in this final report.

[2] See Appendix E for excerpts from Federal Regulations.

2. Route Description and Characteristics

2.1 Route I-70 Description

The project study area along Interstate 70 (I-70) extends approximately from Mile 205.4 at Silverthorne to Mile 216.2 at Loveland Ski Area. It should be noted that I-70 is a part of the National Highway Defense System. The Eisenhower/Johnson Memorial Tunnels (EJMT) are located at the eastern end of this area, along I-70 between Mile 213.7 and 215.4. Within this stretch, the Interstate is a divided freeway and has generally two lanes each way plus a climbing lane for slow traffic. Route I-70 passes through both Summit and Clear Creek counties within the study area. In 2004, the Annual Average Daily Traffic (AADT) was 28,200, out of which approximately 9.7% were trucks. Speed limits are posted at 50 mph within the EJMT and 60 to 65 mph elsewhere. In addition, westbound trucks weighing over 30,000 pounds are restricted to 30 mph between the Tunnel exit and Mile 208.

Figure 1 Typical I-70 Runaway Truck Ramp

At the start of this stretch are the towns of Dillon and Silverthorne; they are accessible via Exit 205. The Loveland Ski Area lies at the end of this stretch and is reached from Exit 216. There are no exits between these two points, though there are some emergency runaway truck exit ramps (Figure 1). The route's alignment gently meanders along Straight Creek canyon with no significant roadway curves. The populations in the area vary greatly throughout the year, with visitors attracted to the nearby ski resorts such as the Loveland, Breckenridge, and Keystone, just to name a few. Visitors are attracted all year round, in winter primarily to ski; activities at other times include hiking, fishing, white water rafting, riding and golf. Table 1 shows the approximate populations for the cities adjacent to I-70 as well as for the counties in terms of permanent population and peak ski population. The ski season starts in late October and lasts until late March. The number of guests staying in the area varies considerably from day to day.

Table 1 City and County Population for Study Region

City/County	2005 Approximate Permanent Population	2005 Approximate Peak Ski Population
Dillon[3]	2800	5,200
Silverthorne[4]	5,000	10,000
Loveland Ski Area[5]	50	1,250 weekday 3,000 weekend
Summit County[6]	27,740	156,400
Clear Creek County[7]	9,300	12,300

The Eisenhower and the Johnson Tunnels each consist of two lanes and carry one-way traffic most of the time except during maintenance or when an accident blocks one tunnel. The tunnels are approximately 9,000 feet long. Figure 2 shows a view of the eastern portal where the tunnel control center is located. The western end of the tunnel has an elevation of about 11,158 feet above sea level and the eastern end an elevation of about 11,013 feet, a difference of about 145 feet. The tunnel traverses through the Continental Divide at an average elevation of 11,112 feet. The facility lies entirely within the Arapaho National Forest but is divided by two counties, Clear Creek County at the east portal and Summit County at the west portal. The length of the eastbound (south) tunnel is 8,960 feet (Johnson Tunnel) and the length of the westbound (north) tunnel is 8,939 feet (Eisenhower Tunnel). The westbound or north bore was built first and was opened to two-way traffic in March 1973. The eastbound or south bore was then constructed and opened to eastbound traffic in December 1979, at which time the north bore was converted to one-way traffic westbound. The average grade of both tunnels is 1.64 percent rising toward the west. The approach grades are steep, being 7 percent on the western approach and 6 percent on the eastern approach. The profile along I-70 is shown in Figure 3.

The tunnels are horseshoe-shaped with asphalt pavement road, concrete-lined sidewalls with wall panels, and concrete slab ceiling with ceiling panels. There are ventilation buildings at both ends of the tunnels with a fully transverse ventilation system. Both fresh air and exhaust ducts are located side-by-side above the ceiling. Each bore is configured so that there are two 13-foot-wide lanes with a vertical clearance for vehicles of 13 feet-nine inches and walkways along the travel lanes for tunnel attendants. There are three passageways between the two tunnels. The westbound bore curves slightly at about the midpoint while the eastbound tunnel is generally straight. Centerline-to-centerline, the two bores are about 115 feet apart at the east entrance, 120 feet at the west entrance and 230 feet at the widest point of separation.

Traffic flow in the tunnels is constantly monitored by attendants from the control room in the East Ventilation Building using closed circuit television. A camera is located in each of the

[3] From http://www.townofdillon.com and I-70 PEIS Travel Demand Model (see Appendix A items A71 – A75)
[4] From http://www.silverthorne.org and I-70 PEIS Travel Demand Model (see Appendix A items A71 – A75)
[5] From observation by CDOT personnel and communication with ski area personnel
[6] From http://www.co.summit.co.us/Planning/dempgraphics.htm and I-70 PEIS Travel Demand Model (see Appendix A items A71 – A75)
[7] From http://www.co.clear-creek.co.us/

11 zones (800-foot intervals) throughout each tunnel. Additional cameras monitor the approaches and the portals of the tunnels. In addition to the monitoring system, message boards in each zone of the tunnel are used to inform motorists of lane closures, adverse road conditions, maintenance operations, reduced speed limits, etc., throughout the tunnels. These message boards are controlled by the tunnel attendant at the east portal control room.

Figure 2 East Portal of Eisenhower/Johnson Memorial Tunnels

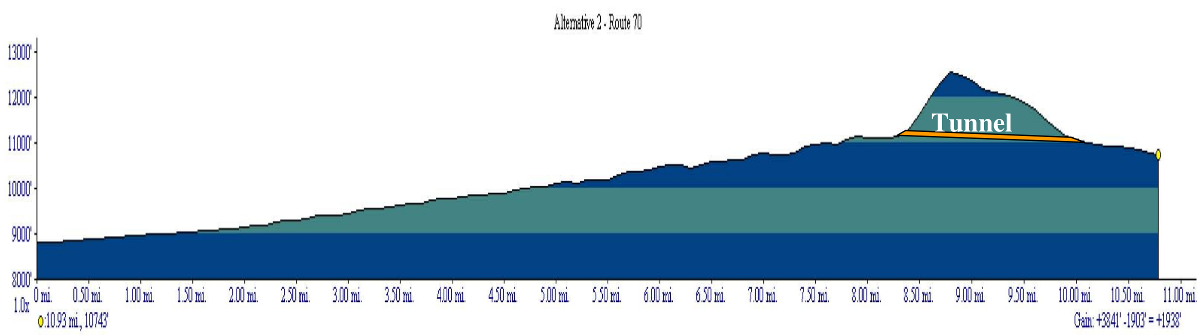

Figure 3 Profile of Route I-70

According to the Colorado State Patrol (CSP) representatives[8], the route geometry of the I-70 route in the study region is steep, but not as treacherous as the U.S. 6 route over Loveland

[8] Based on teleconference of January 25, 2006; see minutes of teleconference in Appendix G.

Pass, as described below. The primary concern of the CSP is the safety of the EJMT if Hazmat trucks are allowed through the tunnel rather than the current designated route of U.S. 6. The CSP indicated that the probabilities of an accident in the EJMT are much lower than on the U.S. 6 route; however, a Hazmat incident such as a tanker truck fire could result in closure of the EJMT. Closure of the even one tube of the EJMT would disrupt the I-70 corridor traffic flow and severely impact the local economy and cargo transportation in the area, especially for locations west of the study region. The CSP indicated that the consequences of a serious Hazmat incident in the tunnel are so great that if these vehicles were allowed through the tunnel, even with additional safety measures such as escorts and safety inspections, the risk is too high. The current policy of the CSP is to prohibit Hazmat truck access through EJMT and require the trucks to use Loveland Pass unless the pass is closed due to weather conditions (see map of Hazmat route restrictions for the state of Colorado in Appendix item A69).

Another key issue with the I-70 route is the steep grades outside the tunnel. Trucks trying to maintain speed will often encounter brake failure due to overheating and be forced to use the truck runaway ramps. If Hazmat trucks were using the tunnel on a regular basis, the truck runaway ramps would require re-design to mitigate potential incidents from Hazmat trucks that may have to use the ramps. According to the CSP, the mixing of truck and car traffic outside the tunnel is often a dangerous situation following the release of cars that were held back while trucks are convoyed through the tunnel. With an increase in convoys due to a changed policy, this dangerous situation would be more frequent. The CSP also raised the concern of security (terrorism) risk in the tunnel and the potential increase in this risk if Hazmat trucks were allowed through the tunnel on a regular basis.

2.2 Route U.S. 6 Description

This study also encompasses that part of U.S. 6 that connects to and from I-70 over the Loveland Pass. This includes U.S. 6 from approximately Mile 208 (I-70 Exit 205) in the west to Mile 230 (I-70 Exit 216) in the east. Within these two limits, U.S. 6 is also referred to as Loveland Pass and it provides access to several key resorts and towns. It is a mountain pass with tight switchbacks and steep grades. Loveland Pass has a 5% – 6% grade and the roadway width is about 26 ft. It is a two-lane two-way roadway with little or no shoulder, and also serves bicycles. It has several vehicle pull-outs to serve as scenic lookouts. Refer to Figure 4 and Figure 6 for typical views of this road and Figure 5 for a profile along U.S. 6.

According to the Colorado Motor Carriers Association (CMCA) representative[9], U.S. 6 over Loveland Pass is a very difficult route for truck drivers to navigate. Their greatest challenge is the road geometry that was designed without full consideration of the volume of truck traffic that would be using the route. The steep grades combined with small radius turns make navigating the road with heavy vehicles stressful and difficult. Another issue with road geometry such as this is the "load shifting" on trucks carrying bulk quantities of liquid products such as gasoline. Even with load-shifting safeguards such as compartmentalized tanks, the load shifting effect in the horizontal direction can contribute to truck drivers losing control and running off the road. The difficult road geometry combined with adverse

[9] Based on teleconference of January 19, 2006; see minutes of teleconference in Appendix G.

weather conditions makes the U.S. 6 route treacherous and at times, impassable, especially for drivers not familiar with the route conditions.

The CMCA also indicated that the mandated local delivery times for gasoline in towns west of the route study region require the truck drivers to travel over the U.S. 6 route late at night. This schedule puts strain on the drivers as it forces them to traverse a difficult route when it is dark and when the drivers are tired. According to the Colorado State Patrol representatives, the number of people gathering at night in the area surrounding Loveland Pass and parking on the side of the road has increased dramatically. This contributes to the difficulty in traversing Loveland Pass with a large truck.

The CMCA submitted a separate proposal for "Pilot Program for Movement of Hazardous Materials through Eisenhower Tunnel" to the Colorado DOT (see Appendix . The proposal is to run a pilot program from June 1, 2006 through November 30, 2006 that would alter the current practice of routing hazardous materials trucks over Loveland Pass.

Figure 4 View of Route U.S. 6

2.3 Route Traffic, Accident, and Hazmat Transport Data

2.3.1 I-70 Route Data

The section of highway I-70 included in the study region extends from reference point 205.43 in the town of Silverthorne to reference point 216.254, east of the Eisenhower Johnson Memorial Tunnels. Traffic count data for this section of highway I-70[10] are shown in Table 2 for the reference point 205.43. The data shown are the total number of vehicles

[10] Taken from CDOT web site: http://www.dot.state.co.us/App_DTD_DataAccess/Traffic/index.cfm

per day crossing this point, averaged over each month for the years 2001 through 2005. Table 2 shows that on average, the most heavily traveled months are July, August, and March, while the months with the lightest traffic are May, April, October, and November. The traffic information data for this section of highway I-70[11] indicate that the average annual daily traffic (AADT) was 28,200 vehicles in 2004, 9.7% of the vehicles are trucks, and the design hourly volume is 3,666 vehicles.

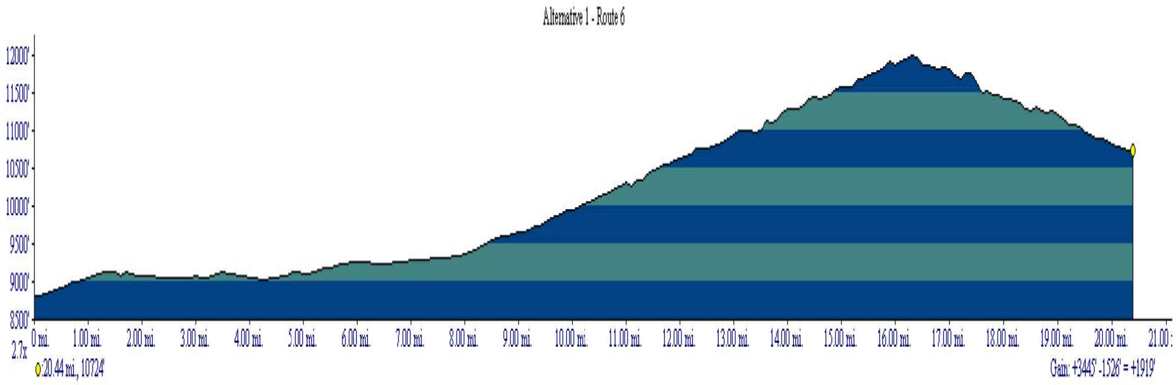

Figure 5 Profile of Route U.S. 6

Figure 6 Route U.S. 6 zigzags down the mountain

[11] Taken from CDOT web site: http://www.dot.state.co.us/App_DTD_DataAccess/Highways/index.cfm

Truck accident data for highway I-70[12] from reference point 205.43 to reference point 216.254 include a total of 159 truck accidents over the five-year period from January 1, 1999 through December 31, 2003. This results in an annual accident rate of 31.8 along this stretch of highway I-70. Only 9 of these 159 truck accidents are reported to have occurred in the EJMT, resulting in an annual accident rate of 1.8 on the segment of highway I-70 within the EJMT. On an accident per million truck mile basis, the annual accident rate is 2.94 for the entire I-70 route in the study region and 1.06 for the segment of the route within the EJMT.

Table 2 I-70 Daily Traffic Count Data Averaged by Month for 2001 through 2005

	2001	2002	2003	2004	2005	Average
Jan	27,747	29,563	30,515	29,581	29,958	**29,473**
Feb	28,808	28,507	29,678	29,721	30,682	**29,479**
Mar	32,235	34,381	30,080	31,659	32,556	**32,182**
Apr	25,266	23,745	23,692	23,033	24,356	**24,018**
May	22,715	24,295	23,310	23,692	23,788	**23,560**
Jun	29,563	29,583	28,697	29,074	29,814	**29,346**
Jul	34,934	34,312	34,480	34,750	35,338	**34,763**
Aug	35,338	34,276	34,626	32,923	31,250	**33,683**
Sep	30,381	29,080	28,275	29,318	29,237	**29,258**
Oct	24,001	24,297	25,402	25,051	24,462	**24,643**
Nov	24,734	25,850	23,901	24,285	NA	**24,693**
Dec	29,349	30,733	28,080	29,443	NA	**29,401**

Table 3 shows route closure information for highway I-70 from reference points 205 to 228 during the years of 2004 and 2005. For the highway I-70 study route extent (reference points 205.43 to 216.254), there was only one route closure in 2004 involving a truck accident. In 2005, there were 8 route closures involving truck accidents in the study region, with one resulting in closure of both directions of traffic along the route. The duration of closure for these nine incidents ranges from 1 hour and 48 minutes to 10 hours and 39 minutes, with an average of 4 hours and 38 minutes.

Figure 7 shows a summary of the Hazmat trucks that were allowed to pass through the EJMT due to closure of the U.S. 6 route during the time period of July 2004 through June 2005[13]. During this two year period, the U.S. 6 route was closed for a total of 387.79 hours and 2338 Hazmat trucks passed through the tunnel, resulting in a rate of approximately 6 Hazmat trucks per hour. As shown in Figure 7, there were no Hazmat trucks passing through the EJMT during the months of May and October in this two-year period. The Hazmat commodity types shown in Figure 7 are those that correspond to the information displayed on the truck placard as it is processed prior to escort through the tunnel. The most common Hazmat commodity type is flammable fuels, representing nearly 80% of the total Hazmat truck shipments. Note that this is by number of shipments, not necessarily weight or volume, as the size of truck is not reported with these data.

[12] Data provided by CDOT (see Appendix A item A46)
[13] Data provided by CDOT (see Appendix A item A36)

Table 3 Road Closure Log for Highway I-70 for 2004-2005[14]

Date closed	Time closed	Date opened	Time opened	Closure mile marker	Direction of travel	Incident mile marker	Reason: select from list below	Notes
4-5-04	2329	4-6-04	0235	228	WB		4, 8, 12	
4-5-04	2357	4-6-04	0231	205	EB		4, 8, 12	
12-9-04	0300	12-9-04	0447	218	EB	218	6	Jackknife
3-13-05	1330	3-13-05	1600	216	WB	208.5	6	Rollover
3-17-05	2014	3-17-05	2051	228	WB	221	6	Jackknife
3-30-05	1513	3-30-05	1618	226	EB	227	4, 8, 12	
4-5-05	0345	4-5-05	0616	209	WB	208	6	Jackknife
6-12-05	2025	6-12-05	2213	212	WB		6	Jackknife
6-12-05	2115	6-12-05	2316	205	EB		4, 8, 12	
7-15-05	2214	7-16-05	0416	205-221	EB	221	6	
10-14-05	1549	10-14-05	1614	222	EB		9	
11-12-05	1904	11-13-05	0018	205	BOTH		4, 8, 12	
11-14-05	1529	11-14-05	2351	205-228	EB	180-240	4, 8, 12	
11-17-05	1301	11-17-05	1341	203	EB	204	6	Car carrier
12-11-05	1852	12-12-05	0531	207	WB	207	6	Rollover
12-29-05	0943	12-29-05	1049	228	WB		4, 8, 12	
Reasons for closure:	1: Avalanche hazard 2: Avalanche blocking the road 3: Accident – Single non truck 4: Accident – Multi Non Truck			5: Tie up – Non Truck 6: Accident – Single Truck 7: Accident – Truck Double 8: Accident – Multiple Trucks		9: Tie up – Truck single trailer 10: Tie up – Truck double trailer 11: Tie up – Multiple Trucks 12: Due to Weather 13: Rocks on the road		

HAZMATS PROCESSED THROUGH EJMT DURING LOVELAND PASS CLOSURES

			HZ Mat Commodity Type										
Fiscal Year	Month	Hours Closed	Flammable Fuels	Flammable Other	Dangerous	Explosive	Non Flammable	Poison Toxic	Oxidizer Combustible	Corrosive	Radioactive	Dangerous When Wet	Total HZ Mats
04	July	4.34	45	3	2	1	1	1	1	3			57
04	August	0.55	4			1			1	1		1	8
04	September	16.27	75	10	4		4	1	3	10			107
04	October	1.5											0
04	November	64.1	232	30	12	5	5	1	2	24	9	1	321
04	December	1.26	2										2
04	January	10.8	111	1		1	2		1		1		117
04	February	30.8	113	4	2	1			3	8	1		132
04	March	36	177	7	8		4	2	2	3		1	204
04	April	20	77	3	5	2	3	2	3	8	5		108
04	May	1.8											0
04	June	2.2	19							2			21
05	July	12.55	37	1	1					2			41
05	August	3.33	30		2		2		2	4			40
05	September	13.35	95	9	1		2	2		9			118
05	October	0											0
05	November	27.75	190	23	4		2	2	2	16	1		240
05	December	62	204	17	5	2	5	1	1	13			248
05	January	23.6	80	7	3	3	1		3	3			100
05	February	4.34	92	9	2	3	2			4	5		117
05	March	45.75	240	27	12	5	10	4	13	18		1	330
05	April	5.5	27										27
05	May	0											0
05	June	0											0
		Totals By Commodity	1850	151	63	24	43	16	37	128	22	4	2338

Total Hours Closed	FY04 189.62	Total HZ Mats Processed	FY04 1077
	FY05 198.17		FY05 1261
Average Per 24 Hr	FY04 136.3	Average Per Hour	FY04 5.7
	FY05 152.7		FY05 6.4

Figure 7 Summary data for Hazmat trucks processed through EJMT in 2004-2005

2.3.2 U.S. 6 Route Data

The section of route U.S. 6 included in the study region extends from reference point 208.659 in the town of Silverthorne to reference point 229.328, east of the Eisenhower Johnson

[14] Data provided by CDOT (see Appendix A item A68)

Memorial Tunnels. Traffic count data for this section of route U.S. 6[15] are shown in Table 4 for the reference point 210.66. The data shown are the total number of vehicles per day crossing this point, averaged over each month for the years 2001 through 2005. Table 4 shows that on average, the most heavily traveled months are March, February, December, and January, while the months with the lightest traffic are May and October.

The traffic information data for this section of route U.S. 6[16] vary by segment of the route. Table 5 shows, for each segment, the average annual daily traffic (AADT) in 2004, the percentage of vehicles that are trucks, and the design hourly volume. As shown in Table 5, the AADT varies from 21,000 in Silverthorne to 1,400 on the segment east of Keystone. The percentage of vehicles that are trucks varies from about 3% to 6% along the route.

Truck accident data for route U.S. 6[17] from reference point 208.659 to reference point 220 (western end of the segment approaching Loveland Pass) include a total of 19 truck accidents over the three-year period from January 1, 2001 through December 31, 2003. This results in an annual accident rate of 6.3 along this stretch of route U.S. 6. The data for reference point 220 to reference point 229.328 cover the ten-year period of January 1, 1994 through December 31, 2003 and include 45 truck accidents, resulting in an annual accident rate of 4.5 along this stretch of route U.S. 6. Of these 45 accidents, 21 occurred on the three-mile segment that includes Loveland Pass (reference points 224 to 227).

Table 4 U.S. 6 Daily Traffic Count Data Averaged by Month for 2001 through 2005

	2001	2002	2003	2004	2005	Average
Jan	NA	14,148	14,879	14,434	13,651	**14,278**
Feb	NA	15,112	14,710	15,026	14,997	**14,961**
Mar	NA	16,673	15,961	15,838	15,945	**16,104**
Apr	11,631	10,616	10,509	10,268	9,956	**10,596**
May	9,418	8,911	8,905	8,832	9,181	**9,049**
Jun	11,771	10,920	10,403	10,466	10,549	**10,822**
Jul	13,567	13,499	12,604	12,683	13,352	**13,141**
Aug	12,839	12,701	12,277	11,792	11,912	**12,304**
Sep	10,602	10,613	9,712	9,859	10,328	**10,223**
Oct	9,464	9,300	9,251	9,264	8,905	**9,237**
Nov	11,401	12,185	10,591	11,304	NA	**11,370**
Dec	14,211	14,713	13,782	14,757	NA	**14,366**

The rate of truck accidents per million truck miles varies along the route U.S. 6 due to the variation in AADT by segment as shown in Table 6. For these same seven segments along route U.S. 6, the annual rate of truck accidents per million truck miles is as shown in Table 6. The rate shown in Table 6 for the segment of route U.S. 6 that is east of Keystone and includes Loveland Pass (reference points 216.340 to 229.328) is more than 3.5 times that of the I-70 highway route in the study, and more than 10 times the rate for the EJMT.

[15] Taken from CDOT web site: http://www.dot.state.co.us/App_DTD_DataAccess/Traffic/index.cfm
[16] Taken from CDOT web site: http://www.dot.state.co.us/App_DTD_DataAccess/Highways/index.cfm
[17] Data provided by CDOT (see Appendix A item A32)

Table 5 Route U.S. 6 Traffic Information (Reference Points 208.69 to 229.328)

Ref Point (start)	Ref Point (end)	Description	Average Annual Daily Traffic	Percent Trucks (%)	Design Hour Volume
208.659	208.950	On SH 6 SE/O I-70, Silverthorne	21,000	6.0	2,520
208.950	209.844	On SH 6, W/O CR 7, Dillon Dam Road	15,400	5.9	1,386
209.844	210.662	On SH 6, E/O Evergreen St, Dillon	11,600	3.2	1,392
210.662	213.131	On SH 6 W/O Swan Mountain Rd	11,900	3.1	1,666
213.131	215.952	On SH 6 E/O Swan Mountain Rd	9,800	3.3	1,176
215.952	216.340	On SH 6 W/O on-ramp from Montezuma Road, Keystone	4,000	4.7	480
216.340	229.328	On SH 6 0.25 mi. E/O on-ramp from Montezuma Road, Keystone	1,400	6.3	168

Table 6 Route U.S. 6 Truck Accident Data (Reference Points 208.69 to 229.328)

Ref Point (start)	Ref Point (end)	Description	Annual Truck Accident Rate	Annual No. of Trucks-Miles	Annual Accidents per Million Truck-Miles
208.659	208.950	On SH 6 SE/O I-70, Silverthorne	1.33	133831	9.96
208.950	209.844	On SH 6, W/O CR 7, Dillon Dam Road	2.00	296485	6.75
209.844	210.662	On SH 6, E/O Evergreen Street, Dillon	0.33	110829	3.01
210.662	213.131	On SH 6 W/O Swan Mountain Road	0.33	332447	1.00
213.131	215.952	On SH 6 E/O Swan Mountain Road	1.67	332994	5.01
215.952	216.340	On SH 6 W/O on-ramp from Montezuma Road, Keystone	0.33	26625	12.52
216.340	229.328	On SH 6 0.25 mi. E/O on-ramp from Montezuma Road, Keystone	4.80	418123	11.48

The Hazmat transport data described in the previous section also pertain to the U.S. 6 route; i.e., there is no separate breakdown of Hazmat trucks traveling exclusively over Loveland Pass. It is assumed that the rate and material distribution of trucks passing through the tunnel

(Figure 7) when the U.S. 6 route is closed is the same as would be passing over the U.S. 6 route when the U.S. 6 route is open.

Table 7 shows route closure information for the U.S. 6 route from reference points 217 to 229 (Loveland Pass) during the years of 2004 and 2005. During this two-year period, there were eight closures involving truck accidents in the study region, all resulting in closure of both directions of traffic along the route. The duration of closure for these eight incidents ranges from 40 minutes to 47 hours and 43 minutes, with an average of 20 hours and 52 minutes.

Table 7 Road Closure Log for Route US-6 for 2004-2005[18]

Date closed	Time closed	Date opened	Time opened	Closure mile marker	Direction of travel	Incident mile marker	Reason: select from list below	Notes
4-7-04	0858	4-7-04	0938	217-229	BOTH		11	
7-24-04	0129	7-24-04	1406	217-229	BOTH	224.5	6	Rollover
9-23-04	0155	9-23-04	1510	217-229	BOTH		6	Off Road
11-5-04	0730	11-6-04	1030	217-229	BOTH	222	6	Rollover
12-30-04	0416	12-31-04	0803	218-229	BOTH	227.3	6	Off Road
2-15-05	1729	2-16-05	0835	218-229	BOTH		1, 12	
3-8-05	0914	3-9-05	0804	218-229	BOTH		1, 12	
11-14-05	0919	11-16-05	0902	218-229	BOTH	225	6	Upright
Reasons for closure:	1: Avalanche hazard 2: Avalanche blocking the road 3: Accident – Single non truck 4: Accident – Multi Non Truck			5: Tie up – Non Truck 6: Accident – Single Truck 7: Accident – Truck Double 8: Accident – Multiple Trucks		9: Tie up – Truck single trailer 10: Tie up – Truck double trailer 11: Tie up – Multiple Trucks 12: Due to Weather 13: Rocks on the road		

[18] Data provided by CDOT (see Appendix A item A68)

3. Tunnel Structural, Mechanical, and Electrical Systems

3.1 Tunnel Structure

The Eisenhower Johnson Memorial Tunnels (EJMT) consist of two bores that pass through the Continental Divide and are about 1.8 miles in length. Both tunnels were bored and allow for two lanes of traffic. The tunnel lining itself is made up of reinforced concrete three feet thick. At about the midpoint of the tunnel, the surrounding bedrock is much softer and thus the lining of the tunnel in this section is much thicker. The actual bore itself has a radius of about 21 feet. A cross-section of the tunnel is shown in Figure 8 (see Section 3.2.3). The top semi-circular portion of the tube is made up of the tunnel ventilation shafts with the supply and return spaces separated by a bulkhead. The bulkhead also provides support for the roadway ceiling, which is made of concrete slab. The supply and return grills are evenly spaced along the length of the tunnel. Beneath the road surface, space is provided to accommodate water supply lines and waste water lines, as described below.

3.2 Tunnel Systems[19]

3.2.1 Water Supply

The fresh water to the tunnels is supplied by a 120,000-gallon tank at the west end of the tunnels and distributed through lines buried beneath the roadway in the Eisenhower Tunnel and through lines buried beneath the walkway in the Johnson Tunnel. Pressure reducing valves are necessary throughout the tunnel to maintain workable water pressures in these fresh water supply lines. Fire hydrants are located at 250-foot intervals throughout both tunnels. The tunnels have no fire sprinklers.

3.2.2 Waste Water

Because of the slope of the tunnels, the wastewater treatment plant and all groundwater and wastewater discharge points are located at the east end of the tunnels. Groundwater or "seep" water is collected in perforated drain pipes beneath the roadway and behind the tunnel walls throughout the length of the tunnels. The volume of such water varies significantly by season. This water does not require treatment at the wastewater treatment facility.

Water that must be treated includes sanitary sewage and water collected by the catch basins throughout the tunnels. Catch basins are located along both sides of each tunnel at about 150-foot intervals and are used to collect any liquids that may be spilled in the tunnels. Manhole accesses to buried water lines are located at alternating catch basins or at 300-foot intervals. Catch basin water enters the main sewage line at each manhole through an opening in the top of the pipe, which makes the wastewater main essentially an open channel. Access to seep water main lines can be made through a capped access at each manhole. A considerable amount of groundwater also infiltrates into this collection system, as evidenced by the wide seasonal variance in volume. Flows generally stay in the range of 6,000 to 60,000 gallons per day. However, flows as high as 188,000 gallons in a single day have been experienced. Since

[19] Much of this information is taken from the Leigh, Scott & Cleary report dated 1990 (Appendix A Item A30).

this water must be treated before being discharged, the wastewater treatment plant must be capable of handling this wide range of flow rates.

The current method of wastewater treatment consists of primary settling, sand filtration, and chlorination. Wastewater entering the treatment plant from both tunnels and from sources within the east portal building converges at the two sedimentation tanks. Valves allow flows to be shut off from either of the two tanks. However, the flows from the separate tunnels cannot be sent to different tanks. The "normal" capacity of these tanks is about 63,000 gallons each. If a spill should occur in a tunnel, valves can be closed increasing the water level in these tanks to the "gasoline draw off level" which increases the volume in the tank to about 66,000 gallons. This allows a light liquid such as gasoline or oil to be drawn off the top of the sedimentation tanks and sent to the 20,000 gallon tank which is available for temporary storage of hazardous spills. A similar method of collection for liquids which are heavier than water does not currently exist. However, this type of spill would have a tendency to settle in the sedimentation tanks. If the line to the hazardous waste storage tank is closed, the water level in the sedimentation tanks can increase above the level of the gasoline draw-off line resulting in a maximum capacity of about 75,000 gallons for each tank.

After going through the sedimentation tanks, the wastewater flows to the sand filter beds. The flow from the two sedimentation tanks converges into the same line that goes to the sand filter beds. Valves allow the flow to be shut off from the individual sedimentation tanks. Slide gates control which of the eight filter beds are used for sand filtration of the wastewater. The number of filter beds that are used at a given time is dependent upon the volume of wastewater being treated, and the condition of the filter beds. The filter beds typically require cleaning about three or four times per year. Cleaning consists of removing the top layer of sand and replacing it with clean sand. The sand that is removed is hauled to a landfill for disposal along with the sediment removed from the sedimentation tanks.

It is possible to bypass the wastewater from the tunnels directly to Clear Creek. However, there is no method of bypassing the wastewater from only one of the tunnels. In the event of an extremely large or hazardous spill in the tunnel, the method of last resort to contain the spill would be to allow the entire wastewater treatment plant to flood. This type of action would be necessary were a spill to occur during a time of year when the wastewater treatment plant is operating at a very high volume.

3.2.3 Ventilation

The EJMT utilize independent fully transverse ventilation systems for each bore with ventilation buildings at each portal. The Eisenhower Tunnel (westbound) has four supply fans (533,000 CFM) and four exhaust fans (542,000 CFM) in each ventilation building, and the Johnson Tunnel (eastbound) has three supply fans (420,000 CFM) and three exhaust fans (460,000 CFM) in each ventilation building[20]. The exhaust and supply ducts are located side-by-side in the ceiling above the roadway, separated by a bulkhead. Transverse bulkheads at the midpoint of each tunnel separate the area of influence of each ventilation building. Fresh air can be supplied from both ends of a bore and air can be exhausted from both ends.

[20] Source: "Eisenhower Johnson Memorial Tunnels, Fire Emergency Ventilation Study" prepared by Sverdrup, Appendix A Item A33.

There are two reasons that the eastbound bore does not have as many fans as the westbound bore. The westbound bore was the first one constructed and ventilation had to be provided for two-way traffic, which takes more ventilation than one-way traffic. In addition, vehicles emit more carbon monoxide while going upgrade than they do going downgrade, and since the westbound traffic goes upgrade, more ventilation is required for that bore in order to maintain adequate air quality. Because of these differences in air volume requirements, the normal system capacity of the eastbound tunnel is 2.1 million cubic feet per minute (cfm) and the westbound tunnel capacity is 3.2 million cfm. It should be noted that if the eastbound tunnel is operated with two-way traffic, all fans may need to be used to provide adequate ventilation.

In May 2001, Sverdrup Civil, Inc., performed a Fire Emergency Ventilation Study (FEVS) for a 20 MW fire, and recommended to CDOT to program the supply and exhaust fans in “run” or “off” mode depending on the location of the fire. It is the understanding of the PB team that CDOT has already programmed the fans to operate according to the recommendations made by Sverdrup.

The fresh air and exhaust fans are not interchangeable. However, all exhaust fans from both bores are identical and interchangeable, as are all intake fans. The exhaust fans have a considerably larger shaft and hub than the intake fans and the "squirrel cages" are slightly different in size. In addition to the differences between supply and exhaust fans, there are differences in how the north bore's fans and the south bore's fans are configured. The north tunnel fans are set up to run at three different speed settings: 12.5, 100 and 600 horsepower. The south tunnel fans have four different settings: 25, 100, 200, and 600 horsepower.

If replacement fans were necessary due to failure resulting from an extreme fire, delivery would probably take six to seven months for each fan lost. Due to the distance between the east and west portals of the tunnels, it is unlikely that fans at both ends of a tunnel would be damaged in a single fire. It is therefore reasonable to assume that in the worst case situation, four exhaust fans at either end of the westbound tunnel would be the worst scenario. However, the maximum ventilating capacity of 3.2 million cfm may not be adequate. This would result in a reduction of safe traffic capacity in one of the tunnels. In addition to the loss of ventilating fans, a large fire in one of the tunnels would most likely result in the loss of portions of the tunnel lining and ductwork. Structural concrete lining in the tunnel could potentially fail in a fire of extreme proportions.

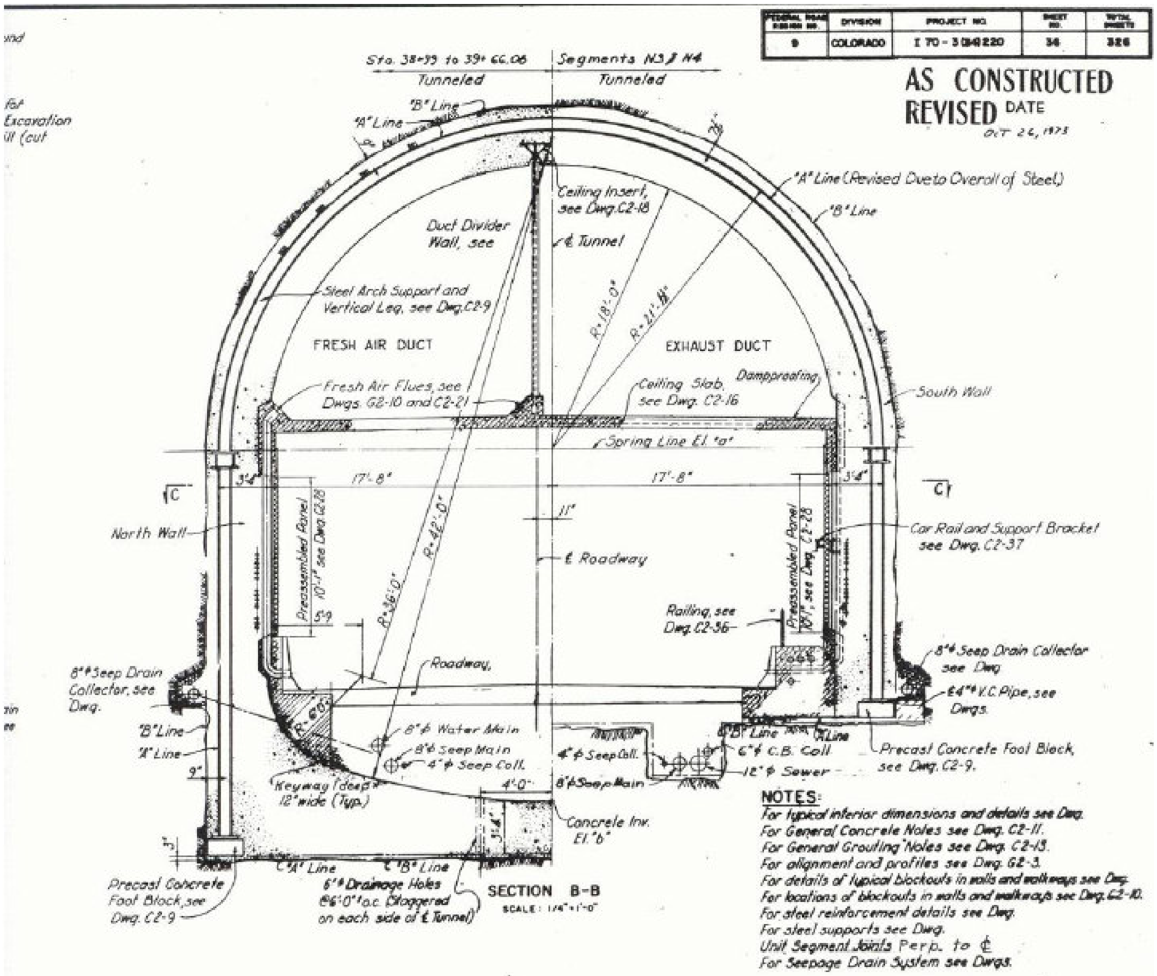

Figure 8 Typical Cross section of the Eisenhower Memorial Tunnel

3.2.4 Vehicles

The emergency equipment at the tunnels, located in a garage at the eastern end of the tunnel, includes two fire trucks. One truck has a roof turret deluge gun supplying water at 500 gallons per minute, a 1000-gallon water tank, and hoses to connect to the tunnel fire hydrants that are located at 250-foot intervals throughout the tunnels.

The two wrecker trucks also have fire fighting equipment. Each truck has hoses for connecting to hydrants, a 30-gallon capacity foam system, and dry chemical extinguishers with a total of 125 pounds on each truck. One of these trucks is located at the east portal house and one is located at the west portal house.

3.2.5 Staff

Fifty full-time equivalent employees staff the tunnels. The staff includes a tunnel superintendent, four tunnel supervisors, about 27 tunnel operations workers, five tunnel mechanics, four electronics workers, two automotive mechanics, two utility workers. two store room attendants, one water/wastewater treatment plant operator, one highway maintenance management section coordinator and one clerical worker. The tunnels operations workers are divided into six separate crews. Each crew generally has one person located at each portal, one or two at the east portal control room and one person located wherever needed at the time.

3.2.6 Electrical Systems

Electrical systems that run along the inside of the tunnels include: CCTV, emergency phones, wiring, lighting, and variable message boards (VMS). An emergency power system is also-installed at the tunnels that can supply about 500 kilowatts of power if the regular power supply is lost. This amount of power is enough to operate some tunnel lighting and enough of the ventilation fans at low speed to allow limited traffic volumes. The ventilation that can be provided using emergency power is not adequate for typical weekend traffic volumes.

3.2.7 Tunnel Operations

The tunnel control center is located above the east portal of the tunnels. The control center is manned 24 hour a day, 365 days a year by CDOT personnel. The tunnel operators monitor the traffic using CCTV. If an emergency occurs, there are established procedures that are followed to quickly respond. In the case of a fire incident, the response procedures include: stop traffic, activate emergency ventilation, notify on-site fire-fighting personnel, and notify local fire-fighting authorities. The tunnel maintains two wrecker trucks to handle minor accidents and breakdowns.

Control of the western ventilation equipment is via a control cable in each tunnel from the east portal control center. Since the cable may be damaged during a severe fire, the equipment must be capable of being controlled by either control cable or local manual control. The same is true for communication between the two sides, since the Continental Divide makes direct communication impossible without repeaters or using telephone.

3.3 Effects of Hazmat Incidents

To discuss the effect of hazardous material, a grouping convention is used to classify hazardous materials into classes where hazardous materials in the same class can be expected to react similarly. The convention used in this report is that developed by PIARC that classifies all dangerous goods (i.e., hazardous materials) into five groupings as shown in Table 8. In addition to the grouping system, the 13 scenarios in Table 9 and the effect they will have on the tunnel systems are discussed. The scenarios are those used in the OECD Quantitative Risk Assessment Model (QRAM)[21], as described in Section 5.

Each scenario is explored with its impact on tunnel infrastructure and potential damage to the tunnel and its mechanical and electrical systems. Possible mitigation options are also discussed. Nearly all hazardous materials are flammable and the following sections apply to most hazardous material releases.

[21] Adapted from "Safety in Tunnels, Transport of Dangerous Goods through Road Tunnels" OECD 2001, (Appendix A Item A17).

Table 8 PIARC Hazardous Materials Classification System[21]

Group A	All hazardous materials authorized on open roads
Group B	All materials in Group A except those that may lead to a very large explosion (*hot BLEVE*[22] or equivalent)
Group C	All materials in Group B except those which may lead to a large explosion (*cold BLEVE* or equivalent) or a large toxic release (toxic gas or volatile toxic liquid)
Group D	All materials in Group C except those which may lead to a large fire
Group E	Hazardous and other materials that require no special marking and no placards on the vehicle

Table 9 Main Characteristics of the 13 Selected Scenarios[21]

Scenario No.	Description	Capacity of tank	Size of breach (mm)	Mass flow rate (kg/s)
1	HGV fire 20 MW	-	-	
2	HGV fire 100 MW	-	-	
3	BLEVE of LPG in cylinder	50 kg	-	
4	Motor spirit pool fire	28 tonnes	100	20.6
5	VCE of motor spirit	28 tonnes	100	20.6
6	Chlorine release	20 tonnes	50	45
7	BLEVE of LPG in bulk	18 tonnes	-	
8	VCE of LPG in bulk	18 tonnes	50	36
9	Torch fire of LPG in bulk	18 tonnes	50	36
10	Ammonia release	20 tonnes	50	36
11	Acrolein in bulk release	25 tonnes	100	24.8
12	Acrolein in cylinders release	100 litres	4	0.02
13	BLEVE of carbon dioxide in bulk (not including toxic effects)	20 tonnes	-	-

Key: BLEVE = Boiling liquid expanding vapour explosion; HGV = Heavy goods vehicle; LPG = Liquid petroleum gas; VCE = Vapour cloud explosion.

3.3.1 Heavy Goods Vehicle (HGV) fire 20MW-100MW

Hazardous materials that fit Scenarios 1 and 2 from Table 9 include all of those in Groups B through E of Table 8. The effects of these scenarios on the EJMT can be compared to both the effects of the Caldecott Tunnel fire of 1982[23] and the Holland Tunnel Fire of 1949[24]. The Caldecott tunnel is located on California State Highway 24 between Oakland and Walnut Creek, and the Holland Tunnel is located on I-78 and connects the states of New York and New Jersey beneath the Hudson River. All three tunnels share similar geometries.

The Caldecott tunnel fire occurred on April 7, 1982. A multi-vehicle collision occurred between a transit bus, a tank truck and trailer, and a stalled car approximately half-way through the tunnel. The trailer, carrying gasoline overturned and released gasoline at approximately 75 to 375 liters per minute. The gasoline ignited and burned approximately

[22] Boiling Liquid Expanding Vapor Explosion
[23] Larson D.E., et al., "The Caldecott Tunnel Fire Thermal Environments: Regulatory Considerations and Probabilities" Sandia National Laboratories, 1983 (Appendix A Item A49).

32,000 liters of gasoline in 40 minutes, totally engulfing all vehicles involved in the collision. The damage to the tunnel structure indicated that no explosion occurred and the temperature of the fire was estimated to be about 1000°C, reaching no more than 1083°C. The energy output of the fire was approximately 42 MW and the effect of the fire on the tunnel structure was extensive spalling of the concrete ceiling and walls. It also exposed the steel reinforcing and bucked ventilation plate covers but did not cause a tunnel collapse. All of this damage was spread over a 200 m length of the tunnel going uphill from the collision. Examination of air flow conditions based on geometric analysis and first hand accounts, determined that the "pumping" effect of the fire was insufficient to generate the fire in the tunnel, and that local wind conditions was the deciding factor in fire size. The ventilation fans, which automatically started due to the increased levels of CO, were immediately shut off, and had no effect on the fire. The report from the local fire department indicated that the fire was allowed to burn down before final extinguishing took place with foam and dry powder[24].

Reports from first hand accounts indicate that the tunnel communication system was rendered inoperable within one and one-half minutes of the incident. Overall damage to the tunnel included destruction of nearly all tunnel support systems: lighting, emergency phones, signs, alarms, wiring, commercial broadcast antenna, and firefighting water supply. There was no mention of damage to ventilation fans.

In 1949, the Holland Tunnel suffered extensive damage from a truck carrying 4,100 gallons of carbon disulphide in 80 drums (with a capacity of 55 gallons each) that caught fire; ten other trucks were then also destroyed. A total of 600 feet of tunnel wall and ceiling were completely demolished. Two of the three exhaust fans located approximately 300 feet away from the fire were disabled by the hot 540°C (1000°F) air, whereas the third fan was kept operational by applying a continuous water spray to cool the interior. The fire was approximately 100 MW in size. All electrical systems in the fire vicinity were completely destroyed. The Holland tunnel prohibits the transportation of hazardous materials and the truck was not placarded, in violation of ICC rules and Holland tunnel policies.

Initially, exhaust ventilation was inefficient as firefighters sought relief from smoke by breathing fresh air at curb level. Eventually when the ceiling collapsed, the smoke problem was alleviated because it rose into the ventilation space and was exhausted by the remaining exhaust fan, which has been accelerated to full speed.

3.3.1.1 Experimental Data

In the FHWA report, *Prevention and Control of Highway Tunnel Fires*[24], there are several graphs establishing the relationship between fire/temperature characteristics, and distance from the incident location for a reference tunnel. The reference tunnel upon which the following figures are based is 33 feet wide, 16 feet high, and one mile long with a horizontal tunnel bore. The reference tunnel dimensions are close enough to those of the EJMT so that the data in the following figures can also apply to the EJMT even though hot air and smoke will tend to flow up-gradient. The discussion of the following data assumes fully developed fire conditions.

[24] Egilsrud, Philip P.E., "Prevention and control of Highway Tunnel Fires", US Department of Transportation Federal Highway Administration, 1984 (Appendix A Item A34).

Figure 9 shows the temperature versus distance along the tunnel, assuming that the fire occurs midway through the tunnel and that fumes from the fire travel in one direction. Should the fumes travel in both directions, the temperature values can be expected to be half the values given in Figure 9. These values do not represent the actual temperature of the tunnel structure, but the temperature of the tunnel space. The same assumptions hold true for Figure 10, which shows the distance of the flame along the ceiling as a function of fire intensity. A maximum flame distance along the ceiling of about 400 feet is indicated, with the maximum being reached at a fire intensity of about 70 MW. This data is important for determining the survivability of the ventilation system. It can be assumed that any electrical system near the incident will be destroyed or severely damaged including any CCTV, emergency phones, wiring, signs, and communications equipment.

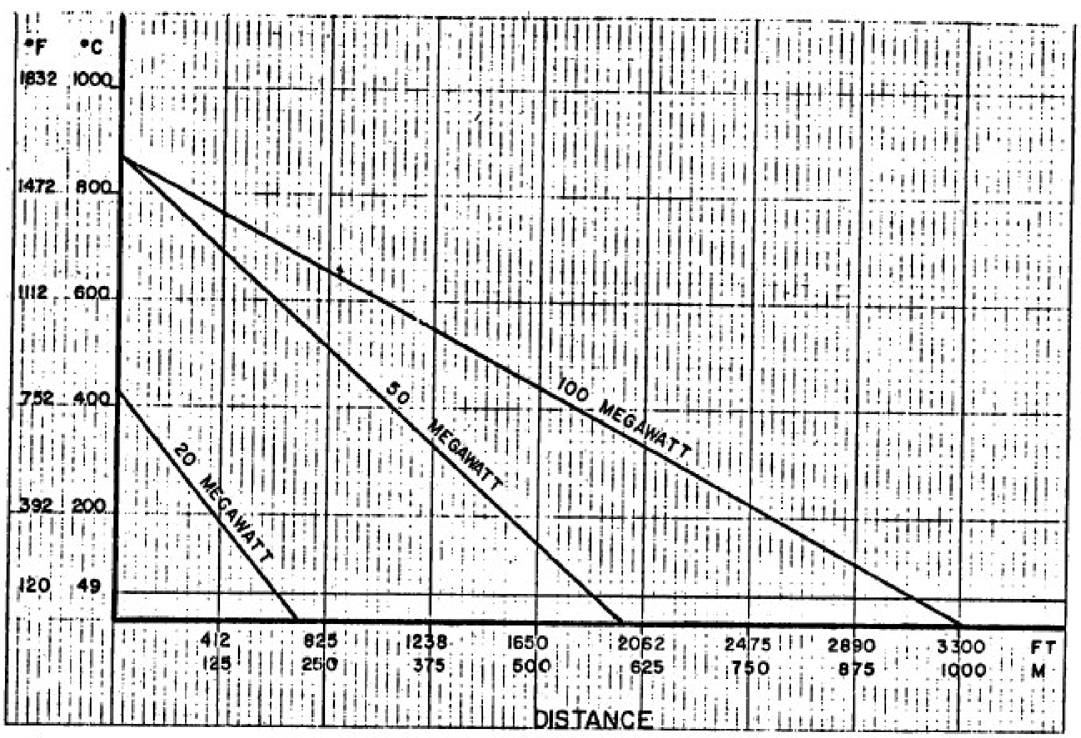

Figure 9 Tunnel Temperature versus Distance

3.3.1.2 Damage to Tunnel

If a fire similar to that of the Holland Tunnel fire were to occur in the EJMT, it can be expected to cause similar damage to the tunnel walls and ceiling. The configuration of the tunnel ventilation system for EJMT places the supply and exhaust fans at the east and west portals. The length of the EJMT is approximately 8976 feet, thus the temperature of air reaching the ventilation fans from a fire occurring in the middle of the tunnel would drop to within reasonable limits of the ventilation fans. As the seat of the fire occurs closer and closer to either end, the probability of damage to the ventilation fan system will increase. Because the ventilation system has supply and exhaust fans at both ends, the failure of fans at one end can, to some extent, be compensated for by fans at the other end of the tunnel. As shown in Figure 11, forced ventilation greatly reduces the temperature of the tunnel at greater distances. Forced ventilation will also help contain the damage to a smaller area, and allow firefighters greater access to the fire. Forced ventilation will have no effect on survival of the electrical systems.

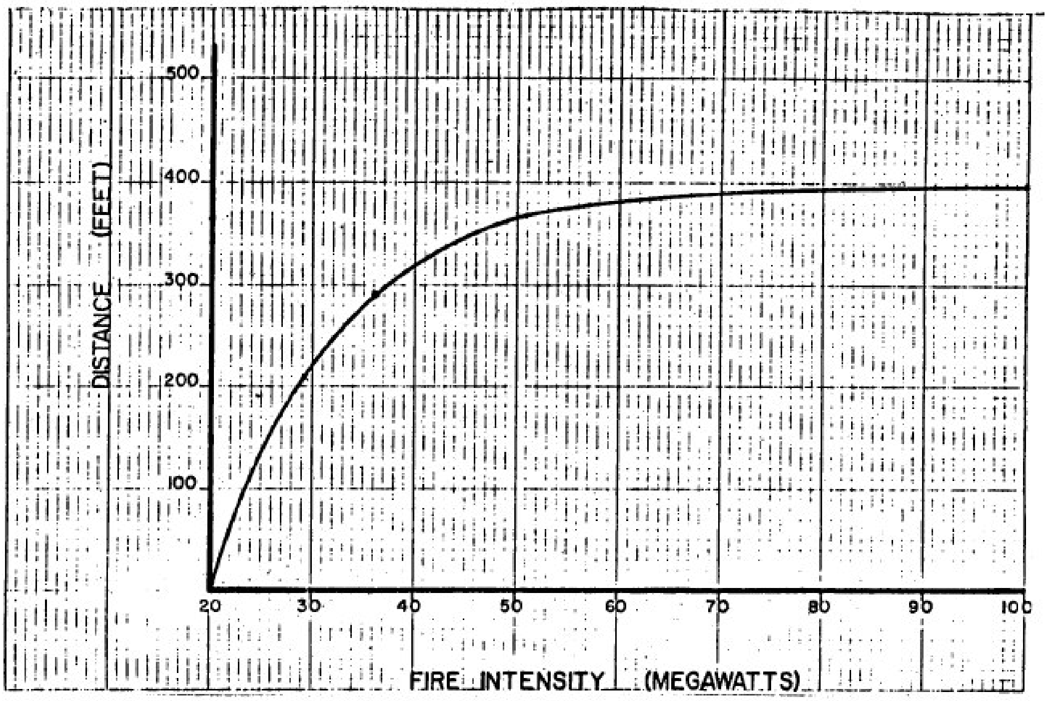

Figure 10 Distance of Flame along Ceiling versus Fire Intensity

3.3.2 Boiling Liquid Expanding Vapor Explosions (BLEVE)

Hazardous materials that fit this scenario include groupings A and B from Table 8. Scenarios 3, 4, 5, 7, 8, 9, 11 and 12 from Table 9 represent various degrees of possible explosion dangers. In other respects they are the same as Scenarios 1 and 2. The effects of an explosion can vary from localized damage to full tunnel collapse. Furthermore, explosions are extremely fast acting, giving motorists and tunnel operators little to no time to react. By their very nature, these scenarios would destroy emergency tunnel electrical systems before they could be used, thus not only delaying the reaction time of emergency services, but also perhaps preventing their approach to handle any ensuing fire. Besides material damage and flying debris, the immediate health effects of explosions include:

- Smoke inhalation
- Trauma and burns due to the force and heat of the blast
- Flying debris
- Worsening of pre-existing medical conditions as a result of acute physiological or psychological stress

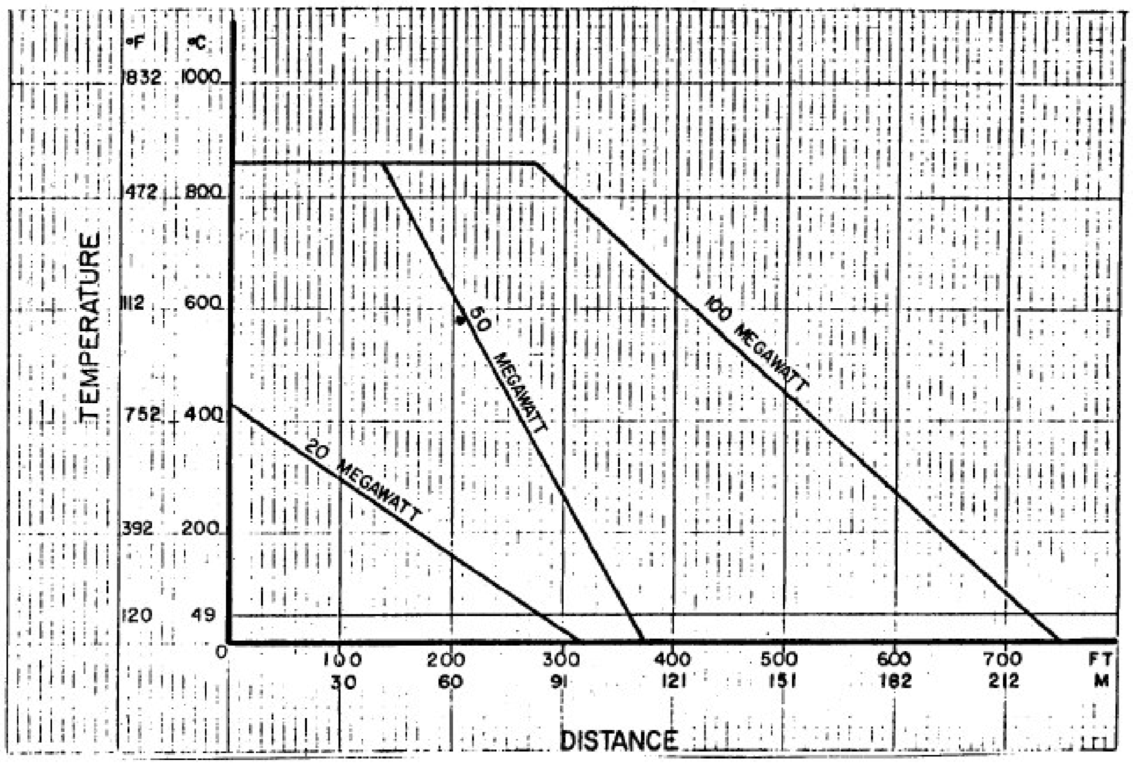

Figure 11 Tunnel Temperature versus Distance (with smoke extraction of 127 cfm/ft)

3.3.2.1 Scenario 3: BLEVE of LPG in Cylinder

An explosion of Liquid Petroleum Gas (LPG) has the potential to cause mostly localized damage. The pressure wave caused by such an explosion will threaten the structural integrity of the tunnel increasing the chance of ceiling collapse, or wall damage. Damage to the electrical systems would be localized to the incident. An explosion in the cylinder would create numerous high velocity metal shards that could cause additional explosions and fires in surrounding vehicles. An explosion directly underneath a ventilation fan is likely to severely damage the fan.

3.3.2.2 Scenario 4: Motor Spirit Pool Fire

This scenario could fit under HGV fires as discussed in the previous section. A motor spirit pool fire also has the potential to vaporize fuel creating clouds of highly flammable vapors which may ignite or explode (see Figure 12). The results of such an explosion will be similar to that of Scenario 3, but otherwise the event would be Scenario 1 or 2. Extinguishing a Scenario 4 fire with water has the potential to create vapor clouds of steam and fuels that can propagate to other portions of the tunnel (since they float on water) and potentially ignite there.

3.3.2.3 Scenario 5: Vapor Cloud Explosion (VCE) of Motor Spirit

This scenario is similar to scenario 3 expect that upon detonation, it will not send debris in all directions. The overpressure created will cause damage to tunnel structure and vehicles nearby. It also has the potential to start new fires and hence create further potential vapor cloud explosions.

Figure 12 Example fuel tanker fire

3.3.2.4 Scenarios 7 and 8: BLEVE or VCE of LPG in Bulk

This is the same as Scenario 3 except that the material is carried in bulk instead of cylinders. An explosion from this scenario would be much greater than Scenario 3. Tunnel collapse is likely, and severe damage to the tunnel ventilation and electrical systems is extremely likely.

3.3.2.5 Scenario 9: Torch Fire of LPG in Bulk

This scenario presents the same dangers as Scenario 7 and 8 but the delayed possible explosion provides time for motorists or tunnel operators to take action. An explosion is still extremely likely with all the same consequences as Scenario 7 and 8, but this scenario may allow time for evacuation or even total containment.

3.3.2.6 Scenario 11 and 12: Acrolein in Bulk/Cylinder Release

Acrolein is highly toxic, heavier than air, and vaporizes easily. It is also highly flammable and explosive. It will explosively polymerize when heated or when involved in a fire. Like LPG, acrolein will flow downhill and pool in low areas; unlike LPG, acrolein is highly reactive and corrosive. Direct contact including inhalation and skin contact is extremely harmful. Potential damage to tunnel systems is not limited to explosion and fire damage but also corrosion damage.

3.3.3 Nonflammable Hazardous Material Releases

Hazardous materials that fit Scenarios 6, 10, and 13 from Table 9 include all of those in Groups C through E in Table 8. These scenarios are all nonflammable releases of hazardous materials. Unlike all the other scenarios, these do not present much of a danger to tunnel mechanical or electrical systems. They do pose a great threat to motorists, tunnel operators, and the environment, but would do little damage to the tunnel structure.

3.3.3.1 Scenario 6: Chlorine Release

Chlorine is a highly toxic gas that is heavier than air and would flow downhill. It would do very little damage to tunnel infrastructure. In its pure form, chlorine is a greenish-yellow gas and highly reactive and corrosive. Quite apart from the risk of asphyxiation by displacement of air, it poses a major health hazard to all motorists downhill or downwind of a release.

3.3.3.2 Scenario 10: Ammonia Release

Like chlorine, ammonia is highly toxic, but lighter than air. When dissolved in water it becomes corrosive. In gaseous form, it is clear and colorless but has a strong odor. Ammonia by itself poses no real threat to tunnel mechanical or electrical systems. A release of ammonia gas can to some extent be controlled using the tunnel ventilation system. Being colorless, a release of ammonia would be difficult for tunnel operators to identify on remote monitoring screens. Despite being lighter than air, there is a risk of asphyxiation by displacement of air and it poses a major health hazard to all motorists who breathe it; those uphill or downwind of a release would be more likely to be exposed.

3.3.3.3 Scenario 13: BLEVE of Carbon Dioxide in Bulk

Carbon dioxide (CO_2) by itself is not particularly hazardous although there is a risk of asphyxiation by displacement of air. Carbon dioxide carried in bulk is used as a cryogenic fluid. When heated, the liquid CO_2 will expand creating an explosion hazard. Coming into contact with a liquid CO_2 leak will cause freezer burns. Damage to tunnel road surfaces and walls is possible because the extremely low temperature of the gas may make the materials into which it comes into contact very brittle. It will also freeze water and water vapor. Gaseous CO_2 can be controlled by the tunnel ventilation system. Liquid CO_2 can potentially damage the tunnel drainage system.

4. Policies and Procedures at Tunnels Elsewhere

The allowance of hazardous materials (Hazmat) through a tunnel is highly dependent upon the local authority having jurisdiction (usually the local fire department) and this decision varies depending on locality. If a Hazmat incident were to occur in a tunnel, it could be a catastrophic event because tunnel fire-life safety could be compromised, there may be structural integrity issues, and the result may be long term closure of the tunnel. Historically, large fire events have been poorly understood.

Hazmats in many tunnels are banned due to insufficient ventilation systems in case of an emergency event. Since test programs such as the Memorial Tunnel Fire tests, the understanding of how better to manage smoke and heat from a large fire has improved, and analysis techniques have improved through the use of computer programs such as computational fluid dynamics (CFD). In many cases, the tunnel ventilation system was not designed for a large fire and the banning of Hazmats was used to justify not spending the money required for larger air ducts and larger ventilation equipment. Depending on traffic volume, escorting Hazmats through the tunnel while traffic is stopped from entering the tunnel may be another option. In every case, a ventilation analysis is required in order to determine the best way to operate the ventilation system in the event of a fire (if it has not already been done); this gives the authority the ventilation capacity and its ability to manage a large fire event. An emergency ventilation mode table can then be prepared that is easily understood by the tunnel operators and/or programmed as part of an emergency response plan. Coordination with the local fire department must be organized as well.

Most tunnels are very rugged, especially those in rock. They are well suited to withstand internal pressures, although fires are more of an issue. Structural integrity analysis could be undertaken using blast analysis software; results from such analysis may indicate that, perhaps with some retrofit, sufficient capacity may exist to withstand a blast or fire for an agreed-to vehicle hazard. As a parallel benefit, this could be treated as an upgrade against terrorist attack.

The runoff of potential spills into sumps is another aspect that requires examination. Flammable vapor may potentially move from wet areas to dry areas and electrical equipment may be a source of ignition leading to an explosion, such as during a gasoline spill. A risk analysis of just such a situation was made in the New York area for the Queens Midtown Tunnel and Brooklyn Battery Tunnel drainage pumping stations; risks were found to be very low at the locations studied, not least because such spills are rare there when traffic volumes, the length of tunnel, the posted speed within the tunnel and the national accident rate are taken into account. Lane and shoulder widths may affect statistics too.

Practice regarding Hazmats varies considerably depending on locality. The tunnels in New York City ban Hazmats. In Virginia, at the Monitor Merrimac, vehicles with Hazmats are escorted through the tunnel while traffic is stopped. Some rural tunnels allow the free flow of Hazmats, for example Hanging Lakes. These types of decisions are made based upon an understanding of the risk involved, availability of alternative routes, and the willingness of the authority having jurisdiction to take on such a risk.

Table 10 Serious Fires at Selected Road Tunnels

Tunnel	Date	Dead	Injured	Vehicles Destroyed
Holland Tunnel	1949	0	66	23
Velsen Tunnel	1978	5	3	6
Nihonzaka Tunnel	1979	7	2	173
Caldecott Tunnel	1982	7	2	8
Pecorile Tunnel	1983	8	22	10
L'Arme Tunnel	1986	3	5	5
Huguenot Tunnel	1994	1	28	1
Pfaender Tunnel	1995	3	4	4
Mont Blanc Tunnel	1999	41		

There have been numerous fires in tunnels that have resulted in loss of life and long term closure of the tunnel due to structural damage and the requirement to upgrade the ventilation system. The Mont Blanc tunnel was closed for 2-3 years while the tunnel was rehabilitated. Some fire incidents in tunnels are listed in Table 10. Table 11 and Table 12 indicate tunnel access to Hazmat trucks in the U.S. and other countries, respectively.

Table 11 Tunnel Access for Hazmat Trucks in Selected U.S. Tunnels

Location	Decision Maker	Decision	Reason
Bradfield Road Tunnel, Alaska	FHWA and Alaska DOT	Exclude tankers from the tunnels (unless escorted by emergency vehicles, with no other vehicles in the tunnel at the same time)	Ventilation requirements too extreme if a tanker fire has to be considered
Tunnels under New York City rivers	TBTA and PANYNJ	Hazmat vehicles prohibited	Use alternate routes
Central Artery Tunnels, Boston, MA	Commonwealth of Massachusetts (Regulations 730CMR = CFR 49 Ch.1C)	Prohibited in all 7 road tunnels are: Vehicles with any amount of Hazmat, tandem units, bulk liquid carriers of any kind, and empty tank vehicles or any vehicle transporting an empty container last used for the transportation of flammable compressed gas, flammable liquid, poisonous substance or any type of explosive	Alternate routes through city
Baltimore MD I-95 and I-895		Combustibles, even propane on campers, are prohibited	Use alternate routes
Virginia Bridge-Tunnels	Virginia Commonwealth Transportation Board	Some Hazmats prohibited, see Appendix C for regulations	
3 Trans-Koolau Tunnels, Hawaii	HDOT	Transport of explosives is prohibited, but not flammable or other Hazmats	Maybe because other routes are in populated areas on narrow roads

Table 12 Hazmat Regulations in Selected Overseas Tunnels

Location	Decision Maker	Decision	Reason
East London, U.K: M25 Dartford Tunnel		Hazmats are permitted with an escort vehicle with the tunnel empty	Only tunnels exist east of Tower Bridge (central London)
East London, U.K: Other tunnels		Hazmats prohibited	Alternate route is Dartford Tunnel
Tyne, U.K.[25]		Vehicles with extremely hazardous material escorted	
Mersey Kingsway Tunnel, U.K.[25]		Vehicles with extremely hazardous material escorted	
Mersey Queensway Tunnel, U.K.[25]		Hazmat vehicles have basically no access, but vehicles with extremely hazardous material escorted	
Leopold II Tunnel, Brussels, Belgium.[25]		Hazmat vehicles have basically no access	
Elbe Tunnel, Hamburg, Germany.[25]		Hazmat restricted to times of low traffic during the night	
Fourvière, Lyon, France.[25]		The transport of particularly dangerous goods prohibited	
Tauern, Austria.[25]		Vehicles with extremely hazardous material escorted	
Singapore		Hazmat vehicles are prohibited from entering road tunnels	Hazmat vehicles are tracked by the government using GPS
Harbor tunnels in Hong Kong		Hazmat (IMDG[26]) vehicles prohibited	High volume of other traffic; use ferry services
Tate's Cairn Tunnel, Hong Kong		Hazmat vehicles prohibited[27]	The Tunnel Company may fix the hours during which all or any of the vehicles to which the by-law applies may enter the tunnel area (see items 1 to 3 at the bottom of the website)

[25] Tunnel Tests 2000: Safety of Road Tunnels in Europe, The AA Motoring Trust (Appendix A Item A43).
[26] International Maritime Dangerous Goods – same categories as U.S. placards.
[27] For regulations, see http://www.tctc.com.hk/eng/laws_prohibited.html and dangerous goods are defined in http://www.legislation.gov.hk/blis_export.nsf/CCD1DC74C1B00D2C48256D52002198AE/12DFC747CCE387F0C82564830029E75B?OpenDocument

5. Quantified Risk Assessment

5.1 Risks Associated with Hazmat Transport

5.1.1 Exposed Population

The primary risk to the exposed population is the potential for casualties (fatalities and injuries) caused by an accident and subsequent Hazmat release. The exposed population includes the road users, local residents, and temporary visitors. The physiological consequences of a Hazmat incident include those associated with toxic release and dispersion, vapor cloud explosion, and heat and smoke from fire. These consequences are estimated with models for gas and liquid dispersion, cloud mass and geometry, ignition, overpressure, toxicity, smoke movement, thermal radiation, and others, in combination with the number and location of exposed people.

Casualty risk is typically expressed in terms of the expected number of fatalities and injuries per year. Additional casualty risk indicators include the spatial distribution (location with respect to the Hazmat transport route) of the expected annual fatalities or injuries, and curves showing the annual probability (or frequency) of occurrence versus the expected number of fatalities or injuries.

Secondary risks to the exposed population include potential costs associated with evacuation and traffic delays following an incident[28]. Models for these secondary risks can be quite complicated. For example, evacuation costs include lost wages and business disruption, inconvenience to the public, cost of agencies assisting with evacuation, and temporary lodging.

5.1.2 Infrastructure Damage

The primary risk of infrastructure damage is that associated with the transport route, typically roadway and related structures and/or tunnel structure and equipment. The risk depends on several factors, including the type and amount of material released, the intensity and duration of the potential fire, and the specific design characteristics of the tunnel or roadway. Risk associated with infrastructure damage can also include other property losses, such as the other vehicles that may be involved in a truck accident, nearby buildings or utilities, and to a lesser extent, the material that is released in the incident and the carrier (truck and equipment transporting the material).

5.1.3 Environmental Impact

The primary risks to the environment associated with Hazmat transport include contamination of the atmosphere, surface water, soil, and groundwater. In most cases, environmental impact risk is modeled qualitatively, although some costs can be quantified, such as the costs associated with cleanup, i.e., stopping the spill and removing spilled materials, and the costs associated with loss of tourism, property value, and agricultural

[28] "Comparative Risks of Hazardous Materials and Non-Hazardous Materials Truck Shipment Accidents/Incidents", prepared for Federal Motor Carrier Safety Administration by Batelle, March, 2001.

production. The environmental impact varies widely, depending on the size, type, and location of the incident.

Incidents leading to the release of toxic gases or corrosive liquids, such as chlorine and ammonia, impact the atmosphere through dispersion and disposition and can also contaminate the surface water and soil. Incidents leading to explosions produce combustion products that can contaminate the atmosphere, surface water, and soil. The water used to fight a fire results in groundwater contamination as well as soil and surface water contamination.

Factors of the Hazmat transport route that affect the risk of environmental impact include the type of drainage retention system, means used to control fire water, and the type and relative location of agriculture, flora, wildlife habitat, and aquatic systems.

5.1.4 Local Economic Impact

The Hazmat transport risk to the local economy depends on the land use of the areas surrounding the route over which the Hazmat trucks travel and the availability of adequate alternative vehicle routes. The primary potential impact to the local economy from a Hazmat incident resulting in long term route closure is loss of business, where business can include retail sales, professional services, tourism, manufacturing, and others. Secondary potential impacts to the local economy include those discussed in the previous sections – loss of tourism revenue and reductions in property values resulting from an incident that causes long term environmental damage.

In addition to the impact on the local economy that relies on the route, there is the potential for a regional or national economic impact if the route is heavily used for interstate commerce. The impact depends on the duration of route closure and availability of adequate alternative routes.

5.2 Risk Assessment Methods

5.2.1 Qualitative Approach

Risk is comprised of two components:

- Probability of an event occurring
- Consequences given the event occurs

In Hazmat transport, quantification of risk is difficult as the probability of the event occurring is very low, but the consequences given an event occurs can be enormous. Numerous factors and variables influence the probabilities and consequences, contributing to the difficulty in quantifying Hazmat transport risk.

Qualitative approaches to characterizing Hazmat transport risk focus on describing a limited set of discrete accident scenarios and their expected consequences. Instead of using computed probabilities and annual expected values, the scenario events and consequences are described in terms of assumed accident time and location, quantity and type of material release, relative likelihood of occurring, and a detailed narrative of the resulting impacts on the exposed population, route infrastructure, environment, and local or regional economy. This approach – qualitative descriptive assessment of a small set of deterministic scenarios – is suitable when historical data are limited or when mitigation or policy alternatives are being evaluated for a single route. However, when several years of historical data are available, when a comparison between two alternative routes is to be made, or when risk is to be compared to some pre-determined acceptable risk level (e.g., annual number of expected fatalities), then a quantitative risk assessment approach should be used.

5.2.2 Quantitative Approach

Quantitative approaches to Hazmat transport risk assessment focus on computing probabilities of incidents and accurate and objective estimates of the consequences of the incidents for various types of Hazmat cargo and transport environments. The quantitative results typically include annual expected numbers of casualties (fatalities and injuries), and annual expected dollar losses due to infrastructure damage, route closure, and environmental damage. Results can also be expressed as annual probabilities of exceeding a given number of casualties or dollar loss value. These results provide a quantitative and objective means for making decisions related to possible Hazmat transport routes and restriction policies, route design alternatives (especially for routes through tunnels), emergency response planning, and mitigation alternatives based on cost-benefit comparisons.

A common quantitative risk assessment approach is the event tree model; see Figure 13 for a simple example of an event tree model of Hazmat transport risk. In this case the initiating event is a truck accident, which occurs with an annual probability that can be computed from historical data for the given route. Given the truck accident occurs, a Hazmat release will occur some fraction of the time; this fraction (or probability) can also be computed from historical data or from nationwide statistics if historical data are limited. Given a release occurs, a fire will occur some fraction of the time, depending on the specific type and quantity of material. Given a fire occurs, an explosion will occur some fraction of the time, again depending on the specific type and quantity of material.

Casualty, damage, and loss models that depend on the specific characteristics of the route and exposed population, are used to compute the expected consequences for each sequence of events, where a sequences is the path from the initiating event (left side of the tree in Figure 13) to the terminal events (right side of the tree in Figure 13). The expected annual consequences for each sequence are computed as the product of the annual probability of each sequence occurring times the expected consequences given the sequence occurs. The total risk is then the sum of the expected annual consequences for all sequences in the tree. For the example event tree shown in Figure 13, the expected annual number of fatalities, F, would be computed as follows:

$$F = (P1 \times P2 \times P4 \times P6) \times F1 + (P1 \times P2 \times P4 \times P7) \times F2 + (P1 \times P2 \times P5) \times F3 + (P1 \times P3) \times F4 \qquad (1)$$

where $P1$, $P2$, $P3$, $P4$, $P5$, $P6$, and $P7$ are the probabilities shown in Figure 13, $F1$ is the expected number of fatalities for an accident with release, fire, and explosion, $F2$ is the expected number of fatalities for an accident with release, fire, and no explosion, $F3$ is the expected number of fatalities for an accident with release, no fire, and no explosion, and *F4* is the expected number of fatalities for an accident with no release, no fire, and no explosion.

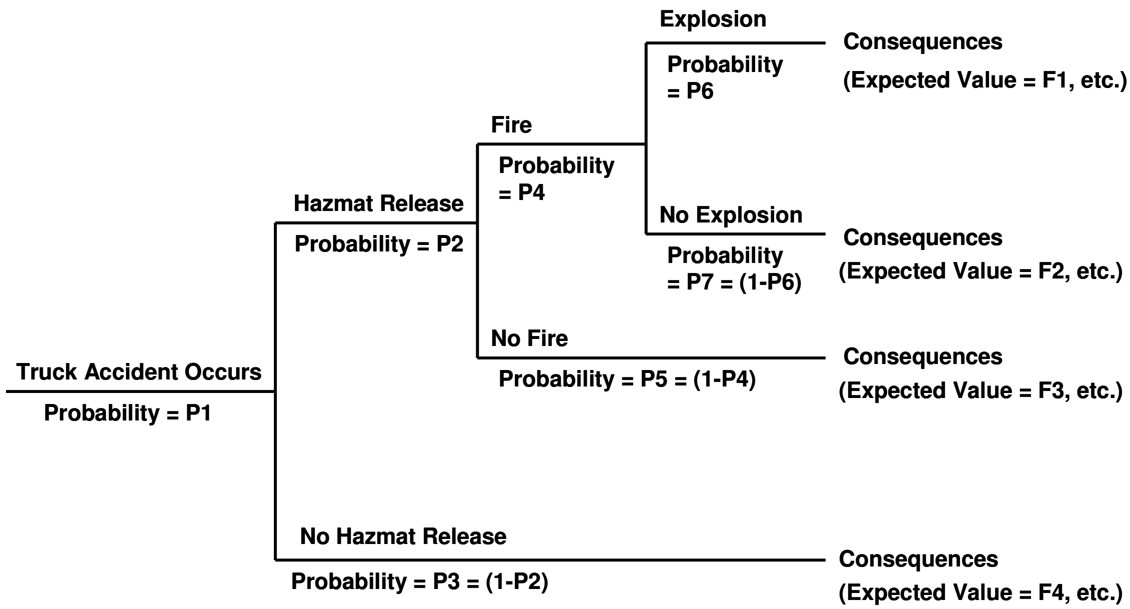

Figure 13 Example event tree model of Hazmat transport risk

In a typical quantified risk assessment for Hazmat transport, an event tree model is developed for each type and assumed quantity of material, and often for a few traffic periods (e.g., normal, heavy, light), more than one exposure region (e.g., urban or rural), and all relevant route types (e.g., tunnel or open road). The event trees, and related consequence models can easily become very large and complicated, necessitating implementation in an automated computer software tool as discussed in the next section.

5.3 Quantitative Risk Assessment Model (QRAM)

5.3.1 Background

In the mid-1990s, a joint effort between the OECD (Organization for Economic Cooperation and Development) Road Transport and Intermodal Linkages Research Program and the PIARC (World Road Association) Committee on Road Tunnels was initiated to develop a method for managing the risks involved with transporting hazardous materials through road tunnels[29]. The scope of the effort included the development of a quantitative risk assessment method for comparing the risks of transporting Hazmat through tunnels and alternate routes. The effort was completed in 2001, and the resulting risk assessment method, developed with expertise and data from 11 countries including the United States, was implemented in a software tool (QRAM). This tool has become the international industry standard for quantified risk assessment of Hazmat transport through tunnels, especially for comparing tunnel routes to alternative open road routes.

[29] "Safety in Tunnels: Transport of Dangerous Goods Through Road Tunnels", OECD, 2001.

5.3.2 Modeling Assumptions

In the ideal case, a complete assessment of risk involving Hazmat transport would require the consideration of all possible hazardous materials, weather conditions, accidents, sizes of breaches, route conditions; vehicles fully or partially loaded; and many other variables. For the purposes of bounding the Hazmat transport risk assessment problem, QRAM was developed with a limited but comprehensive set of incident scenarios. The 13 scenarios are shown in Table 13 (the same as those described in Section 3.3) and were selected to represent the various groupings of hazardous materials and evaluate the related severe effects, including overpressure, thermal loads, and toxicity. Each of the 13 scenarios is modeled using an event tree approach. The general method involves determining the probability of each scenario occurring based on the characteristics of the route, and then determining the expected consequences if each scenario occurs.

Table 13 Main Characteristics of 13 Scenarios in QRAM Model

Scenario No.	Description	Capacity of tank	Size of breach (mm)	Mass flow rate (kg/s)
1	HGV fire 20 MW	-	-	
2	HGV fire 100 MW	-	-	
3	BLEVE of LPG in cylinder	50 kg	-	
4	Motor spirit pool fire	28 tonnes	100	20.6
5	VCE of motor spirit	28 tonnes	100	20.6
6	Chlorine release	20 tonnes	50	45
7	BLEVE of LPG in bulk	18 tonnes	-	
8	VCE of LPG in bulk	18 tonnes	50	36
9	Torch fire of LPG in bulk	18 tonnes	50	36
10	Ammonia release	20 tonnes	50	36
11	Acrolein in bulk release	25 tonnes	100	24.8
12	Acrolein in cylinders release	100 litres	4	0.02
13	BLEVE of carbon dioxide in bulk (not including toxic effects)	20 tonnes	-	-

Key: BLEVE = Boiling liquid expanding vapour explosion; HGV = Heavy goods vehicle; LPG = Liquid petroleum gas; VCE = Vapour cloud explosion.

The probability of each scenario occurring is computed as a function of several model parameters, such as the truck accident frequency along the route, the vehicle and truck average daily traffic, the percentage of trucks carrying Hazmat, the type of Hazmat cargo carried by the trucks, and the assumed probability of each scenario being initiated given a truck accident occurs.

The consequences are limited to the following:

- Injuries and Fatalities
- Structural Damage to Tunnels
- Environmental Impacts

The expected consequences for each scenario are computed as functions of several model parameters, such as the vehicle traffic, the location of the route, the surrounding population density, the speed limit, the number of lanes, the emergency response planning, and the design features of the route (tunnel or open road).

The format of the QRAM results is described in more detail below; however, it is important to note that the model does not quantify several consequences, such as the costs associated with evacuation and time delay, structural damage to open routes and nearby infrastructure, and impacts on the local and national economy. The model does provide basic information about route closure and other descriptive information that can be used for estimating the impacts that are not explicitly considered in the model.

5.3.3 Required Input Data

The input data required by the QRAM model include information on the route characteristics, traffic composition, Hazmat transport, and population density. If a section of the route is a tunnel, additional information about the tunnel structure and operation is required. In general, the route is divided into segments of relatively constant geometry and traffic characteristics; the segments can have different characteristics for each direction if necessary. In addition, the characteristics of each section can vary by a maximum of three time periods to account for high, average, and low seasonal traffic activity (by percentage of the year) or high, average, and low traffic periods (by percentage of a 24-hour period).

The input data for the route that is constant for all segments (but may vary by time period and/or direction) include the following:

- Average number of people in a passenger car (light vehicle)
- Average number of people in a truck (heavy goods vehicle)
- Average number of people in a bus
- Number of Hazmat trucks per hour
- Breakdown of Hazmat cargo by product capable of generating scenarios

The input data for each segment (and time period and/or direction if these variation options are used) include the following:

- Coordinates of the segment end points
- Length of segment
- Total traffic (number of vehicles per hour)
- Percentage of vehicles that are trucks (heavy goods vehicles)
- Percentage of vehicles that are buses
- Average speed of passenger cars (light vehicles)
- Average speed of trucks (heavy goods vehicles) and buses
- Number of lanes
- Delay time for stopping traffic approaching a Hazmat vehicle accident
- Area surrounding route (urban or rural)
- Average population density surrounding route
- Accident rates for trucks (heavy goods vehicles)

For tunnel segments, additional input data include:

- Effective width

- Effective height
- Camber
- Open area of discrete drains or continuous slot
- Interval between drains or slot length used to define open area
- Average spacing between emergency exits
- Type of emergency communications
- Type of tunnel construction
- Ground type
- Internal radius and lining thickness if TBM
- Wall and roof slab thickness if cut and cover
- Road support and mid-wall thickness
- Overburden depth (water depth if applicable)
- Fire protection lining (temperature and time rating)
- Number of segments within tunnel, and for each of these segments:
  - Segment length
  - Segment gradient
  - Normal ventilation flow rate extracted from segment
  - Normal ventilation flow rate along segment
  - Time needed to activate emergency ventilation for segment
  - Emergency ventilation flow rate extracted from segment
  - Emergency ventilation flow rate along segment

5.3.4 Format of Results

The results of the QRAM model focus on the risk in terms of the likelihood and severity of the consequences of:

- Injuries and Fatalities
- Structural Damage to Tunnels
- Environmental Impacts

Injuries and fatalities are quantified as the expected number of injuries and fatalities per year for each of the 13 scenarios (see Table 13) and for each of a more general grouping of scenarios that includes fire, BLEVE, flammable liquids, toxic products, and propane in bulk. In addition to the expected number of casualties per year, injuries and fatality results are also represented by F/N curves that show the cumulative frequency (rate per year) of reaching various levels of fatalities. Injury and fatality estimates are limited to those associated with the Hazmat incident and do not include those due exclusively to a vehicular accident that may be related to the initiating truck accident.

Structural damage to tunnels is characterized by four categories of damage as shown in Table 14[30]. The QRAM model uses cost breakdowns for the two types of tunnels (driven and cut-and-cover) to compute the total cost of structural damage to a tunnel. For each breakdown item, the damage is estimated in terms of the proportion of the tunnel length that would require replacement of the item. Thus, cost of damage to the tunnel is quantified as the

[30] ibid

percentage of the replacement cost, separated for the four damage categories shown in Table 14, and aggregated according to the cost breakdown shown in Table 15[31].

Table 14 Categories of Damage to Tunnels in QRAM Model

	Damage scenario
1	Tunnel structure (collapse or structural integrity problems).
2	Internal civil structures including roadway (general integrity is not an issue).
3	Damage to protected equipment
4	Damage to unprotected equipment, *e.g.* lighting.

Environmental impacts are characterized in a more qualitative format than casualties and structural damage. For each scenario, the environmental impact is estimated in the QRAM model as negligible, low, medium, or high. The key factors of the route that affect the severity of the environmental impact include the drainage retention system, the system to control fire water, and the type and location of adjacent flora, fauna, and aquatic systems.

Table 15 Default Percentage Cost Breakdowns for Tunnels in QRAM Model

Cost items	Damage category	Driven tunnel %	Cut-and-cover %
Excavation	4	50	15
Tunnel lining	4	25	60
Internal civil structures, including roadway	3	12.5	12.5
Ventilation	2	6.5	6.5
Safety equipment	2	2	2
Lighting	1	3	3
Traffic equipment	1	1	1

5.4 Assessment of U.S. 6 Route

5.4.1 Route Model and Input Data

The U.S. 6 route extends from reference point 208.659 in the town of Silverthorne to reference point 229.328, east of the Eisenhower Johnson Memorial Tunnels. The endpoints of the route are essentially the intersection points with the I-70 highway. Daily traffic count data averaged by month (see Table 4 in Section 2.3.2) are used to define the following periods of normal, peak, and quiet traffic by month for the U.S. 6 route:

- Normal: April, June, July, August, September, and November (50% of total year)
- Peak: December, January, February, and March (33% of total year)
- Quiet: May and October (17% of total year)

For the rate of Hazmat trucks per hour on the U.S. 6 route, it is assumed that the Hazmat trucks that used the EJMT during the periods that the U.S. 6 route was closed (see Figure 7 in Section 2.3.1) represent the same rate and breakdown by type of Hazmat trucks that would

[31] ibid

use the U.S. 6 route when it is open. Thus, there were 2338 Hazmat trucks over a period of 387.79 hours, resulting in a rate of 6.0 Hazmat trucks per hour.

The breakdown of the Hazmat truck cargo by placard type shown in Figure 7 is used to define the proportion of Hazmat trucks carrying the various types of materials for the 13 scenarios (see Table 13) used in the QRAM model. Table 16 shows the proportions of Hazmat trucks by material used in the assessment for the U.S. 6 route.

The traffic information for the U.S. 6 route shown in Table 5 in Section 2.3.2 is used to define the segmentation model for the route. Information on speed limits, number of lanes, and access (urban/rural) along the route that is included in the on-line GIS data[32] of the route is also used to define route segments. In total, the U.S. 6 route is divided into 18 open road segments, as shown in Figure 14, which is a GIS map created from the on-line data.

The population statistics for the region that are discussed in Section 2.1 are used to develop the population density parameters needed for each segment in the U.S. 6 route. The area covered by each populated region is approximated from the GIS data and from the demographic information collected as discussed in Section 2.1. Table 17 summarizes the population density values used in the assessment for the U.S. 6 route. Note that the values vary by period – Normal, Peak, and Quiet – as defined earlier in this section.

Table 16 Proportion of Hazmat Trucks by Material Type

Material Type	**U.S. 6 and I-70 Routes**
Flammable Liquids in Bulk (gas, oil, etc.):	0.141
Propane (flammable liquefied gas) in cylinders:	0.135
Propane (flammable liquefied gas) in bulk:	0.135
Chlorine (severe toxic gases) in bulk:	0.025
Ammonia (toxic gases) in bulk:	0.025
Acrolein (toxic liquids) in bulk:	0.008
Acrolein (toxic liquids) in cylinders:	0.008
Compressed CO2 (non-flammable non-toxic gases) in bulk:	0.009
Materials leading to large (100 MW) fire (except liquids):	0.014
Empty trucks	0.500

The truck accident data for the U.S. 6 route[33] shown in summary format in Table 6 in Section 2.3.2 are used to determine the truck accident rates for each segment of the route and for each time period. Truck accident rates are typically expressed in terms of the annual number occurring per truck-mile, computed by dividing the number of accidents per year by the product of AADT × % trucks × 365 × segment length.

[32] Available from http://www.dot.state.co.us/App_DTD_DataAccess/GeoData/index.cfm

[33] Information provided by Colorado DOT (see Appendix A item A43).

Table 18 and Table 19 provide a complete summary of the 18 segments used to characterize the U.S. 6 route in the QRAM model. Table 18 includes the segment descriptions and traffic data, while Table 19 includes additional segment information and accident data.

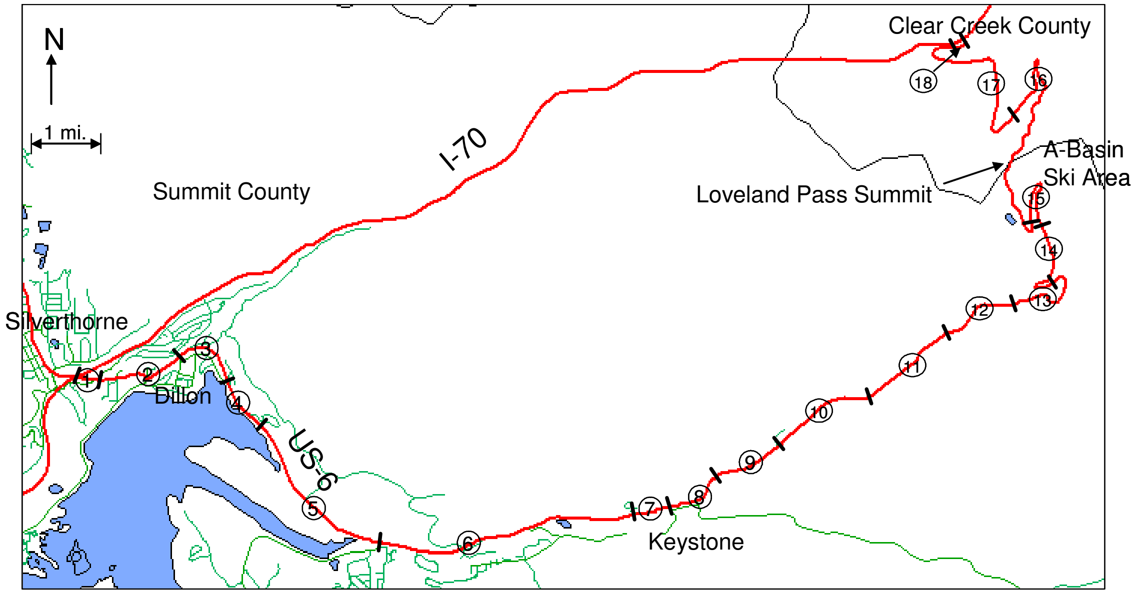

Figure 14 GIS map of U.S. 6 route showing segments defined for QRAM model

Table 17 Summary of Population Density Values for U.S. 6 Route Model

Region[a]	**Area (mi^2)**	**Population (#)**			**Density (#/mi^2)**			**Applicable Segments**[e]
		Normal[b]	**Peak**[c]	**Quiet**[d]	**Normal**	**Peak**	**Quiet**	
Dillon[34]	1.3	4,000	5,200	2,800	3,077	4,000	2,154	2,3,4
Silverthorne[35]	3.2	8,000	10,000	5,000	2,500	3,125	1,563	1
Keystone[f]	3.2	10,000	25,000	5,000	3,125	7,813	1,563	7,8
A-Basin Ski Area[f]	0.8	935	2,800	30	375	26959	38	15
Loveland Pass Summit[f]	0.4	75	100	50	188	250	125	16

Notes:

a. All other regions are assumed to be unpopulated.
b. Normal period is April, June, July, August, September, and November.
c. Peak period is December, January, February, and March.
d. Quiet period is May and October.
e. Refer to Figure 14 and Table 18 for location of segments.
f. Values are estimated from observation by CDOT personnel and communication with ski area personnel.

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[34] Data from http://www.townofdillon.com and I-70 PEIS Travel Demand Model (see Appendix A items A71 - A75)

[35] Data from http://www.silverthorne.org and I-70 PEIS Travel Demand Model (see Appendix A items A71 - A75)

Table 18 Location and Traffic Data for U.S. 6 Route Segments in QRAM Model

Segment Number	Start Ref. Point	End Ref. Point	Length (mi.)	Start Ref. Point Description	Annual Average Daily Traffic	Percent Trucks	Type of Access
1	208.659	208.950	0.291	ON SH 6 SE/O I-70, SILVERTHORNE	21,000	6.0%	Urban Arterial
2	208.950	209.844	0.894	ON SH 6 W/O CR 7, DILLON DAM RD	15,400	5.9%	Urban Arterial
3	209.844	210.662	0.818	ON SH 6 E/O EVERGREEN ST, DILLON	11,600	3.2%	Urban Regional Highway
4	210.662	211.253	0.591	ON SH 6 W/O SWAN MTN RD	11,900	3.1%	Urban Regional Highway
5	211.253	213.131	1.878		11,900	3.1%	Rural Regional Highway
6	213.131	215.952	2.821	ON SH 6 E/O SWAN MTN RD	9,800	3.3%	Urban Regional Highway
7	215.952	216.340	0.388	ON SH 6 W/O ON RAMP FROM MONTEZUMA RD/KEYSTONE	4,000	4.7%	Urban Regional Highway
8	216.340	217.000	0.660	ON SH 6 0.25MI E/O ON RAMP FROM MONTEZUMA RD/KEYSTONE	1,400	6.3%	Urban Regional Highway
9	217.000	217.891	0.891		1,400	6.3%	Urban Regional Highway
10	217.891	219.000	1.109		1,400	6.3%	Rural Regional Highway
11	219.000	220.000	1.000		1,400	6.3%	Rural Regional Highway
12	220.000	221.000	1.000		1,400	6.3%	Rural Regional Highway
13	221.000	222.000	1.000		1,400	6.3%	Rural Regional Highway
14	222.000	223.000	1.000		1,400	6.3%	Rural Regional Highway
15	223.000	224.000	1.000	A-Basin Ski Area	1,400	6.3%	Rural Regional Highway
16	224.000	227.000	3.000	Loveland Pass	1,400	6.3%	Rural Regional Highway
17	227.000	229.242	2.242		1,400	6.3%	Rural Regional Highway
18	229.242	229.328	0.086	ON SH 6 SE/O I-70, SILVERTHORNE	1,400	6.3%	Rural Regional Highway

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Table 19 Traffic and Accident Data for U.S. 6 Route Segments in QRAM Model

Segment Number	Speed Limit (mph)	No. of Lanes	Annual Accident Rate			Accidents per Million Truck-Miles		
			Normal[a]	Peak[b]	Quiet[c]	Normal	Peak	Quiet
1	35	4	0.67	3.00	0.00	5.06	17.42	0
2	40	4	2.67	2.00	0.00	9.14	5.24	0
3	50	4	0.00	1.00	0.00	0	7.01	0
4	50	4	0.00	1.00	0.00	0	9.77	0
5	55	4	0.00	1.00	0.00	0	3.07	0
6	55	4	1.33	3.00	0.00	4.07	7.00	0
7	50	4	0.67	0.00	0.00	25.46	0	0
8	50	4	0.67	0.00	0.00	31.90	0	0
9	50	2	0.00	0.00	0.00	0	0	0
10	50	2	0.00	0.00	0.00	0	0	0
11	40	2	0.00	0.00	0.00	0	0	0
12	40	3	0.00	0.60	0.00	0	14.48	0
13	40	2	0.40	1.20	0.00	12.63	28.97	0
14	30	2	1.00	0.60	0.00	31.58	14.48	0
15	35	2	0.40	0.60	0.60	12.63	14.48	23.65
16	30	2	2.00	2.70	1.20	21.05	21.72	15.76
17	40	2	0.20	0.30	1.20	2.82	3.23	21.09
18	35	2	0.00	0.00	0.00	0	0	0

Notes:

a. Normal period is April, June, July, August, September, and November.

b. Peak period is December, January, February, and March.

c. Quiet period is May and October.

5.4.2 QRAM Results

The complete set of relevant results of the risk assessment for the U.S. 6 route using the QRAM model is shown in Appendix F (Section F.1). These results include the following:

- Risk curves (F/N curves as described in Section 5.3.4) for all 13 scenarios individually and for the scenarios grouped by type of consequence, which show the cumulative frequency (rate per year) of reaching various levels of casualties (injuries plus fatalities).
- Scenario frequency tables for all 13 scenarios for each segment of the route and for the three different traffic periods (normal, quiet, peak), which show the annual frequency (expected number of occurrences per year) for each scenario.
- Expected values of casualties (expected number of fatalities and injuries per year) for all 13 scenarios individually and for each scenario grouped by type.
- General description of the environmental impact of the scenarios.

Table 20 (repeated from Appendix F, Section F.1) shows the table of expected casualties per year for each scenario. As can be seen in these results, the risk to the U.S. 6 route, in terms of casualties, is dominated by Scenarios 1, 2, and 6.

Table 20 Expected Value Results for Casualties from QRAM Model for U.S. 6 Route

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year
1	HGV fire 20 MW	3.990
2	HGV fire 100 MW	2.060
3	BLEVE of a 50kg LPG cylinder	0.01056
4	Motor spirit pool fire	0.01363
5	VCE of motor spirit	0.00534
6	Chlorine release from a 20 tons tank	1.110
7	BLEVE of an 18 tons LPG tank	0.05437
8	VCE from an 18 tons LPG tank	0.00413
9	Torch fire from an 18 tons LPG tank	0.00114
10	Ammonia release from an 18 tons tank	0.02674
11	Acrolein release from a 25 tons tank	0.01272
12	Acrolein release from a 100 l cylinder	0.00108
13	BLEVE of a 20 ton liquefied CO2 tank	0.00028

The casualty risk is computed as the product of the truck accident rate, the probability of an incident occurring following an accident, the casualty rate during an incident, and the exposed population. For the U.S. 6 route, the accident rates are relatively high, especially along the steep sections with sharp curves. The 20MW and 100MW fires (Scenarios 1 and 2) have a relatively higher probability of occurring following an accident, although a relatively moderate casualty rate, while the Chlorine release (Scenario 6) has a lower probability of occurring, but a very high casualty rate. The exposed population along certain sections of the U.S. 6 route is relatively high due to Silverthorne, Dillon, and the Keystone area. All of these issues contribute to the high casualty risk associated with Scenarios 1, 2, and 6. It should be noted, however, that the results for Scenario 6 may be an overestimate of the true casualty risk. This scenario is based on a Chlorine release from a 20-ton tank. Although the actual Hazmat transport data along the route (see Figure 7) are used as input for the QRAM model, the exact quantities of material are not used and it is not likely that Chlorine in this large of a quantity is actually transported over the route. Chlorine transport of this type is prohibited in Canada[36].

The environmental risks due to an incident on the U.S. 6 route include the impacts on the wildlife habitat, the forest and vegetation, and the water supply. Depending on its location and the time of year, a significant fire would spread rapidly, endanger the sensitive wildlife habitat, and destroy forest and other plant life. In addition, the Snake River and Dillon Reservoirs could be polluted from the run-off of firefighting water. Other non-fire incidents, such as fuel spills or release of soluble toxic materials, could cause contamination of the soils, surface water, and groundwater, and endanger the wildlife habitat and forested lands in the area.

5.4.3 Additional Impacts of Incident on U.S. 6 Route

There are other adverse consequences of an incident along the U.S. 6 route that are not considered in the QRAM method and include the following:

[36] "Safety in Tunnels: Transport of Dangerous Goods Through Road Tunnels", OECD, 2001.

- Route closure would occur following an incident; the duration of closure would depend on the location and type of incident. Although this would cause disruption to recreation-related traffic, it is not critical as the duration of closure is likely to be relatively short, and the route is closed at other times so the traveling public is accustomed to this disruption. The cost of route closure, from a user perspective, is estimated from delay time as $14.52 per vehicle-hour for a passenger car and $28.87 per vehicle-hour for a multi-unit truck[37].
- The U.S. 6 roadway could be damaged, the extent of which depends on the location and type of incident. It is also possible that adjacent buildings and other infrastructure could be damaged by an explosion or spreading fire. The cost of replacement of the U.S. 6 route roadway is estimated at $5.5M/mile[38].
- Soil, groundwater, and surface water clean-up costs could be significant, depending on the type of incident and speed of response to the spill, explosion, and or fire. There could also be a loss of recreational area along Loveland Pass if the extent of the clean-up is significant.
- The local economy along the route, for example in Keystone and the A-Basin ski area, depends heavily on the tourism industry during the ski season as well as the summer months. Temporary disruption of the route for incident response would have a minor impact on the tourism-related economy, as discussed above; however, the economy would be severely impacted if one or more of the ski resorts were forced to close for a significant period due to a soil and/or water contamination problem. In addition to the direct loss of revenue there would also be the long term effects of negative publicity associated with environmental contamination. These effects can impact property values and attractiveness of the resort areas as a recreation destination.

5.5 Assessment of I-70 Route

5.5.1 Route Model and Input Data

The I-70 route extends from reference point 205.43 in the town of Silverthorne to reference point 216.254, east of the Eisenhower Johnson Memorial Tunnels. The endpoints of the route are essentially the intersection points with the U.S. 6 route. Daily traffic count data averaged by month (see Table 2 in Section 2.3.1) are used to define the following periods of normal, peak, and quiet traffic by month for the I-70 route:

- Normal: January, February, June, September, and December (42% of total year)
- Peak: March, July, and August (25% of total year)
- Quiet: April, May, October, and November (33% of total year)

For the rate of Hazmat trucks per hour on the I-70 route, it is assumed that the Hazmat trucks that used the EJMT during the periods that the U.S. 6 route was closed (see Figure 7 in Section 2.3.1) represent the total number of trucks that traveled on the I-70 route during the two-year period. It is also assumed that the data in Figure 7 represent the same rate and

[37] Values used in CDOT road closure calculator (see Appendix A item A47), updated from 1999 $ values using 3% inflation rate.
[38] Value provided by CDOT, Ina Zisman, personal communication.

breakdown by type of Hazmat trucks that would use the I-70 at any time if the trucks were not restricted to the U.S. 6 route when it is open. Thus, the risk assessment of the I-70 route is done for the following two Hazmat truck rates:

1. The current situation: 2338 Hazmat trucks (escorted through EJMT) over a period of 2 years = 0.133 Hazmat trucks per hour
2. The changed situation (a changed policy to allow unrestricted Hazmat truck transport on I-70): Same rate as current situation for U.S. 6 route = 6.0 Hazmat trucks per hour (unescorted through EJMT)

Similar to the model of the U.S. 6 route discussed in the previous section, the breakdown of the Hazmat truck cargo by placard type shown in Figure 7 is used to define the proportion of Hazmat trucks carrying the various types of materials for the 13 scenarios (see Table 13) used in the QRAM model. The proportions of Hazmat trucks by material used in the assessment for the U.S. 6 route (see Table 16) is also used for the I-70 route.

The traffic information for the I-70 route discussed in Section 2.3.1 is used to define the segmentation model for the route. Information on speed limits, number of lanes, and access (urban/rural) along the route that is included in the on-line GIS data[39] of the route is also used to define route segments. In total, the I-70 route is divided into 6 open road segments and one tunnel segment as shown in Figure 15, which is a GIS map created from the on-line data.

The population statistics for the region that are discussed in Section 2.1 are used to develop the population density parameters needed for each segment in the I-70 route. The area covered by each populated region is approximated from the GIS data and from the demographic information collected as discussed in Section 2.1. Table 21 summarizes the population density values used in the assessment for the I-70 route. Note that the values vary by period – Normal, Peak, and Quiet – as defined earlier in this section. These periods are based on the monthly traffic counts and are not the same for the I-70 route as they are for the U.S. 6 route. For example, the summer months are the Peak period for the I-70 route and the Normal period for the U.S. 6 route, while the winter months are the Normal period for the I-70 route and the Peak period for the U.S. 6 route.

The truck accident data for the I-70 route[40] discussed in summary format in Section 2.3.1 are used to determine the truck accident rates for each segment of the route and for each time period. As described above for the U.S. 6 route, truck accident rates are typically expressed in terms of the annual number occurring per truck-mile, computed by dividing the number of accidents per year by the product of AADT × % trucks × 365 × segment length.

Table 22 and Table 23 provide a complete summary of the 7 segments used to characterize the I-70 route in the QRAM model. Table 22 includes the segment descriptions and traffic data, while Table 23 includes additional segment information and accident data.

[39] Available from http://www.dot.state.co.us/App_DTD_DataAccess/GeoData/index.cfm
[40] Information provided by Colorado DOT (see Appendix A items A62 and A63).

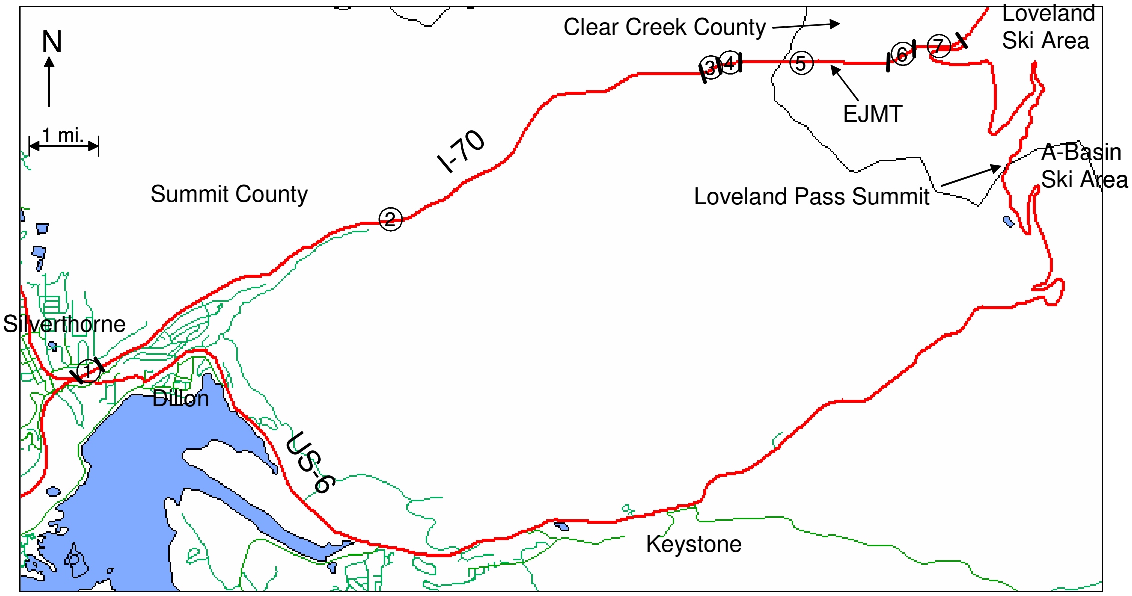

Figure 15 GIS map of I-70 route showing segments defined for QRAM model

Table 21 Summary of Population Density Values for I-70 Route Model

Region[a]	Area (mi^2)	Population (#)			Density (#/mi^2)			Applicable Segments[e]
		Normal[b]	Peak[c]	Quiet[d]	Normal	Peak	Quiet	
Silverthorne[41]	3.2	10000	8000	5000	3125	2500	1563	1
Loveland Ski Area[f]	2.3	3000	30	30	1304	13	13	7
West Tunnel Portal Area[f]	.04	50	50	50	1250	1250	1250	4
East Tunnel Portal Area[f]	.04	50	50	50	1250	1250	1250	6

Notes:

a. All other regions are assumed to be unpopulated.
b. Normal period is January, February, June, September, and December.
c. Peak period is March, July, and August.
d. Quiet period is April, May, October, and November.
e. Refer to Figure 15 and Table 22 for location of segments.
f. Values are estimated from observation by CDOT personnel and communication with ski area personnel.

As discussed in Section 5.3.3, the QRAM model for tunnel segments requires several parameters that characterize the construction and operation of the tunnel. For the I-70 route model, segment number 5 is the EJMT. The tunnels consist of a single bore for each direction of traffic, thus each direction is modeled separately. Table 24 lists the tunnel model

[41] Data from http://www.silverthorne.org and I-70 PEIS Travel Demand Model (see Appendix A items A71 - A75).

parameters for the QRAM model of the EJMT. The information is taken from the recent tunnel ventilation study report[42] and tunnel construction drawings[43].

Table 22 Location and Traffic Data for I-70 Route Segments in QRAM Model

Segment Number	Start Ref. Point	End Ref. Point	Length (mi.)	Start Ref. Point Description	Annual Average Daily Traffic	Percent Trucks	Type of Access
1	205.423	205.749	0.326	DILLON/SILVERTHORNE INTERCHANGE SH 9 NW AND SH 6 SE OVERPASS STRS F-12-S EB AND F-12-R WB	28,200	9.7%	Interstate
2	205.749	213.094	7.345	CHANGE SPEED LIMIT	28,200	9.7%	Interstate
3	213.094	213.418	0.324	SPEED LIMIT CHANGE	28,200	9.7%	Interstate
4	213.418	213.651	0.233	RAMP ON WEST PORTAL PARKING AREA LT	28,200	9.7%	Interstate
5	213.651	215.35	1.699	EISENHOWER/JOHNSON MEMORIAL TUNNELS WEST PORTAL STRS F-13-X EB AND F-13-Y WB ELEVATION 11,155 FT	28,200	9.7%	Interstate
6	215.35	215.661	0.311	EISENHOWER/JOHNSON MEMORIAL TUNNELS EAST PORTAL STRS F-13-X EB AND F-13-Y WB ELEVATION 11,013 FT CHANGE WIDTH	28,200	9.7%	Interstate
7	215.661	216.254	0.593	CHANGE WIDTH	28,200	9.7%	Interstate

Table 23 Traffic and Accident Data for I-70 Route Segments in QRAM Model

Segment Number	Speed Limit (mph)	No. of Lanes	Annual Accident Rate			Accidents per Million Truck-Miles		
			Normal[a]	Peak[b]	Quiet[c]	Normal	Peak	Quiet
1	65	6	0.96	0.80	1.20	2.83	2.07	4.29
2	60	6	23.52	22.40	25.20	3.08	2.57	4.00
3	50	4	0.48	0.80	0.00	1.42	2.08	0.00
4	50	4	0.48	2.40	0.60	1.98	8.67	3.00
5	50	4	2.40	0.00	2.40	1.36	0.00	1.65
6	50	4	1.92	0.80	1.20	5.93	2.17	4.50
7	65	6	2.88	3.20	1.20	4.67	4.54	2.36

Notes:

a. Normal period is January, February, June, September, and December.
b. Peak period is March, July, and August.
c. Quiet period is April, May, October, and November.

[42] "Eisenhower/Johnson Memorial Tunnels Report: Fire Emergency Ventilation Study", prepared by Sverdrup Civil for Colorado DOT, May, 2001 (see Appendix A item A33).
[43] Information provided by Colorado DOT (see Appendix A item A42).

Table 24 Tunnel Parameters for QRAM Model of EJMT

Parameter	South Tube (Johnson)	North Tube (Eisenhower)	Parameter Notes and Assumptions
Traffic direction	W to E	E to W	
Width, ft	34.3	34.3	
Height, ft.	16.5	16.5	
Camber, %	0	0	
Length, ft.	8960	8940	
Gradient, %	-1.73	-1.64	Positive is uphill from W to E
Normal ventilation, extraction, cfm	159,620	596,200	Johnson = 1 fan @ 25HP; Eisenhower = 4 fans @ 12.5HP
Normal ventilation, supply, cfm	145,740	439,725	Johnson = 1 fan @ 25HP; Eisenhower = 3 fans @ 12.5HP
Emergency ventilation, extraction, cfm	2,760,000	3,200,000	Johnson = 6 fans @ full capacity; Eisenhower = 6 fans @ full capacity
Emergency ventilation, supply, cfm	0	3,252,000	Johnson = No fans; Eisenhower = 6 fans @ full capacity
Time to activate emergency ventilation, min.	5	5	Time until ventilation is completely activated
Open area of discrete drains, sf	4.7	4.7	
Interval between drains, ft.	150	150	
Traffic density	1	1	1 = Light = 10% trucks
Average spacing between emergency exits, ft.	2240	2235	Total of 3 evenly spaced
Type of emergency communication	3	3	3 = CCTV plus variable signage
Type of construction	1	1	1 = TBM
Ground type	2	2	2 = Fragmented
Internal radius, ft.	18	18	
Internal thickness, ft.	3	3	
Road support thickness, ft.	5	5	
Fire protection lining	1	1	1 = Yes
Temperature rating, °C	1350	1350	Default value
Time rating, min.	120	120	Default value

5.5.2 QRAM Results

The complete set of relevant results of the risk assessment for the I-70 route using the QRAM model is shown in Appendix F (Sections F.2 and F.3). These results include the following:

- Risk curves (F/N curves as described in Section 5.3.4) for all 13 scenarios individually and for the scenarios grouped by type of consequence, which show the cumulative frequency (rate per year) of reaching various levels of casualties (injuries plus fatalities).
- Scenario frequency tables for all 13 scenarios for each segment of the route, which show the annual frequency (expected number of occurrences per year) and the return period (time between occurrences) for each scenario.
- Expected values of casualties (expected number of fatalities and injuries per year) for all 13 scenarios individually and for each scenario grouped by type.
- General description of the environmental impact of the scenarios.
- Damage to each tunnel for each of the 13 scenarios for five possible accident locations along the length of the tunnel. Damage is characterized in terms of the length of tunnel that would require repair or replacement and the cost of the repair or replacement (as a percentage of the total tunnel capital cost). As discussed in Section 5.3.4 (Table 14), damage is broken down into four tunnel components.

As discussed in Section 5.5.1, the risk on the I-70 route is evaluated using the QRAM model for two situations – the current one with a small number of Hazmat vehicles using the tunnel under convoy conditions when Loveland Pass is closed, and the changed one with the Hazmat vehicles no longer restricted to the U.S. 6 route and allowed to use the tunnel freely. The results for the current situation (Appendix F Section F.2) are used primarily to establish a baseline so that the results for the changed situation (Appendix F Section F.3) can be used to compute the increase in risk due to the potential change in Hazmat routing policy.

It should be noted that the QRAM model does not directly allow for convoy conditions of Hazmat trucks, or any traffic for that matter. The input data such as the truck accident rates, Hazmat vehicle rates, and exposed population within the tunnel, do not assume convoy conditions – the current procedure in the tunnel to stop regular traffic and allow the Hazmat trucks to pass through the tunnel at 1000-foot intervals. Issues such as clustering of trucks (which may increase the likelihood of a scenario if an accident occurs and increase the consequences if a scenario occurs, and thus increase the risk), segregation of trucks from regular traffic in the tunnel (which may decrease the likelihood of truck accidents occurring and decrease the exposed population, and thus decrease the risk), and sudden mixing of trucks and regular traffic when the convoy period ends (which may increase the likelihood of truck accidents occurring, and thus increase the risk) are not included in the assessment. Due to these simplifications associated with the QRAM assessment of the current I-70 route situation, the focus of this section is primarily on the results associated with the changed situation for the I-70 route.

Table 25 (repeated from Appendix F, Section F.3) shows the table of expected casualties per year for each scenario. As can be seen in these results, the risk to the I-70 route in terms of casualties is dominated by Scenarios 1 and 2, the 20MW and 100MW fires, respectively.

The exposed population along most of the I-70 route is relatively low, thus the casualty risk is dominated by the most probable scenarios, in this case, Scenarios 1 and 2.

Table 26 shows the change in the casualty risk for each of the 13 scenarios for the I-70 route changed situation (Hazmat allowed in EJMT; same results as in Table 25) compared to the I-70 current situation (Hazmat convoyed only when Loveland Pass closed). As expected, the increase in the 20MW and 100MW fires, which depends primarily on the accident rates, is not significant. For the other scenarios, the increase is approximately 44-fold, which is consistent with the increase in the rate of Hazmat trucks per hour from the annual rate of 0.133 Hazmat trucks per hour due to closure of Loveland Pass to 6.0 Hazmat trucks per hour, the current rate on the U.S. 6 route.

The expected tunnel damage for each scenario is summarized in Table 27. Note that these are not annualized expected values (the format for casualty risk) – they are the damage (or percent of replacement cost) that is expected to occur if the given scenario occurs. Table 27 is a subset of the results included in Appendix F and shows the damage value for the accident occurring at the worst location along the tunnel length. Four of the Scenarios (Scenarios 6, 10, 11, and 12) are toxic gas releases, and in the QRAM model, do not produce damage to the tunnel. The worst damage is caused by Scenarios 5 and 8, the Motor Spirit and LPG events, respectively, both resulting in VCE (Vapor Cloud Explosion) incidents that are estimated to produce damage equal to 12.5% of the tunnel replacement value. The tunnel replacement value is reported to be $738,000,000[44] (assumed equal to the cost of a third bore of the EJMT), thus the damage is estimated to be $92,250,000. The QRAM tunnel damage results are somewhat limited, and in most cases, appear to be on the conservative (low) side (e.g., the 100MW fire damage is estimated as 0.2% of the tunnel replacement value). Section 3.3 of this report provides additional description of the impacts of each scenario on the tunnel structure and systems, which may be more accurate than the percent replacement values computed with the QRAM model.

The environmental risks due to an incident on the I-70 route include the impacts on the wildlife habitat, the forest and vegetation, and the water supply. Depending on its location and the time of year, a significant fire outside of the EJMT would spread rapidly, endanger the sensitive wildlife habitat, and destroy forest and other plant life. East of the EJMT along the I-70 route is the location of the Clear Creek headwaters. The EJMT drainage system also discharges to Clear Creek. Clear Creek provides drinking water to the communities downstream such as Georgetown, Silver Plume, Idaho Springs, and a number of cities in the Denver metropolitan area such as Golden, Broomfield, and Northglenn[45]. West of the EJMT along the I-70 route is Straight Creek, which provides drinking water to the town of Dillon and is a tributary to the Blue River. Straight Creek is also on the EPA list of endangered streams[46]. All of these water sources could be polluted from the run-off of firefighting water. Other non-fire incidents, such as fuel spills or release of soluble toxic materials, could cause contamination of the soils, surface water, and groundwater, and endanger the wildlife habitat and forested lands in the area.

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[44] Information provided in I-70 PEIS Technical Report: www.i70mtncorridor.com/I70_TechReports.asp.
[45] Information provided by CDOT (see Appendix A item A45).
[46] ibid.

Table 25 Expected Value Results for Casualties from QRAM Model for I-70 Route (Changed to Allow Hazmat)

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year
1	HGV fire 20 MW	9.190
2	HGV fire 100 MW	4.510
3	BLEVE of a 50kg LPG cylinder	0.0026840
4	Motor spirit pool fire	0.0056090
5	VCE of motor spirit	0.0031820
6	Chlorine release from a 20 tons tank	0.10180
7	BLEVE of an 18 tons LPG tank	0.0184500
8	VCE from an 18 tons LPG tank	0.0029860
9	Torch fire from an 18 tons LPG tank	0.0288000
10	Ammonia release from an 18 tons tank	0.0239300
11	Acrolein release from a 25 tons tank	0.0078870
12	Acrolein release from a 100 l cylinder	0.0005626
13	BLEVE of a 20 ton liquefied CO2 tank	0.0000772

Table 26 Change in Expected Value Results for Casualties from QRAM Model for I-70 Route

		Expected Value (fatalities+injuries)/year			
Scenario	Scenario Description	Current	Changed to Allow Hazmat	Increase from Current	% Increase from Current
1	HGV fire 20 MW	9.15	9.19	0.04	0
2	HGV fire 100 MW	4.51	4.51	0	0
3	BLEVE of a 50kg LPG cylinder	0.0000597	0.002684	0.0026243	4396
4	Motor spirit pool fire	0.0001247	0.005609	0.0054843	4398
5	VCE of motor spirit	0.0000707	0.003182	0.0031113	4401
6	Chlorine release from a 20 tons tank	0.00226	0.1018	0.09954	4404
7	BLEVE of an 18 tons LPG tank	0.0004102	0.01845	0.0180398	4398
8	VCE from an 18 tons LPG tank	0.0000664	0.002986	0.0029196	4397
9	Torch fire from an 18 tons LPG tank	0.0006404	0.0288	0.0281596	4397
10	Ammonia release from an 18 tons tank	0.000532	0.02393	0.023398	4398
11	Acrolein release from a 25 tons tank	0.0001754	0.007887	0.0077116	4397
12	Acrolein release from a 100 l cylinder	0.0000125	0.000563	0.0005501	4401
13	BLEVE of a 20 ton liquefied CO2 tank	0.0000017	7.72E-05	0.0000755	4441

Table 27 Summary of QRAM Model Tunnel Damage Results for EJMT (Changed to Allow Hazmat)

Scenario	Scenario Description	Worst-case Accident Location	Cost (% of construction capital cost)				
			Tunnel structure	Internal civil	Protected equipment	Unprotected equipment	Total
1	HGV fire 20 MW	Same for all locations	0.00	0.00	0.02	0.03	0.05
2	HGV fire 100 MW	Same for all locations	0.00	0.00	0.10	0.06	0.16
3	BLEVE of a 50kg LPG cylinder	Same for all locations	0.00	0.00	0.16	0.19	0.36
4	Motor spirit pool fire	Tunnel mid-point	0.00	0.00	0.28	0.14	0.42
5	VCE of motor spirit	Tunnel portal	0.00	0.00	8.50	4.00	12.50
6	Chlorine release from a 20 tons tank	Same for all locations	0.00	0.00	0.00	0.00	0.00
7	BLEVE of an 18 tons LPG tank	Tunnel mid-point	6.67	0.00	2.64	1.44	10.75
8	VCE from an 18 tons LPG tank	Same for all locations	0.00	0.00	8.50	4.00	12.50
9	Torch fire from an 18 tons LPG tank	Tunnel mid-point	6.67	0.00	2.64	1.44	10.75
10	Ammonia release from an 18 tons tank	Same for all locations	0.00	0.00	0.00	0.00	0.00
11	Acrolein release from a 25 tons tank	Same for all locations	0.00	0.00	0.00	0.00	0.00
12	Acrolein release from a 100 l cylinder	Same for all locations	0.00	0.00	0.00	0.00	0.00
13	BLEVE of a 20 ton liquefied CO2 tank	Tunnel mid-point	0.00	0.00	0.68	0.40	1.07

5.5.3 Additional Impacts of Incident on I-70 Route

As discussed in Section 5.4.3 for the U.S. 6 route results, there are other adverse consequences of an incident along the I-70 route that are not considered in the QRAM method and include the following:

- Route closure would occur following an incident; the duration of closure would depend on the location and type of incident. For incidents outside of the EJMT, full route closure time would likely be relatively short because response time is typically quick and there are multiple lanes that can be used for detour options. Following an incident requiring extensive clean-up and investigation, however, traffic would move through the I-70 corridor at a significantly reduced rate. The cost of route closure, from a user perspective, is estimated from delay time as $14.52 per vehicle-hour for a passenger car and $28.87 per vehicle-hour for a multi-unit truck[47].

- For incidents within the EJMT, even without significant damage, it is likely that the one of the tubes would require closure for some period of time for clean-up and investigation. In this case, the other tube would be converted to two-way traffic, and the capacity for traffic flow through the I-70 corridor would be significantly reduced. If the tunnel structure or systems were damaged such that repair and replacement were needed in order to operate the tunnel, closure time of the impacted tube could be very long (e.g., fan replacement is on the order of several months). It is unlikely that both tubes would require closure due to an incident; however, if a significant fire or explosion were to occur just outside one of the portals, it could impact both tubes requiring closure of both directions of traffic, which would be devastating to the region.
- The I-70 roadway outside the tunnel could be damaged, the extent of which depends on the location and type of incident. It is also possible that adjacent buildings and other infrastructure could be damaged by an explosion or spreading fire. The cost of replacement of the I-70 route roadway is estimated at $5.5M/mile[48].
- Soil, groundwater, and surface water clean-up costs could be significant, depending on the type of incident and speed of response to the spill, explosion, and or fire. The Loveland Ski area, located near the eastern end of the EJMT, would be adversely impacted by an incident in this region, possibly requiring closure if a soil and/or water contamination problem occurred.
- Several local economies along the I-70 route, particularly at the western end (e.g., Silverthorne and Dillon) and beyond (e.g., Vail and Aspen), depend heavily on the tourism industry during the ski season as well as the summer months. Disruption of the route, even if it is temporary, and any additional reduction in traffic flow capacity for incident response would have an impact on the tourism-related economy of these areas.
- The I-70 route in this region is a major east-west corridor for the state as well as the country. It is heavily used for travel between the Denver metropolitan area and the major recreational areas on the western slope of the Rocky Mountains. Closure of the EJMT for a significant period of time, even one tube with the other operating with bi-directional traffic, could have state-wide implications. Closure of both tubes for a significant period of time, requiring all east-west traffic to use the U.S. 6 alternate route over Loveland Pass would be devastating, especially if this were to occur in the winter months.

[47] Values used in CDOT road closure calculator (see Appendix A item A47), updated from 1999 $ values using 3% inflation rate.
[48] Value provided by CDOT, Ina Zisman, personal communication.

5.6 Summary of Results

The risks associated with transporting Hazmat over the two routes – U.S. 6 including Loveland Pass and I-70 including the EJMT – are compared in terms of the casualty risk, the environmental impact, the infrastructure damage, and the local economic impact. The comparison is based on the results from the QRAM analysis as well as the additional impacts of a potential incident on each route that are discussed in Sections 5.4.3 and 5.5.3.

5.6.1 Casualty Risk

Table 28 shows a side-by-side comparison of the expected casualties per year for each scenario for the U.S. 6 route with its current rate of Hazmat truck traffic and the I-70 route with its changed condition to allow for unrestricted Hazmat truck use. Without including the values for Scenario 6 (Chlorine release) due to the uncertainty in the quantity of this material that is actually transported on the route, the expected annual casualties for all scenarios for the I-70 route are more than double those for the U.S. 6 route. Even with the inclusion of Scenario 6, the results for the I-70 route are still nearly double those for the U.S 6 route. Scenarios 1 and 2 (20MW and 100MW fires) account for the majority of the casualties in each case.

As indicated earlier, the expected value of casualties is a function of the probability of truck accidents, the probability of an incident occurring given an accident occurs, the probability of death or injury given an incident occurs, and the exposed population. For most of the U.S. 6 route segments, the accident rate and exposed population densities are significantly higher than on the I-70 route, thus resulting in higher expected casualties for the U.S. 6 route for most scenarios. However, for the fire scenarios (Scenarios 1 and 2), the probability of death or injury given an incident occurs are significantly higher for the tunnel (I-70 route segment) than the open road (U.S. 6 route), thus resulting in higher expected casualties for the I-70 route for these two scenarios.

It should be emphasized that the results shown in Table 28 (as well as Table 20 and Table 25) are expected values per year, i.e., the number of casualties expected to occur for each scenario based on probabilistic analysis. If an actual scenario were to occur, the number of casualties would likely be much higher. This is especially true for one of these scenarios occurring in the EJMT during a period of peak traffic – the consequences in terms of casualties could potentially be catastrophic and several orders of magnitude greater than the annualized values shown here.

5.6.2 Environmental Impact

Both routes have a significant potential for environmental impact from a Hazmat incident. Sensitive wildlife habitat, forest and vegetation, and water supply sources could all be adversely affected by a Hazmat-related spill, explosion, or fire. For the U.S. 6 route, the Snake River and Dillon Reservoirs are at risk, and for the I-70 route, the Clear Creek and Straight Creek are at risk. All of these water sources could be polluted from the run-off of firefighting water. Other non-fire incidents, such as fuel spills or release of soluble toxic materials, could cause contamination of the soils, surface water, and groundwater, and endanger the wildlife habitat and forested lands in the area along both routes.

Table 28 Comparison of Expected Casualties per Year from QRAM Model Results

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year	
		U.S. 6 Route (Current)	I-70 Route (Changed to Allow Hazmat)
1	HGV fire 20 MW	3.990	9.190
2	HGV fire 100 MW	2.060	4.510
3	BLEVE of a 50kg LPG cylinder	0.01056	0.0026840
4	Motor spirit pool fire	0.01363	0.0056090
5	VCE of motor spirit	0.00534	0.0031820
6	Chlorine release from a 20 tons tank	1.110	0.10180
7	BLEVE of an 18 tons LPG tank	0.05437	0.0184500
8	VCE from an 18 tons LPG tank	0.00413	0.0029860
9	Torch fire from an 18 tons LPG tank	0.00114	0.0288000
10	Ammonia release from an 18 tons tank	0.02674	0.0239300
11	Acrolein release from a 25 tons tank	0.01272	0.0078870
12	Acrolein release from a 100 l cylinder	0.00108	0.0005626
13	BLEVE of a 20 ton liquefied CO2 tank	0.00028	0.0000772
All Scenarios		**7.28**	**13.90**
All Scenarios (without Scenario 6)		**6.17**	**13.80**

5.6.3 Infrastructure Damage

A Hazmat incident on U.S. 6 route and outside of the EJMT on the I-70 route would result in similar damage to the roadway on each route, with a replacement cost of approximately \$5.5M/mile[49]. There is also the possibility that adjacent buildings and other infrastructure would be damaged in an explosion or spreading fire. The U.S. 6 route contains several populated areas, including Keystone, Dillon, and the A-Basin ski area, presenting a significantly higher infrastructure risk than exists along the open sections of the I-70 route, which are relatively unpopulated. However, when the EJMT is included in the comparison, the infrastructure risk along I-70 is far greater. According to the QRAM results, the worst scenario in terms of damage to the EJMT would require repairs on the order of 12.5% of the replacement value of the tunnel. Replacement value is assumed to be \$30,000 per foot per tube, which includes design, construction, CM, and CDOT costs. Although the damage

[49] Value provided by CDOT, Ina Zisman, personal communication.

could potentially be very severe, it is highly unlikely that the tunnel structure would collapse, even over a limited length of the tunnel.

5.6.4 Local Economic Impact

The local economy of the region is focused on tourism, during the ski season as well as in the summer months. For the U.S. 6 route, the economies of Keystone, Dillon, and the A-Basin ski area are all dependent on the full functioning of the route. In addition, the economy of these areas could be severely impacted if a Hazmat incident nearby resulted in a soil or water contamination problem. Not only would there be the loss of revenue, but also there would be the potential loss of property value and bad publicity associated with environmental contamination. For the I-70 route, an incident resulting in closure of one of the EJMT tubes, even for a short period of time, would impact the local economies of Silverthorne and Dillon. Closure of a tube for an extended period of time, and worse, closure of both tubes, would be devastating to not only Silverthorne and Dillon, but also communities such as Vail and Aspen located west of the region. The tunnel represents a major east-west corridor in this region and its reduced capacity or closure would have a significant statewide impact.

6. Mitigation Options

6.1 Tunnel Structure and Life Safety Systems in a Fire

Having reviewed the effects of the 13 Hazmat scenarios in the tunnel, several options were developed to mitigate the effects of some scenarios on portions of the tunnel, and for people in the tunnel when an incident occurs. These options are:

- Lining the tunnel ceiling with fireproof insulation
- Reinforcing the tunnel ceiling
- Installing a foam/deluge sprinkler system
- Installing a fan cooling system

These options are evaluated below for potential benefits to the tunnel, viability, and cost.

<u>Lining the tunnel ceiling</u> with a fireproof material, for example Promat, would be effective only in protecting the tunnel ceiling from collapse. The desirability of this is mixed. A ceiling collapse would allow much more smoke locally up into the ventilation space, greatly assisting in reducing the amount of smoke within the tunnel; however, a collapse would also subject the tunnel lining to intense heat and may weaken the tunnel structure, increasing the risk to firefighters in the vicinity of a lining collapse as well. The primary benefits of preserving the tunnel ceiling are that required tunnel structural repairs would be limited, and there would be increased safety against the roof collapsing upon attending firefighters. The consequence of a tunnel lining collapse within the rock portion of the tunnel is unlikely to cause much of the surrounding rock to collapse and repairs are likely to be relatively straightforward. Within the fault zone of the tunnel, an extent of about 1,000 ft, considerable water ingress is likely, though the stacked adit construction here (the colored blocks in the model, Figure 16) is so thick that the risk of total collapse is not high. It would be possible, though expensive, to obtain greater smoke extraction without ceiling collapse by the installation in the ceiling of additional dampers for emergency use, remotely-operated, though the PB team does not recommend this due to high maintenance requirements. The cost of a Promat lining would be approximately $9,000,000 in material costs alone for each tube. In addition, engineering evaluation would have to be done to determine if the ceiling structure could support the weight of the Promat lining. If not, additional costs for reinforcing the ceiling structure would be required.

<u>Reinforcing the tunnel ceiling</u> has the same benefits as above in that it helps to protect the tunnel structure and its concrete lining, and it enables firefighters to approach closer to the seat of the fire by reducing the risk of the ceiling collapsing on them. The primary disadvantages of this option are its cost (much higher than the application of insulation discussed above), reduced headroom (and perhaps therefore unacceptable), and potentially trapping smoke in the tunnel space instead of allowing the smoke up into the ventilation space, as discussed above. Weighing the advantages against the disadvantages, this option can be considered to provide only marginal benefit, thus making it an undesirable option.

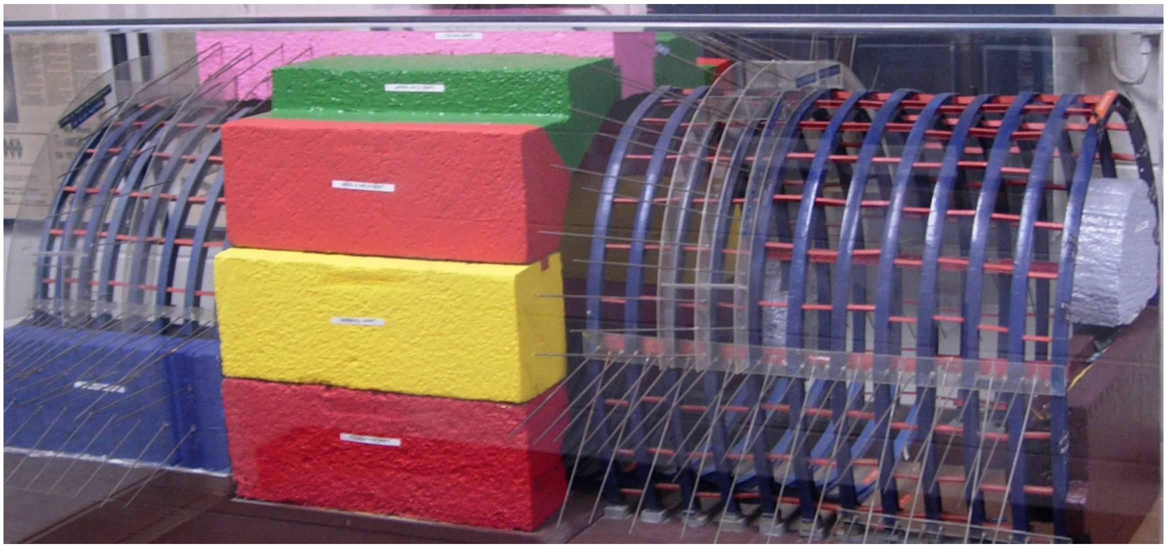

Figure 16 Model of Tunnel Primary Support System (Blocks Used Exclusively at Fault Zone)

A foam/deluge sprinkler installation would work quickly and effectively at containing a Hazmat fire. Tests using this system were done in the Memorial Tunnel Fire Test Program and showed that a foam system is capable of extinguishing a 100MW fire in approximately two minutes[50]. Although these tests were done under ideal conditions, the expanding nature of the foam smothers and insulates flammable liquids and vapors effectively preventing the spread of fire. Although the system will not extinguish fires inside vehicles due to the shielding effect of the vehicle roof, its effectiveness in containing fires has been proven. It can control exposed fires such as fuel spills or cargo spills. It would also control the spread of fire between vehicles, reducing the chance of multiple vehicle fires such as the Mt. Blanc Tunnel fire. This system would be effective in preserving the tunnel structure and saving lives. The disadvantage of this system is that it is a relatively complex system that requires frequent maintenance. Automatic fire detection and activation is prone to false alarms which are highly undesirable since they may cause traffic accidents; thus, around-the-clock surveillance and manual operation is required. The material and equipment costs of this system would be approximately $3,000,000 for each tube. Installation, testing, monitoring and maintenance costs, including excavation and traffic disruptions, would be in addition to this sum. One of the major challenges during installation of this system is locating appropriate spaces for fire pumps, water tanks, control and monitoring equipment, and securing a source of water and back up power. A similar system has been used to retrofit the Mount Baker Tunnel in Washington. The foam/deluge system was installed to protect the tunnel from high-intensity fuel tanker fires.

A fan cooling system would consist of a water spray directing a mist or jet of water into the intake of an exhaust fan, thereby keeping the fan blades within operating temperatures. The advantage of this would be to enable the ventilation fans to continue to run under much higher exhaust gas temperatures and hence continue to purge smoke from the tunnel for a much longer period, thereby allowing people in the tunnel more time to escape. The

[50]Bechtel/Parsons Brinkerhoff, "Memorial Tunnel Fire Ventilation Test Program" 1995 – test 625B

installation costs would be low but would require regular inspections and testing. Tests done in the Memorial Tunnel Fire Ventilation Test Program, show that even with a 100MW fire, temperatures do not exceed 140 degrees F at distances greater than 400 feet from the fire location.[51] The cooling effect from the mixing of cool supply air with the hot smoke may eliminate the need for a fan cooling system all together.

Within tunnels, life safety has a higher priority than protecting the tunnel and its lining. From a life safety viewpoint, the primary focus in the event of a large flammable fuels fire is the evacuation of everyone within the tunnel. If firefighting is too dangerous, it may be safer to allow the fire to burn out. While this strategy would prevent firefighter loss of life, it would bear a very high cost in terms of stopped traffic and tunnel repairs. The best mitigation option appears to be a foam/deluge sprinkler system.

6.3 Additional Mitigations for I-70 Route

Outside the EJMT tunnel, there are very serious concerns about runaway trucks. Despite the provision of the gravel ramps that allow trucks to exit, these are right exit only. It appears difficult for a driver to move at high speed from the left lane to the right lane in order to exit on these ramps. It is recommended that left exit ramps also be provided. It is also recommended that the current runaway truck ramps, and any future ones that are installed, be designed to contain a Hazmat spill should one occur. This is a low probability event, as the Hazmat trucks only use this route when Loveland Pass is closed and they have typically been waiting prior to entering the tunnel allowing their brakes to cool; however, a spill in one of these ramps could cause a soil and water contamination problem.

The current procedures for convoying Hazmat trucks through the EJMT when Loveland Pass is closed should be evaluated for potential revisions. For example, the trucks should be limited in their speed to 30 mph as they pass through the tunnel; currently they are allowed to travel at the posted speed limit of 50 mph. In addition, issues related to the mixing of passenger cars and Hazmat truck traffic in the stretch of I-70 following the exit of the tunnel after the Hazmat truck convoy has ended should be examined. For example, passenger cars are stopped before entrance to the tunnel for approximately 20 minutes while the truck convoy occurs. When these cars are released, they often speed upon exit from the tunnel and pass the previously convoyed trucks creating a potentially dangerous traffic condition.

6.4 U.S. 6 Route Mitigations

The accident rate on the U.S. 6 route in the study region is excessively high. In addition, there are significant problems with the current route geometry and configuration that make Hazmat truck transport over Loveland Pass very difficult. It is recommended that a study be done to develop specific recommendations for reducing the truck accident rate along the U.S. 6 route. In addition, the study should evaluate the current route geometry and configuration and determine if reasonable mitigations exist to help reduce the problem of side-to-side sloshing of liquid Hazmat cargo being transported over Loveland Pass.

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[51] Bechtel/Parsons Brinkerhoff, "Memorial Tunnel Fire Ventilation Test Program" 1995 – test 239(4)

The recreational use along Loveland Pass, especially at night, has recently increased significantly. It is recommended that improvements be made in the areas along the U.S. 6 route to accommodate the parking and pedestrian requirements associated with this recreational use. Hazmat trucks are frequently traveling over Loveland Pass at night. Additional lighting, signage, recreational parking, and condition monitoring would help alleviate the problems that the drivers face during times of heavy recreation use on Loveland Pass.

The U.S. 6 route has very steep grades in many locations. The most critical section is in the westbound direction between Loveland Pass and Montezuma Road at Keystone. A Hazmat truck driver could easily lose the brakes on the vehicle and enter the Keystone area traveling at excessive speed during the peak traffic period. It is recommended that a truck runaway ramp be installed in the westbound direction near Milepost 220 and, as described earlier for the I-70 runaway ramps, that the ramp be designed to contain a possible Hazmat spill.

7. Conclusions and Recommendations

This report documents the study carried out to evaluate the risk of Hazmat truck transport over the U.S. 6 route, including Loveland Pass (the current routing procedure), as compared to a changed routing procedure that would allow Hazmat trucks to travel on the I-70 route passing through the EJMT. The study included a site visit of the EJMT and Loveland Pass; collection of all relevant route information, traffic data, accident data, population exposure, tunnel design information, and Hazmat truck transport data; a comparative risk assessment of the two routes using the industry-standard PIARC/OECD QRAM model; and input from the Colorado State Patrol and Colorado Motor Carriers Association.

The risk assessment focused on comparing the risk to the exposed population (casualty risk), the environmental impact, the potential infrastructure damage, and the local economic impacts related to Hazmat truck transport over each of the two routes. Based on the results of the assessment and the information gathered in the study, the PB team recommends the following:

1. The current policy of routing Hazmat trucks on the U.S. 6 route over Loveland Pass should be maintained. The risk of Hazmat truck transport through the EJMT is too great in terms of potential for catastrophic loss of life, for extensive infrastructure damage, for environmental impact to Clear Creek, and for economic impact to the areas on the western slope to warrant a change in the current policy. In addition, if Hazmat truck transport were allowed through the EJMT, the attractiveness of this asset as a target for terrorism utilizing a Hazmat vehicle as the weapon, would significantly increase. Hazmat truck travel on the I-70 route, including through the EJMT, should be allowed only when Loveland Pass is closed and only under convoy with the tunnel closed to regular traffic, as is the current policy.
2. The current procedures for convoying Hazmat trucks through the EJMT should be revised to limit the speed of the trucks through the tunnel to 30 mph, using CCTV at tunnel exits and Colorado State Patrol personnel to help enforce this speed limit.
3. There are several improvements planned for US Route 6 such as addition of CCTV cameras in 2006 and $600,000 worth of centerline rumble strips and shoulder work, by the end of 2007. Improvements should be made to the U.S. Route 6 at Loveland Pass to accommodate the parking and pedestrian demands associated with the increased recreational use, especially during the nighttime hours when Hazmat truck travel through the area. Since there are significant safety concerns to the traffic on US Route 6, we recommend continuous safety improvements. CDOT shall also look into the process of closing US Route 6 during adverse weather conditions.
4. The U.S. 6 route should undergo evaluation to determine if mitigations to the route geometry and roadway conditions could be done to help reduce the problems faced by Hazmat truck drivers with side-to-side sloshing of liquid cargo in bulk containers while traveling over Loveland Pass.
5. A truck runaway ramp should be installed in the westbound direction on the U.S. 6 route near Milepost 220, and it should be designed to contain a possible Hazmat spill. In addition, the current truck runaway ramps on the I-70 route outside of the EJMT should be modified to contain a possible Hazmat spill, and the regular use of these

ramps should be evaluated to determine if additional ramps are needed for exit from the left side of the road.

6. The Colorado DOT should evaluate the CMCA "Proposal for Pilot Program for Movement of Hazardous Materials through the Eisenhower Tunnel".

Appendix A: Reference Data

Copies of all the following references are provided on an accompanying CD. Hard copies are not provided. For copyrighted © purchased documents, only the cover page is included.

Item	Filename	Author	Title	Summary
A1	1500.doc	Diamantidis	Safety of railway tunnels in Greece	The risk to passengers during operation is computed by considering characteristic initiating events such as derailment, collision and fire.
A2	AssesmentandServiceLife_Ingenieursburo[1].pdf	Schiessl	Assessment And Service Life Updating Of Existing Tunnels	European research project DARTS
A3	DGMethodology_v2.pdf	Egnatia Odos	Risk Assessment Methodology for the Dangerous Goods Transportation Along Egnatia Odos	PowerPoint presentation
A4	Dutchmodel_paper.pdf	Brussaard, Kruiskamp, Essink	The Dutch Model for the Quantitative Risk Analysis of Road Tunnels	Paper describing the QRA model developed by the Netherlands Center for Tunnel Safety
A5	DutchModel.pdf	Kruiskamp, Brussaard, Essink	The Dutch Model for the Quantitative Risk Analysis of Road Tunnels	Presentation for the PSAM 7 –ESREL '04 conference 16-6-2004
A6	Fire-en.pdf	International Association of Public Transport	Preventing and combating fires in metro systems	Position paper
A7	FireGuidelines.pdf	International Tunneling Association	Guidelines For Structural Fire Resistance For Road Tunnels	The purpose of this co-operative effort is to develop guidelines for resistance to fire for road tunnel structures.
A8	FireResponseManagement_Mott MacDonald[1].pdf	Norman Rhodes	Fire Response Management	This paper presents a discussion of the question of emergency response activities arising from a fire in a tunnel.
A9	FMCSA1.pdf	FHWA	Transportation of Hazardous Materials	Regulations
A10	fmcsa2.pdf	FHWA	Transportation of Hazardous Materials	Regulations
A11	fmcsa3.pdf	FHWA	Transportation of Hazardous Materials	Regulations

Item	Filename	Author	Title	Summary
A12	HazardsandtheConsequencesforTunnelStructures_TNO[1].pdf	Vrouwenvelder	Hazards And The Consequences For Tunnel Structures And Human Life	The paper shows the results of the EU sponsored Durable and Reliable Tunnel Structures (DARTS) research project that has focused on rational design methods.
A13	HazardsinTunnels_Cowi[1].pdf	Niels Peter Høj	Hazards In Tunnels Structural Integrity	This paper contains a discussion of modeling hazards and using them as part of structural design.
A14	jcssdd.doc	Diamantidis	Risk Acceptance Criteria: A review	The present note aims at clarifying the discussion about risk acceptability criteria related to human safety
A15	KeyElementsinFutureTunnelDesigns_Min[1].ofTransport.pdf	Sipke E. van Manen	Key Elements In Future Tunnel Designs: Hazards As A Specific Design Issue	General Design Philosophy Of The Darts Project
A16	literature.doc	Diamantidis	Tunnel Safety References	
A17	OECD_PIARC_Report.pdf	PIARC	Safety in tunnels: Transport of Dangerous Goods Through Road Tunnels, 2001	Full Report: Regulatory and technical issues, proposed regulations and enforcement, QRA Model, DSM Model, and effectiveness of measures. 90 pages.
A18	OECD_Safety_in-Tunnels.pdf	PIARC	Safety in Tunnels: Transport of Dangerous Goods Through Road Tunnels, 2001	Highlights: 14 pages.
A19	OECDTRMission2.pdf	OECD/PIARC by DNV	ERS2 "Transport Of Dangerous Goods Through Road Tunnels"	Information on existing road tunnels as well as rules, regulations and policies for the transport of dangerous goods was gathered for many countries
A20	PresentDayDesignFireScenarios_TNO_STUVA[1].pdf	Kees Both	Present-Day Design Fire Scenarios And Comparison With Test Results And Real Fires: Structures & Equipment	This paper discusses present-day design fire scenarios and comparison with test results and real fires.
A21	qra_tauern_tunnel.pdf	Knoflacher	Quantitative Risk Assessment of Heavy Goods Vehicle Transport through Tunnels - the Tauerntunnel Case Study	Validation study of the PIARC QRA model
A22	TRANS-AC9-2-inf09e.pdf	Martin Shipp,	Vehicle Fires And Fire Safety In Tunnels	This paper discusses the various fire safety measures that are currently applied in road vehicles and trains, and discusses some possible ways of reducing the risk from fires in vehicles.

Item	Filename	Author	Title	Summary
A23	TRIB_04_n28_2-11.pdf	ITA Executive Council	Fire in Traffic Tunnels	This leaflet contents the preface of a special issue of Tribune, the ITA newsletter, that will be devoted to Fire in Traffic Tunnels
A24	TUST_02_v17_n2_117-127.pdf	A. Haack	Current safety issues in traffic tunnels	In addition to the manner in which tunnels are furnished, improved control of the state of vehicles and the composition of their loads could have better safety standards in traffic tunnels.
A25	TUST_02_v17_n2_153-158.pdf	F. Vuilleumier,	Safety aspects of railway and road tunnel: example of the Lötschberg railway tunnel and Mont-Blanc road tunnel	Based on two actual examples, the new safety measures are presented in this paper on a practical view for the first and on a theoretical view for the second.
A26	TUST_02_v17_n2_159-161.pdf	A.G. Bendelius	Tunnel fire and life safety within the world road association (PIARC)	This paper presents the global activities of the World Road Association (PIARC) in the area of fire and life safety in road tunnels
A27	Weger.pdf	D. de Weger	Scenario Analysis For Road Tunnels	The scenario analysis described in this paper aims at optimizing the management of the processes occurring before, during and after an accident. The focus is on self rescue and emergency response.
A28	WP2_Design Fire Scenarios_Chapt[1].2.pdf	FIT European Thematic Network	Statistical overview of Real Fires and Fire Effects	Statistical overview of Real Fires and Fire Effects in the UK
A29	WP3_CompilationRoad_Chap1_ListingofGuidelines[1].pdf	Niels Peter Hoj + WP2	FIT European Thematic Network, Fire Safe Design, Road Tunnels	Draft contribution to FIT WP3 report
A30	Leigh Scott & Cleary 1990 Report.pdf	Leigh, Scott and Cleary, Inc and Western Land Exchange Company for Summit County Government, August 3, 1990.	Analysis of Transportation of Hazardous Materials through the Eisenhower/Johnson Tunnels and Over Loveland Pass	Accident study dated in 1990, for the two alternative routes
A31	Traffic Regulations EJMT.pdf	Colorado DOT January 1, 1981	Traffic Regulations governing the use of the EJMT	Regulations specific for EJMT
A32	Truck Accident Report on Loveland Pass .pdf	Colorado DOT	Detailed Accident Summary Report for US-6	Accident statistics on the Loveland Pass 1994-2003 including severity, multi-vehicle, location, accident type, lighting conditions, weather conditions, road description, road conditions, mainline/ramps/frontage roads, and accident rates.

Item	Filename	Author	Title	Summary
A33	Fire Emergency Ventilation Study .pdf	Sverdrup Civil, Inc [Jacobs Engineering]	Fire Emergency Ventilation Study	Numerical study on the ventilation of EJMT, dated 2001
A34	Prevention and Control of Highway Tunnel Fires.pdf	FHWA	Prevention and Control of Highway Tunnel Fires, May 1984	Recommendations to reduce risk, damage and fatalities in existing and future tunnels
A35	Excel Files for each month in folder "A35"	Colorado DOT	EJMT Traffic Counts	traffic counts by hour for years 2003-2005
A36	Hazmats Through EJMT.pdf	Colorado DOT	Hazmats processed through EJMT During Loveland Pass Closures	Excel table with Hazmat breakdown by month for Jul 2004-Jun 2005, including number of trucks by placard type and hours of closure.
A37	Merz Risk Evaluation.pdf	Merz	Methodology and Tools for Risk Based evaluation of Safety Measures for an Existing Road Tunnel	Risk assessment methodologies for the Gotthard Road Tunnel
A38	601-8_Tunnel_RulesDec02.pdf	Colorado DOT January 30, 1986	Traffic Regulations governing the use of the Tunnels on the State Highway System	General traffic regulations
A39	Not Used			
A40	UGH Copenhagen Metro.pdf		UGH Study Tour - Copenhagen Metro	PowerPoint presentation
A41	Ramboll.pdf	Rambøll Denmark	Risk Management	PowerPoint presentation
A42	Plan Profile Proposed SH91 (US6).pdf	Public Roads Administration Federal Works Agency	Plan and Profile of Proposed Federal Aid Project No. F 012-1(1) State Highway No. 91 Summit County [U.S.6]	10 drawings, realignment of existing highway: Sheets 1, 2, 17-24 dated 1948, from 365+50 to 578+75.4 (21,011.2 ft due to stationing gap)
A43	01032000_tunnels.pdf	The AA Motoring Trust	Tunnel Tests 2000: Safety of Road Tunnels in Europe	A total of 25 tunnels were examined in eight European countries.
A44	EJMT Information.doc	http://www.dot.state.co.us/Eisenhower/	Various EJMT descriptions	Mostly data extracted from description.asp, facts.asp, thetwin.asp, eisenhower bore.asp, EdwinCJohnson bore.asp and trafficcounts.asp
A45	Environmental .doc	Colorado DOT	CDOT Hazmat thru EJMT	Email message containing information on sensitive environmental areas.
A46	EJMT Information.ppt	Various on the Internet	EJMT photos and drawings	
A47	Lane Rental Worksheet.xls	Colorado DOT	Road User Cost Calculations	Calculation method for determining cost to user for lane closures

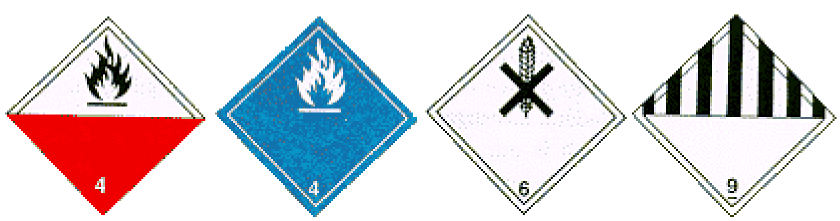
Item	Filename	Author	Title	Summary
A48	Colorado1.pdf	National Geographic	Contour plan of EJMT and Loveland Pass	Profiles were developed from this plan and are included in the Phase II Report.
A49	Caldecott.pdf [cover only], Hard Copy purchased from NTIS	Larson, D.W., Reese, R.T. and Wilmot, E.L.	The Caldecott tunnel fire thermal environments, regulatory considerations and probabilities	PATRAM 83, 7th International Symposium on Packaging and Transportation of Radioactive Materials, May 1983
A50	Recommendations of ECFE Experts on Safety In Road Tunnels Final Report (TRANS-AC7-09e).pdf	United Nations Economic and Social Council Economic Commission for Europe, Inland Transport Committee	Recommendations of the Group of Experts on Safety in Road Tunnels: Final Report, December 2001	A comprehensive catalogue of recommended minimum requirements concerning safety in road tunnels of various types and lengths has been compiled. These proposed measures have yet [2001] to be adopted by ITC and then evaluated for potential incorporation into UNECE legal instruments.
A51	A COMPARATIVE RISK ANALYSIS FOR SELECTED AUSTRIAN tunnels (2004).pdf	Knoflacher H., Pfaffenbichler P. C., Institute for Transport Planning and Traffic Engineering Vienna University of Technology	A Comparative Risk Analysis for Selected Austrian Tunnels	QRA study for 13 selected Austrian tunnels. The tunnel length ranged from about one to ten kilometers. The selection covered uni- and bi-directional tunnels as well as a broad range of different ventilation systems.
A52	UNITED NATIONS - Questionaire - REGULATIONS AND GENERAL DATA ON ROAD TUNNEL SAFETY.doc	United Nations Economic and Social Council Economic Commission for Europe, Inland Transport Committee	Questionaire – Part A Responses: Regulations and General Data on Road Tunnel Safety	Responses listed by country for: Legislation, regulations, recommendations on safety in road tunnels (dealing with geometry, infrastructure, equipment, signaling, operation, traffic, driver education and training, etc.); comments thereon; risk methodology; classification of road tunnels by accident risk of associated with them; and data and statistics.
A53	Erg2004.pdf	U.S. DOT Research and Special Programs Administration	2004 Emergency Response Guidebook	A Guidebook for First Responders During the Initial Phase of a Dangerous Goods / Hazardous Materials Incident
A54	Hmship_all.pdf	Office of Hazardous Materials Safety Research and Special Programs Administration U.S. DOT	Hazardous Materials Shipments, Oct 1998	Estimates of Hazmats shipped in the US

Item	Filename	Author	Title	Summary
A55	hmpe_report.pdf	NE DOT	Departmentwide Program Evaluation of the Hazardous Materials Transportation Programs, Mar 2000	Documents current hazardous materials movements, programs, and effectiveness; recommends improvements; and identifies areas for further study to determine the effectiveness of current programs and resources.
A56	regbrch2005.pdf	US DOT	Registering as an Offeror or Transporter of Hazardous Materials	Outlines registration requirements for 2005-2006
A57	EJMT_1972_Docs.pdf	CDOT	Colorado Project No. I 70-3(48) 222 dated May 1, 1972	Construction control documents modifying *Standard Specifications for Road and Bridge Construction*, East Appr & Plaza Area
A58	Plan_Profile_Proposed_I-70_W_Portal_zone.pdf	CDOT	Plan and Profile of Proposed Federal Aid Project No. I 70 3(77)220 State Highway No. 70 Summit County	7 Drawings covering 400+00 to 35+90.91 (undated, presumably 1972 or earlier)
A59	Plan_Profile_Proposed_I-70_W_Summit_Co.pdf	CDOT	Plan and Profile of Proposed Federal Aid Project No. I 70 3(67)212 State Highway No. 70 Summit County	59 Drawings covering 275+27.6 to 400+00, from 1971 or earlier.
A60	Align_Profile_E_Portal_1973.pdf	TAMS – CDOT	Alignment and Profile I-70	1 as-built drawing from 1973: 1600 ft centered on E vent Building
A61	Plan_Profile_Proposed_I-70_Clear_Creek_Co.pdf	FHWA - CDOT	Plan and Profile of Proposed Federal Aid Project No. I 70 3(48)222 State Highway No. 70 Clear Creek County	85 drawings from 1972
A62	I-70 Accident Summary.pdf	Colorado DOT	Detailed Accident Summary Report for I-70	Summary for years 1999-2003.
A63	sh070a_20500-21600_listing.xls	Colorado DOT	Detailed Accident Summary Report for I-70	Details of each accident.
A64	Catch Basin Plan.pdf	Colorado DOT	Catch Basin, Frame & Grate	Details of catch basins.
A65	North Tunnel Drainage.pdf	Straight Creek Constructors	North Tunnel Drainage Drawings	As constructed.
A66	South Tunnel Drainage.pdf	Colorado DOT (?)	South Tunnel Drainage Drawings	As constructed.

Item	Filename	Author	Title	Summary
A67	Back Up Power Generation Study 1-25-2000.pdf	Planergy / Sverdrup	Back-up Power Generation Study Final Report	Jan 2000 report for EJMT recommending one of four options.
A68	Hazmat Closure Log 2004-2005.doc	Colorado DOT	Road Closure Log	Detailed route closure information for US-6 and I-70 for mileposts 205 to 228, covering 2004 and 2005.
A69	Colorado Hazardous & Nuclear Materials Route Restrictions 2004.pdf	Department of Public Safety, Division of State Patrol – Hazardous Materials Section	Colorado Hazardous and Nuclear Materials Route Restrictions 2004	Large size maps showing designated hazardous materials routes and designated nuclear materials routes throughout the state. CDOT 2003 GIS Files: HazMatFront.mxd and HazMatBack.mxd.
A70	EJMT Resurfacing Drawings.pdf	Colorado DOT	EJMT and I-70 Resurfacing Drawings	Typical cross-sections of tunnels, typical plan views of I-70 roadway and parking areas, and table of catch basin locations.
A71	JFSato.doc	Scott Burger, JF Sato	Population Data Information	E-mail describing information that PEIS study team has compiled at the request of the Colorado DOT.
A72	Demog_data_for_Hazmat_Study.xls	Scott Burger, JF Sato	Relevant Statistics from Brief Internet Search	Population data for Summit County, including residential and peak ski season.
A73	Map_HazMat_Zones.pdf	Scott Burger, JF Sato	Zone System for I-70 PEIS	Zones used for I-70 PEIS Travel Demand Model.
A74	Winter_Peak_PEIS_Travel_Demand_Model.xls	Scott Burger, JF Sato	Winter Data for PEIS Travel Demand Model	Population, Employment, Second Homes, and Winter Trip data for Dillon, Silverthorne, A-Basin, Loveland, and Keystone.
A75	Summer_Peak_PEIS_Travel_Demand_Model.xls	Scott Burger, JF Sato	Summer Data for PEIS Travel Demand Model	Population, Employment, Second Homes, and Summer Trip data for Dillon, Silverthorne, A-Basin, Loveland, and Keystone.
A76	1990 Hazmat Study.pdf	Leigh, Scott, & Cleary, Inc. and Western Land Exchange Company	An Analysis of the Transportation of Hazardous Materials through the Eisenhower/Johnson Tunnels and over Loveland Pass	Report of Hazmat transportation study conducted in 1990 for the Summit County Government.

Appendix B: Typical Hazardous Material Placards[52]

International Shipments



52 http://www.leeric.lsu.edu/le/cover/placards.htm

Appendix C: Rules & Regulations Governing the Transportation of Hazardous Materials through Virginia Bridge-Tunnel Facilities[53]

§ 1. Authority

This regulation is promulgated under the Administrative Process Act (APA) (Chapter 1.1:1, § 9-6.14:1 et seq. of Title 9) of the *Code of Virginia*. Section 33.1-12(3) of the Code of Virginia authorizes the Commonwealth Transportation Board to promulgate regulations "for the protection of and covering traffic on and the use of systems of state highways and to add to, amend or repeal the same. The Interstate System is part of the system of the state highways and the Board has additional specific authority under § 33.1-49 to regulate its use." It applies to all bridge-tunnel facilities in the Commonwealth of Virginia, and establishes the rules by which all interstate, intrastate, and public and private transporters of hazardous materials are governed while traveling through these facilities. It becomes effective if approved by the Commonwealth Transportation Board, and if DMV receives no gubernatorial or legislative objection during the statutory review and post-publication periods required by the APA.

§ 2. List of bridge-tunnel facilities owned by the Commonwealth.

The following table lists the six bridge-tunnel facilities in the Commonwealth. The Virginia Department of Transportation operates all six facilities listed.

Name of Facility	**Telephone Number**
Big Walker Mountain I-77	540-228-5571
East River Mountain I-77	540-928-1994
Elizabeth River-Downtown I-264	757-494-2424
Elizabeth River-Midtown I-58	757-683-8123
Hampton Roads I-64	757-727-4832
Monitor-Merrimac Memorial Bridge I-664	757-247-2123

For purposes of this regulation, the facilities listed above are classified into two groups: rural and essentially distanced from bodies of water; and urban and essentially proximate to bodies of water.

§ 3. Restrictions on hazardous material transportation across rural and distanced-from-water facilities.

The two rural and distanced-from-water tunnel facilities are: The Big Walker Mountain Tunnel and The East River Mountain Tunnel. For these two tunnels, and these two only, no

[53] https://www.vahaulingpermits.com/permits/vahps/Hazmat.html

restrictions apply on the transport of hazardous materials, so long as transporters and shippers are in compliance with the Code of Federal Regulations, 49, Parts 100 through 180; and any present and future state regulations which may become in force to implement the federal regulations.

In addition, the Commonwealth Transportation Commissioner may, at any time, impose emergency or temporary restrictions on the transport of hazardous materials through these facilities, so long as sufficient advanced signage is positioned to allow for a reasonable detour.

Questions on this section of the regulation should be directed to the DMV Emergency Operations Center at the following telephone number: (804-497-7135). Copies of the regulation will be provided free of charge. For copies please write to:

Virginia Department of Motor Vehicles
ATTN: Emergency Operations Center
2300 West Broad Street
P.O. Box 26302
Richmond, Virginia 23260

§ 4. Restrictions on hazardous material transportation across urban and water-proximate facilities.

Hazardous materials are regulated in the four urban and water-proximate tunnels (Elizabeth River (Midtown and Downtown), Hampton Roads, and Monitor-Merrimac), based exclusively on the "hazard class" of the material being conveyed. The following tables list those categories of materials grouped under the designations "PROHIBITED," "NO RESTRICTIONS," or "RESTRICTED." **Please contact the Chesapeake Bay Bridge-Tunnel at (757) 331-2960 for information on their regulation.

Prohibited		
Materials defined in the following classes are not allowed passage through the four urban, water-proximate tunnels.		
CATEGORY	**PLACARD NAME**	**PLACARD REFERENCE**
1.1	Explosives 1.1	49 CFR § 172.522
1.2	Explosives 1.2	49 CFR § 172.522
1.3	Explosives 1.3	49 CFR § 172.522
2.3	Poison Gas	49 CFR § 172.540
4.3	Dangerous When Wet	49 CFR § 172.548
6.1 (PG I, Inhalation hazard only)	Poison	49 CFR § 172.554

No Restrictions		
Materials in the following hazard classes are not restricted in the four urban, water-proximate tunnels.		
CATEGORY	**PLACARD NAME**	**PLACARD REFERENCE**
1.4	Explosives 1.4	49 CFR § 172.523
1.5	Explosives 1.5	49 CFR § 172.524
1.6	Explosives 1.6	49 CFR § 172.525
2.2	Non-Flammable Gas	49 CFR § 172.528
Combustible Liquid	Combustible	49 CFR § 172.544
4.1	Flammable Solid	49 CFR § 172.546
4.2	Spontaneously Combustible	49 CFR § 172.547
6.1 (PG I or II, other than PG I inhalation hazard)	Poison	49 CFR § 172.554
6.1 (PG III)	Keep Away From Food	49 CFR § 172.553
6.2	(None)	
7 Radioactive	Radioactive	49 CFR § 172.556
9	Class 9	49 CFR § 172.560
ORM-D	(None)	

Restricted		
Materials in the following hazard classes are allowed access to the four urban, water-proximate tunnels in "Non-bulk" (maximum capacity of 119 gal/450 L or less as a receptacle for liquids, a water capacity of 1000 lbs/454 kg or less as a receptacle for gases, and a maximum net mass of 882 lbs/400 kg or less and a maximum capacity of 119 gal/450 L or less as a receptacle for solids) quantities per container only.		
CATEGORY	**PLACARD NAME**	**PLACARD REFERENCE**
2.1	Flammable Gas	49 CFR § 172.532
3	Flammable	49 CFR § 172.542
5.1	Oxidizer	49 CFR § 172.550
5.2	Organic Peroxide	49 CFR § 172.552
8	Corrosive	49 CFR § 172.558

Appendix D Hawaii City & County of Honolulu Traffic Code

Transport of explosives is prohibited through all tunnels by the City and County of Honolulu Traffic Code as follows:

> Sec. 15-2.7 - Explosives -- Flammable substances. "Explosive" means any chemical compound or mechanical mixture that is commonly used or intended for the purpose of producing an explosion and which contains any oxidizing and combustive units or other ingredients in such proportions, quantities or packing that an ignition by fire, by friction, by concussion, by percussion or by detonator of any part of the compound or mixture may cause such a sudden generation of highly heated gases that the resultant gaseous pressures are capable of producing destructive effects on contiguous objects or of destroying life or limb; provided, however, that the term "explosives" as defined herein shall not include the following items: (1) Fireworks, as defined in Section 20-4.1, ROH 1990, as amended, including those articles excluded from said definition and set forth in said section; and (2) Fixed ammunition for small arms. "Flammable liquid" means any liquid which has a flashpoint of 70 degrees Fahrenheit or less, as determined by a Tagliabue or equivalent test device. (Sec. 15-2.7, R.O. 1978 (1983 Ed.))

> Sec. 15-24.14 - Transportation of explosives through tunnels. No person shall transport, or cause to be transported, any explosives through any vehicular tunnel which is used by the general public as part of a public street or highway, except that this provision shall not apply to the transport of military munitions or military explosives by an operating division of the United States Department of Defense or its contractors using the H-3 tunnels. The military munitions or explosives shall be transported in accordance with United States Department of Defense standard operating procedures. (Sec. 15-24.14, R.O. 1978 (1983 Ed.); Am. Ord. 03-25)

Local and Federal regulations regarding things such as packaging, inspection, driver qualifications, and vehicle placarding, to name a few, apply to Hazmat transportation. However, transportation of flammable or other hazardous materials, other than explosives, is not prohibited through tunnels by any ordinance, with a representative from HDOT's Motor Vehicle Safety Office (HWY-V).

Note: Both the alternate routes available, should transportation of Hazmat be banned from all three Trans-Koolau tunnels, involve travel "around the island" on stretches of highway that are in some locations narrow, winding, two-lane roadways, some in hilly terrain. While both alternate routes include stretches through relatively sparsely populated areas, both eventually lead to heavily populated areas of East or Central Oahu. It is understood that H-3 was (may still be) preferred by the trucking industry because of the fire and life safety features included in the Tetsuo Harano Tunnel and the more favorable roadway geometrics (wider, straighter, less steep) available on H-3 compared to the other Trans-Koolau routes.

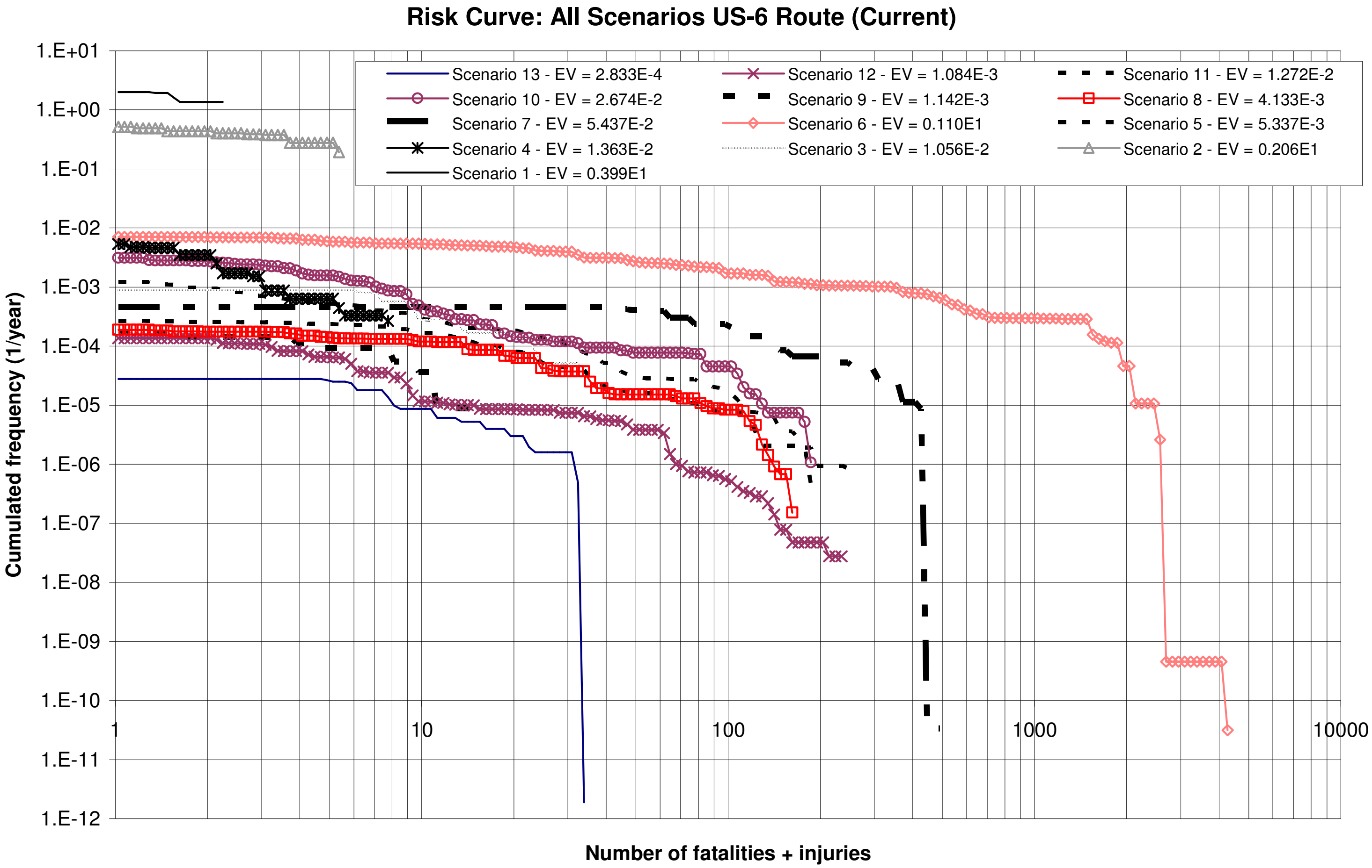
Appendix E Excerpts from Federal Regulations

From Appendix A Items A9, A10 and A11:

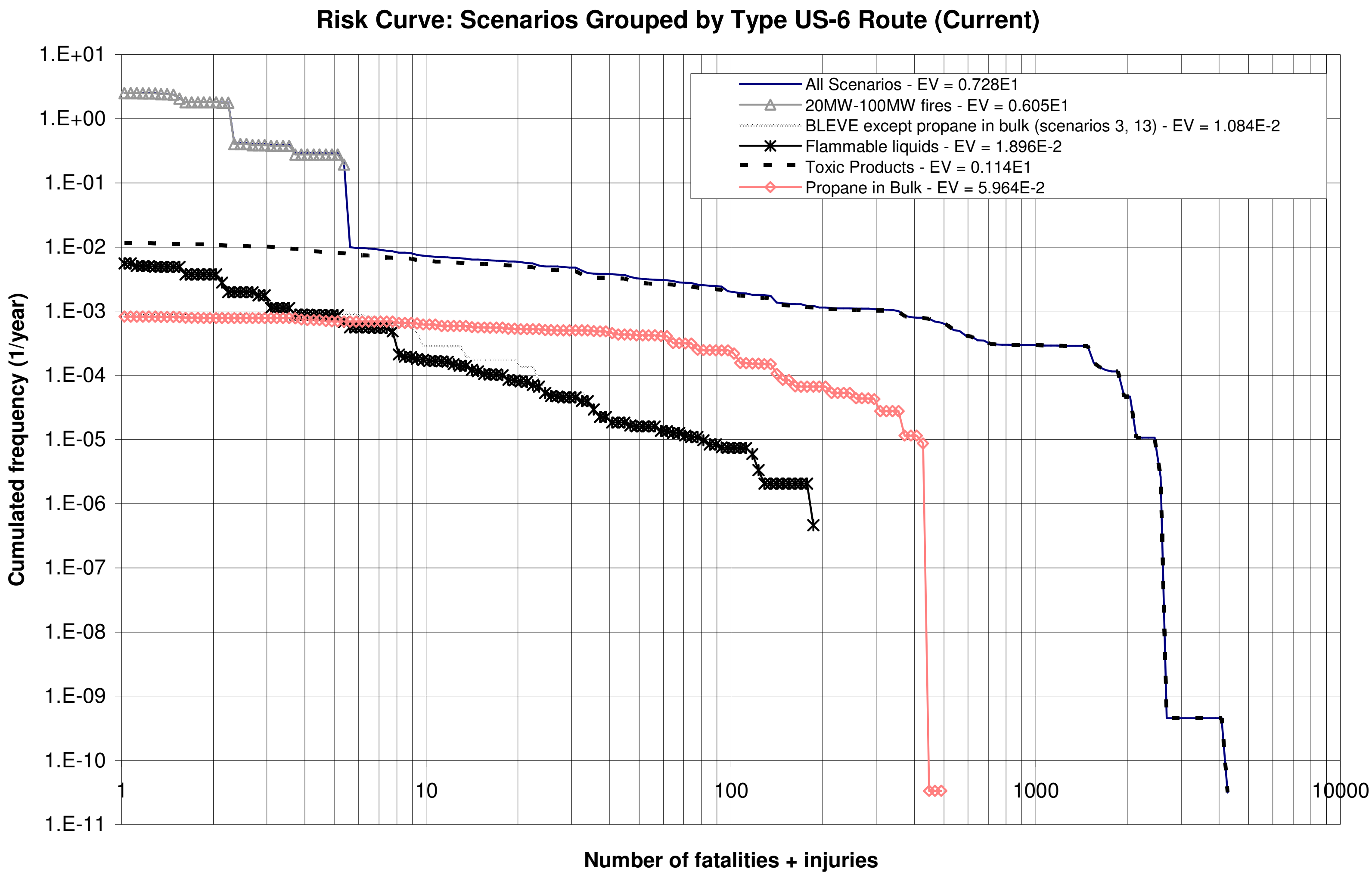
Title 49 CFR 177.810 exempts State and local regulations and ordinances regarding the kind, character, or quantity of any hazardous material, except radioactive materials, transported through urban tunnels used for mass transportation from parts 170 to 189 of the hazardous materials regulations. The regulations address classification, packaging, preparation of shipping papers, marking, labeling, placarding, emergency response information and training. However, this section does not exempt State, Indian tribes and local governments from having to comply with the routing regulations applicable to the transportation of Class 7 (radioactive) materials (49 CFR 397, subpart D) or the routing regulations established herein. Where States and Indian tribes have not established non-radioactive Hazmats routing designations, motor carriers are required to operate in accordance with 49 CFR 397.67, previously set forth in 49 CFR 397.9(a), over routes that avoid heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys.

Appendix F: Output from QRAM Software

F.1 Results for US-6 Route (Current)



EV = Expected Value = Fatalities (+Injuries) / year



EV = Expected Value = Fatalities (+Injuries) / year

Scenario Frequencies
Route = US-6 (Current)
Time Period = Normal

	Frequency per km of Route												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	2.55E-01	5.17E-02	9.51E-06	6.17E-05	6.17E-06	1.28E-04	5.11E-06	5.11E-06	5.11E-05	1.28E-04	3.37E-05	8.73E-06	2.87E-07
2	2.53E-01	5.09E-02	1.72E-05	1.11E-04	1.11E-05	2.32E-04	9.23E-06	9.23E-06	9.23E-05	2.32E-04	6.09E-05	1.58E-05	5.19E-07
3	3.60E-06	7.20E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
4	4.25E-06	8.54E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
5	4.25E-06	8.54E-07	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
6	7.77E-02	1.55E-02	7.64E-06	4.96E-05	4.96E-06	1.03E-04	4.11E-06	4.11E-06	4.11E-05	1.03E-04	2.71E-05	7.02E-06	2.31E-07
7	2.30E-01	4.47E-02	4.78E-05	3.10E-04	3.10E-05	6.46E-04	2.57E-05	2.57E-05	2.57E-04	6.46E-04	1.70E-04	4.39E-05	1.44E-06
8	1.23E-01	2.22E-02	5.99E-05	3.89E-04	3.89E-05	8.09E-04	3.22E-05	3.22E-05	3.22E-04	8.09E-04	2.13E-04	5.50E-05	1.81E-06
9	5.21E-07	9.20E-08	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
10	5.21E-07	9.20E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
11	5.21E-07	9.20E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
12	5.21E-07	9.20E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
13	4.08E-02	7.21E-03	4.44E-05	2.62E-04	2.62E-05	5.59E-04	2.31E-05	2.31E-05	2.31E-04	5.59E-04	1.61E-04	4.45E-05	1.41E-06
14	1.02E-01	1.80E-02	1.11E-04	6.56E-04	6.56E-05	1.40E-03	5.78E-05	5.78E-05	5.78E-04	1.40E-03	4.01E-04	1.11E-04	3.52E-06
15	4.08E-02	7.21E-03	4.44E-05	2.62E-04	2.62E-05	5.59E-04	2.31E-05	2.31E-05	2.31E-04	5.59E-04	1.61E-04	4.45E-05	1.41E-06
16	5.50E-02	9.37E-03	7.40E-05	4.37E-04	4.37E-05	9.32E-04	3.85E-05	3.85E-05	3.85E-04	9.32E-04	2.68E-04	7.42E-05	2.35E-06
17	7.36E-03	1.25E-03	9.91E-06	5.85E-05	5.85E-06	1.25E-04	5.16E-06	5.16E-06	5.16E-05	1.25E-04	3.58E-05	9.94E-06	3.14E-07
18	4.21E-07	7.18E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11

Scenario Frequencies
Route = US-6 (Current)
Time Period = Quiet

Section #	Frequency per km of Route												
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12	Scenario 13
1	4.73E-06	9.52E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
2	2.61E-06	5.18E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
3	1.91E-06	3.75E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
4	2.24E-06	4.42E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
5	2.24E-06	4.42E-07	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
6	1.64E-06	3.22E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
7	8.40E-07	1.57E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
8	3.91E-07	6.56E-08	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
9	3.52E-07	5.75E-08	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
10	3.52E-07	5.75E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
11	3.52E-07	5.75E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
12	3.52E-07	5.75E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
13	3.52E-07	5.75E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
14	3.52E-07	5.75E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
15	5.15E-02	8.43E-03	8.32E-05	4.91E-04	4.91E-05	1.05E-03	4.33E-05	4.33E-05	4.33E-04	1.05E-03	3.01E-04	8.34E-05	2.64E-06
16	3.05E-02	4.83E-03	5.54E-05	3.27E-04	3.27E-05	6.98E-04	2.89E-05	2.89E-05	2.89E-04	6.98E-04	2.00E-04	5.56E-05	1.76E-06
17	4.08E-02	6.46E-03	7.42E-05	4.38E-04	4.38E-05	9.34E-04	3.86E-05	3.86E-05	3.86E-04	9.34E-04	2.68E-04	7.44E-05	2.35E-06
18	3.12E-07	4.94E-08	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11

Scenario Frequencies
Route = US-6 (Current)
Time Period = Peak

	Frequency per km of Route												
Section #	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12	Scenario 13
1	1.78E+00	3.62E-01	3.27E-05	2.12E-04	2.12E-05	4.42E-04	1.76E-05	1.76E-05	1.76E-04	4.42E-04	1.16E-04	3.00E-05	9.89E-07
2	2.94E-01	5.96E-02	9.84E-06	6.39E-05	6.39E-06	1.33E-04	5.29E-06	5.29E-06	5.29E-05	1.33E-04	3.49E-05	9.04E-06	2.97E-07
3	3.44E-01	6.97E-02	1.32E-05	8.55E-05	8.55E-06	1.78E-04	7.08E-06	7.08E-06	7.08E-05	1.78E-04	4.67E-05	1.21E-05	3.98E-07
4	5.70E-01	1.15E-01	1.83E-05	1.19E-04	1.19E-05	2.48E-04	9.86E-06	9.86E-06	9.86E-05	2.48E-04	6.51E-05	1.68E-05	5.54E-07
5	1.79E-01	3.63E-02	1.08E-05	6.38E-05	6.38E-06	1.36E-04	5.62E-06	5.62E-06	5.62E-05	1.36E-04	3.91E-05	1.08E-05	3.43E-07
6	2.92E-01	5.91E-02	1.31E-05	8.53E-05	8.53E-06	1.78E-04	7.07E-06	7.07E-06	7.07E-05	1.78E-04	4.66E-05	1.21E-05	3.97E-07
7	3.00E-06	5.99E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
8	1.18E-06	2.27E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
9	9.19E-07	1.73E-07	3.03E-10	1.97E-09	1.97E-10	4.09E-09	1.63E-10	1.63E-10	1.63E-09	4.09E-09	1.07E-09	2.78E-10	9.15E-12
10	9.19E-07	1.73E-07	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
11	9.19E-07	1.73E-07	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11
12	8.25E-02	1.56E-02	5.09E-05	3.01E-04	3.01E-05	6.41E-04	2.65E-05	2.65E-05	2.65E-04	6.41E-04	1.84E-04	5.11E-05	1.61E-06
13	1.65E-01	3.11E-02	1.02E-04	6.01E-04	6.01E-05	1.28E-03	5.30E-05	5.30E-05	5.30E-04	1.28E-03	3.68E-04	1.02E-04	3.23E-06
14	8.25E-02	1.56E-02	5.09E-05	3.01E-04	3.01E-05	6.41E-04	2.65E-05	2.65E-05	2.65E-04	6.41E-04	1.84E-04	5.11E-05	1.61E-06
15	8.25E-02	1.56E-02	5.09E-05	3.01E-04	3.01E-05	6.41E-04	2.65E-05	2.65E-05	2.65E-04	6.41E-04	1.84E-04	5.11E-05	1.61E-06
16	8.88E-02	1.62E-02	7.64E-05	4.51E-04	4.51E-05	9.62E-04	3.98E-05	3.98E-05	3.98E-04	9.62E-04	2.76E-04	7.66E-05	2.42E-06
17	1.32E-02	2.41E-03	1.14E-05	6.71E-05	6.71E-06	1.43E-04	5.91E-06	5.91E-06	5.91E-05	1.43E-04	4.11E-05	1.14E-05	3.60E-07
18	6.59E-07	1.20E-07	5.67E-10	3.35E-09	3.35E-10	7.14E-09	2.95E-10	2.95E-10	2.95E-09	7.14E-09	2.05E-09	5.69E-10	1.80E-11

Expected Values for All Scenarios
US-6 Route (Current)

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year
1	HGV fire 20 MW	3.990
2	HGV fire 100 MW	2.060
3	BLEVE of a 50kg LPG cylinder	0.01056
4	Motor spirit pool fire	0.01363
5	VCE of motor spirit	0.00534
6	Chlorine release from a 20 tons tank	1.110
7	BLEVE of an 18 tons LPG tank	0.05437
8	VCE from an 18 tons LPG tank	0.00413
9	Torch fire from an 18 tons LPG tank	0.00114
10	Ammonia release from an 18 tons tank	0.02674
11	Acrolein release from a 25 tons tank	0.01272
12	Acrolein release from a 100 l cylinder	0.00108
13	BLEVE of a 20 ton liquefied CO2 tank	0.00028

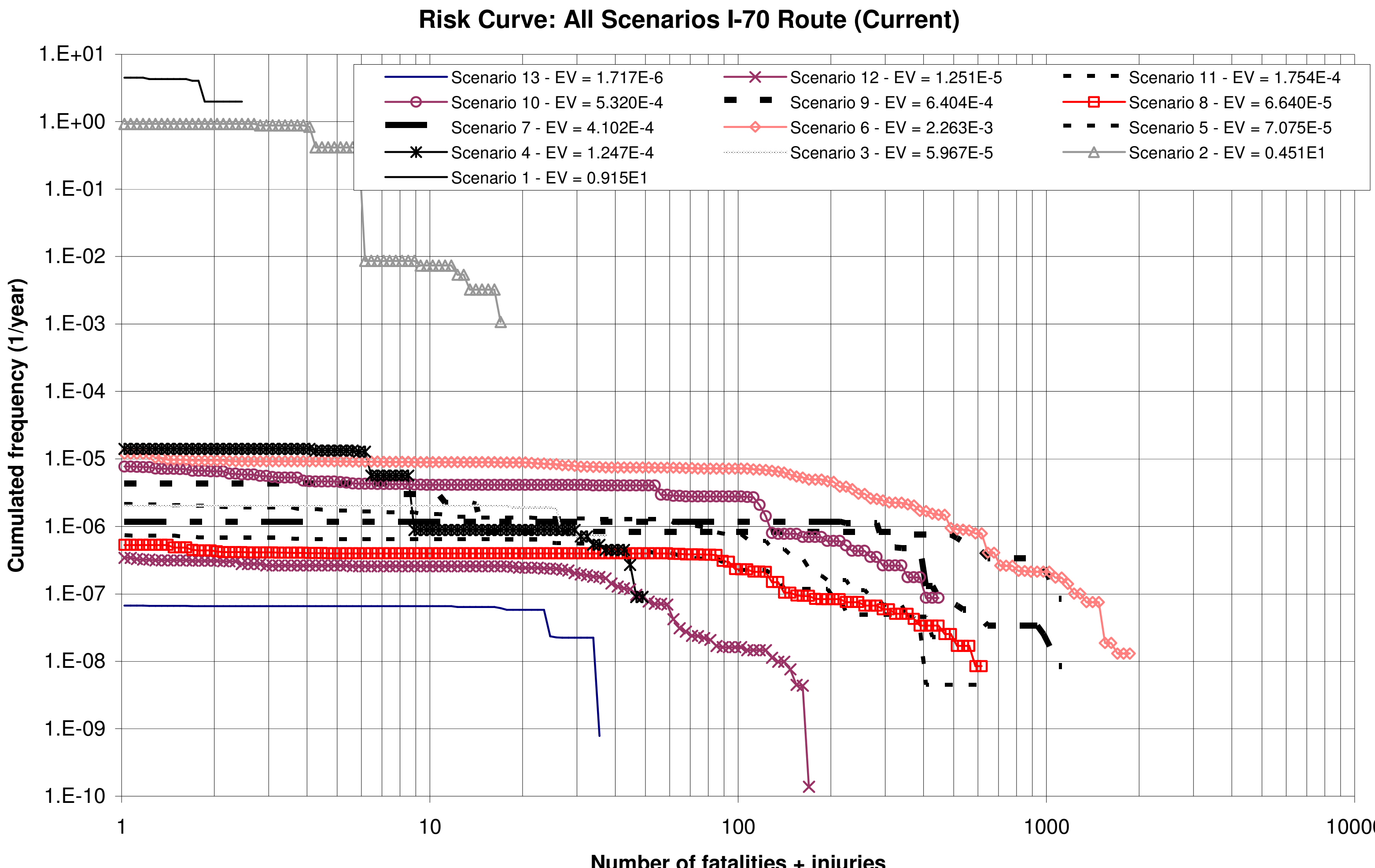
Expected Values for Scenarios by Type
US-6 Route (Current)

Scenario Group	Expected Value (fatalities+injuries)/year
All Scenarios	7.28
10MW-100MW fires	6.050
BLEVE except propane in bulk (scenarios 3,13)	0.01084
Flammable liquids	0.01896
Toxic Products	1.14
Propane in Bulk	0.05964

Environmental Impact: US-6 Route
(Current)

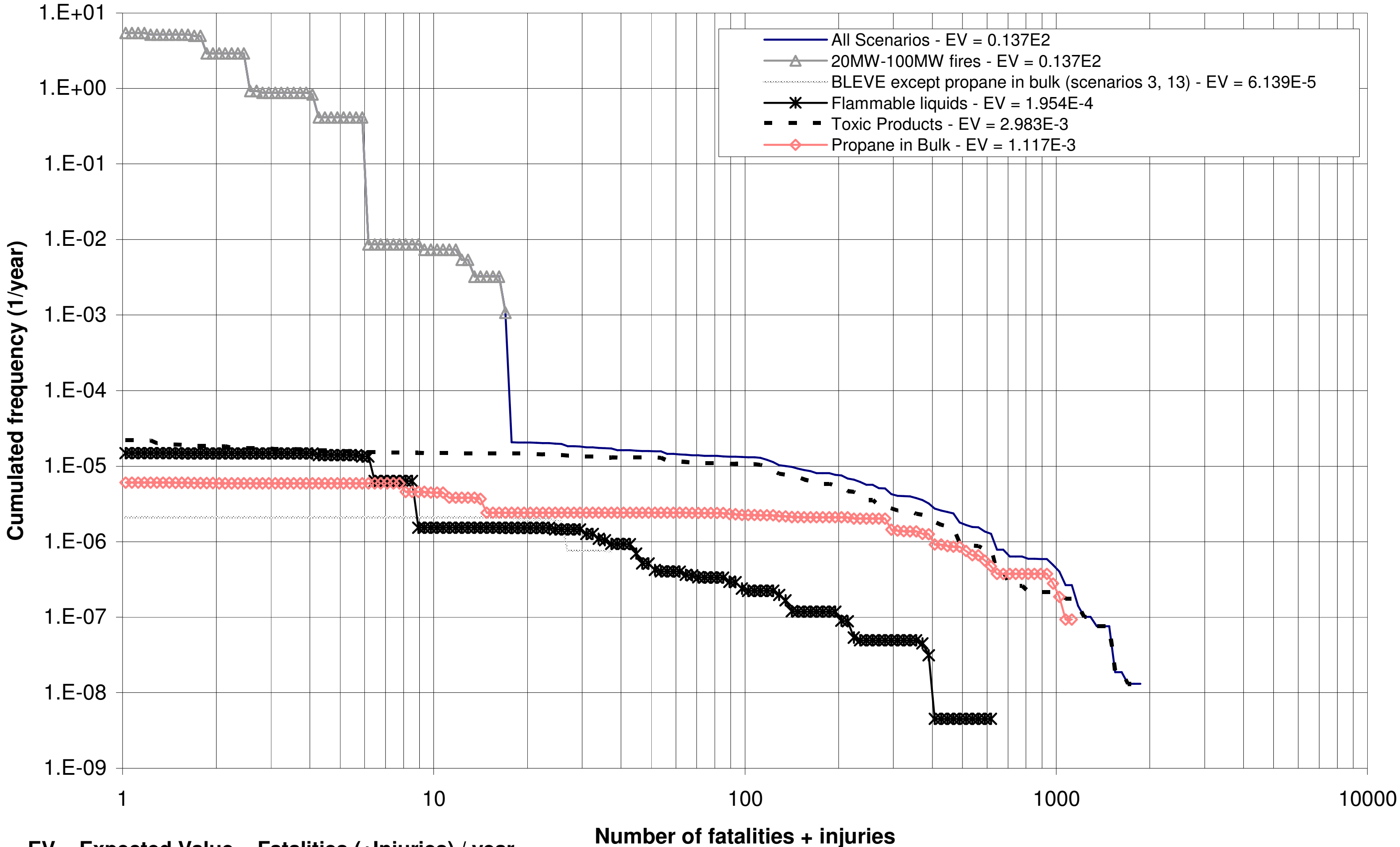
- This QRA model is designed to address principally immediate risks due to road transport of dangerous goods on human beings.
- The choice of the studied scenarios was driven by this main preoccupation.
- Transporting dangerous goods can have other and very different effects. For example: long term health effects on people, immediate or long term effects toward different medias (air, soil, water) and their biomass.
- To address long term health effects on people, a specific QRA would be necessary; to address immediate or long term environmental effects, other QRA model would be necessary. And then, the choice of representative substances would be different.
- For example, the BLEVE of a propane cylinder does not have the same effect toward the environment than a mercury pollution.
- Note that details for possible environmental effects of the selected scenarios are given in paragraph 6.5 of the reference manual
- At least one section of the described route is in a urban area
    - In a urban area, HGV fires and hydrocarbon fires can cause damages to private houses, factories...
    - In a urban area, unburnt liquid hydrocarbons can pollute sewage networks
    - In a urban area, soluble toxic products can pollute sewage networks
- At least one section of the described route is in a rural area
    - In some rural areas, HGV fires and hydrocarbon fires can cause land/forest fires
    - In a rural area, unburnt liquid hydrocarbons can contaminate soils, surface water and/or ground water
    - In a rural area, soluble toxic products can spread into soils, surface water and/or ground water

F.2 Results for I-70 Route (Current)



EV = Expected Value = Fatalities (+Injuries) / year

Risk Curve: Scenarios Grouped by Type I-70 Route (Current)



EV = Expected Value = Fatalities (+Injuries) / year

Scenario Frequencies
Route = I-70 (Current)
Time Period = Normal

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	1.59E-01	3.25E-02	5.91E-08	3.84E-07	3.84E-08	7.98E-07	3.18E-08	3.18E-08	3.18E-07	7.98E-07	2.10E-07	5.43E-08	1.79E-09
2	1.73E-01	3.53E-02	6.42E-08	4.17E-07	4.17E-08	8.68E-07	3.45E-08	3.45E-08	3.45E-07	8.68E-07	2.28E-07	5.90E-08	1.94E-09
3	8.03E-02	1.64E-02	2.99E-08	1.94E-07	1.94E-08	4.04E-07	1.61E-08	1.61E-08	1.61E-07	4.04E-07	1.06E-07	2.74E-08	9.03E-10
4	1.11E-01	2.27E-02	4.13E-08	2.68E-07	2.68E-08	5.58E-07	2.22E-08	2.22E-08	2.22E-07	5.58E-07	1.47E-07	3.79E-08	1.25E-09
5 (Tunnel)	1.15E-02	2.36E-03	1.16E-07	1.97E-07	1.97E-08	3.83E-07	1.86E-08	1.86E-08	1.86E-07	3.83E-07	1.01E-07	2.60E-08	1.22E-09
6	3.33E-01	6.80E-02	1.24E-07	8.04E-07	8.04E-08	1.67E-06	6.66E-08	6.66E-08	6.66E-07	1.67E-06	4.39E-07	1.14E-07	3.74E-09
7	2.62E-01	5.35E-02	9.74E-08	6.32E-07	6.32E-08	1.32E-06	5.24E-08	5.24E-08	5.24E-07	1.32E-06	3.46E-07	8.95E-08	2.94E-09

Scenario Frequencies
Route = I-70 (Current)
Time Period = Quiet

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	1.48E-01	3.03E-02	8.95E-08	5.82E-07	5.82E-08	1.21E-06	4.82E-08	4.82E-08	4.82E-07	1.21E-06	3.18E-07	8.23E-08	2.71E-09
2	1.38E-01	2.82E-02	8.35E-08	5.42E-07	5.42E-08	1.13E-06	4.49E-08	4.49E-08	4.49E-07	1.13E-06	2.96E-07	7.67E-08	2.52E-09
3	5.57E-06	1.14E-06	3.37E-12	2.19E-11	2.19E-12	4.55E-11	1.81E-12	1.81E-12	1.81E-11	4.55E-11	1.19E-11	3.09E-12	1.02E-13
4	1.04E-01	2.12E-02	6.26E-08	4.07E-07	4.07E-08	8.46E-07	3.37E-08	3.37E-08	3.37E-07	8.46E-07	2.22E-07	5.75E-08	1.89E-09
5 (Tunnel)	8.62E-03	1.76E-03	1.40E-07	2.39E-07	2.39E-08	4.64E-07	2.25E-08	2.25E-08	2.25E-07	4.64E-07	1.22E-07	3.16E-08	1.48E-09
6	1.55E-01	3.17E-02	9.39E-08	6.09E-07	6.09E-08	1.27E-06	5.05E-08	5.05E-08	5.05E-07	1.27E-06	3.33E-07	8.62E-08	2.84E-09
7	8.15E-02	1.66E-02	4.92E-08	3.20E-07	3.20E-08	6.65E-07	2.65E-08	2.65E-08	2.65E-07	6.65E-07	1.75E-07	4.52E-08	1.49E-09

Scenario Frequencies
Route = I-70 (Current)
Time Period = Peak

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	9.88E-02	2.02E-02	4.31E-08	2.80E-07	2.80E-08	5.83E-07	2.32E-08	2.32E-08	2.32E-07	5.83E-07	1.53E-07	3.96E-08	1.30E-09
2	1.23E-01	2.51E-02	5.36E-08	3.48E-07	3.48E-08	7.24E-07	2.88E-08	2.88E-08	2.88E-07	7.24E-07	1.90E-07	4.92E-08	1.62E-09
3	9.94E-02	2.03E-02	4.34E-08	2.82E-07	2.82E-08	5.86E-07	2.33E-08	2.33E-08	2.33E-07	5.86E-07	1.54E-07	3.99E-08	1.31E-09
4	4.15E-01	8.47E-02	1.81E-07	1.18E-06	1.18E-07	2.45E-06	9.73E-08	9.73E-08	9.73E-07	2.45E-06	6.42E-07	1.66E-07	5.47E-09
5 (Tunnel)	1.17E-06	2.39E-07	1.38E-11	2.34E-11	2.34E-12	4.55E-11	2.21E-12	2.21E-12	2.21E-11	4.55E-11	1.19E-11	3.09E-12	1.45E-13
6	1.04E-01	2.12E-02	4.52E-08	2.93E-07	2.93E-08	6.11E-07	2.43E-08	2.43E-08	2.43E-07	6.11E-07	1.60E-07	4.15E-08	1.37E-09
7	2.17E-01	4.44E-02	9.48E-08	6.16E-07	6.16E-08	1.28E-06	5.10E-08	5.10E-08	5.10E-07	1.28E-06	3.37E-07	8.71E-08	2.87E-09

Expected Values for All Scenarios
I-70 Route (Current)

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year
1	HGV fire 20 MW	9.150
2	HGV fire 100 MW	4.510
3	BLEVE of a 50kg LPG cylinder	0.0000597
4	Motor spirit pool fire	0.0001247
5	VCE of motor spirit	0.0000707
6	Chlorine release from a 20 tons tank	0.0022600
7	BLEVE of an 18 tons LPG tank	0.0004102
8	VCE from an 18 tons LPG tank	0.0000664
9	Torch fire from an 18 tons LPG tank	0.0006404
10	Ammonia release from an 18 tons tank	0.0005320
11	Acrolein release from a 25 tons tank	0.0001754
12	Acrolein release from a 100 l cylinder	0.0000125
13	BLEVE of a 20 ton liquefied CO2 tank	0.0000017

Expected Values for Scenarios by Type
I-70 Route (Current)

Scenario Group	Expected Value (fatalities+injuries)/year
All Scenarios	13.70
10MW-100MW fires	13.70
BLEVE except propane in bulk (scenarios 3,13)	0.0000614
Flammable liquids	0.0001954
Toxic Products	0.0029830
Propane in Bulk	0.0011170

Environmental Impact: I-70 Route
(Current)

- This QRA model is designed to address principally immediate risks due to road transport of dangerous goods on human beings.
- The choice of the studied scenarios was driven by this main preoccupation.
- Transporting dangerous goods can have other and very different effects. For example: long term health effects on people, immediate or long term effects toward different medias (air, soil, water) and their biomass.
- To address long term health effects on people, a specific QRA would be necessary; to address immediate or long term environmental effects, other QRA model would be necessary. And then, the choice of representative substances would be different.
- For example, the BLEVE of a propane cylinder does not have the same effect toward the environment than a mercury pollution.
- Note that details for possible environmental effects of the selected scenarios are given in paragraph 6.5 of the reference manual
- At least one section of the described route is in a urban area
  - In a urban area, HGV fires and hydrocarbon fires can cause damages to private houses, factories...
  - In a urban area, unburnt liquid hydrocarbons can pollute sewage networks
  - In a urban area, soluble toxic products can pollute sewage networks
- At least one section of the described route is a tunnel section
  - In a tunnel, unburnt liquid hydrocarbons can contaminate drainage systems: it should be taken care of the possibility to collect and treat polluted waters, including fire fighting waters
  - In the tunnel, pay attention that unburnt polluted liquids could mainly go out of the tunnel through portal B

Damage for South/Johnson Tunnel (Current)

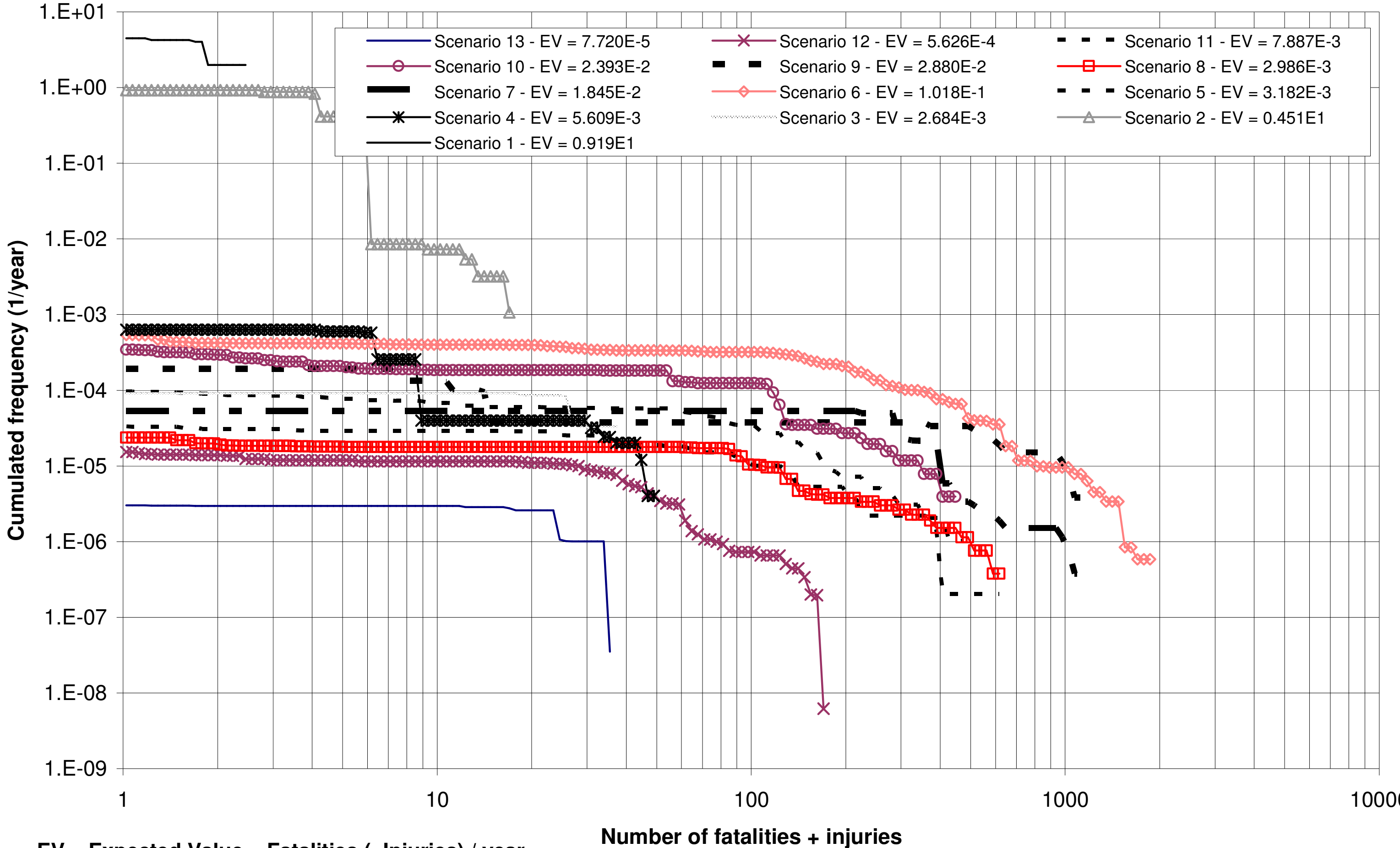
				Damage length (m)				**Cost (% of construction capital cost)**				
Scenario #	DG	Title	Accident location in tunnel (% section length : 0=Portal A ; 100=Portal B)	tunnel structure	internal civil	protected equipment	unprotected equipment	tunnel structure	internal civil	protected equipment	unprotected equipment	Total
1	None	HGV fire, 20MW	17%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	7.9	18.2	0.0	0.0	0.0	0.0	0.1
			67%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
2	None	HGV fire, 100MW	17%	0.0	0.0	32.2	38.8	0.0	0.0	0.1	0.1	0.2
			33%	0.0	0.0	32.4	38.9	0.0	0.0	0.1	0.1	0.2
			50%	0.0	0.0	34.5	39.2	0.0	0.0	0.1	0.1	0.2
			67%	0.0	0.0	32.3	38.8	0.0	0.0	0.1	0.1	0.2
			83%	0.0	0.0	32.3	38.9	0.0	0.0	0.1	0.1	0.2
3	LPG	BLEVE, 50kg cylinder	17%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			33%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			50%	0.0	0.0	53.0	133.5	0.0	0.0	0.2	0.2	0.4
			67%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			83%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
4	Motor spirit	Pool fire, 28te tank	17%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			33%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			50%	0.0	0.0	89.7	98.5	0.0	0.0	0.3	0.1	0.4
			67%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			83%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
5	Motor spirit	VCE, 28te tank	17%	177.5	0.0	774.7	900.5	4.9	0.0	2.4	1.3	8.6
			33%	206.7	0.0	806.6	937.6	5.7	0.0	2.5	1.4	9.5
			50%	242.7	0.0	844.5	981.5	6.6	0.0	2.6	1.4	10.7
			67%	274.7	0.0	890.7	1035.2	7.5	0.0	2.8	1.5	11.8
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
6	Chlorine	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	LPG	BLEVE, 18te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
8	LPG	VCE, 18te tank	17%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			33%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			50%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			67%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
9	LPG	BLEVE (Torch fire), 18 te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
10	Ammonia	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Acrolein	Toxic release, 25te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Acrolein	Toxic release, 100l cylinder	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Liquefied CO2	BLEVE, 20te tank	17%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			33%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			50%	0.0	0.0	219.0	270.6	0.0	0.0	0.7	0.4	1.1
			67%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			83%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1

Damage for North/Eisenhower Tunnel (Current)

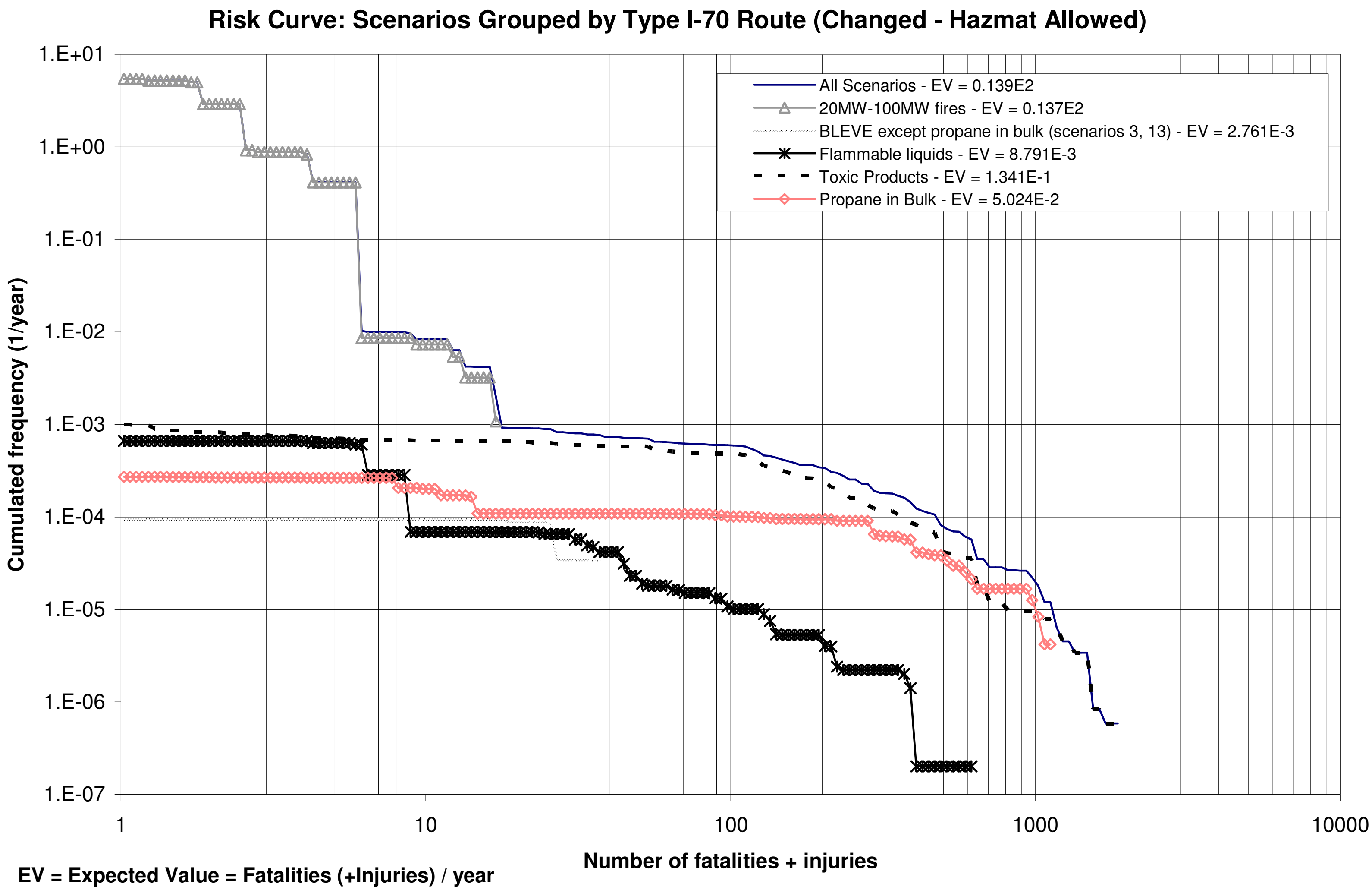
Scenario #	DG	Title	Accident location in tunnel (% section length : 0=Portal A ; 100=Portal B)	Damage length (m)				Cost (% of construction capital cost)				
				tunnel structure	internal civil	protected equipment	unprotected equipment	tunnel structure	internal civil	protected equipment	unprotected equipment	Total
1	None	HGV fire, 20MW	17%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	7.9	18.2	0.0	0.0	0.0	0.0	0.1
			67%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
2	None	HGV fire, 100MW	17%	0.0	0.0	32.2	38.8	0.0	0.0	0.1	0.1	0.2
			33%	0.0	0.0	32.4	38.9	0.0	0.0	0.1	0.1	0.2
			50%	0.0	0.0	34.5	39.2	0.0	0.0	0.1	0.1	0.2
			67%	0.0	0.0	32.3	38.8	0.0	0.0	0.1	0.1	0.2
			83%	0.0	0.0	32.3	38.9	0.0	0.0	0.1	0.1	0.2
3	LPG	BLEVE, 50kg cylinder	17%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			33%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			50%	0.0	0.0	53.0	133.5	0.0	0.0	0.2	0.2	0.4
			67%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			83%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
4	Motor spirit	Pool fire, 28te tank	17%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			33%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			50%	0.0	0.0	89.7	98.5	0.0	0.0	0.3	0.1	0.4
			67%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			83%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
5	Motor spirit	VCE, 28te tank	17%	177.5	0.0	774.7	900.5	4.9	0.0	2.4	1.3	8.6
			33%	206.7	0.0	806.6	937.6	5.7	0.0	2.5	1.4	9.5
			50%	242.7	0.0	844.5	981.5	6.6	0.0	2.6	1.4	10.7
			67%	274.7	0.0	890.7	1035.2	7.5	0.0	2.8	1.5	11.8
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
6	Chlorine	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	LPG	BLEVE, 18te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
8	LPG	VCE, 18te tank	17%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			33%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			50%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			67%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
9	LPG	BLEVE (Torch fire), 18 te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
10	Ammonia	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Acrolein	Toxic release, 25te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Acrolein	Toxic release, 100l cylinder	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Liquefied CO2	BLEVE, 20te tank	17%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			33%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			50%	0.0	0.0	219.0	270.6	0.0	0.0	0.7	0.4	1.1
			67%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			83%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1

F.3 Results for I-70 Route (Changed – Hazmat Allowed)

Risk Curve: All Scenarios I-70 Route (Changed - Hazmat Allowed)



EV = Expected Value = Fatalities (+Injuries) / year


Risk Curve: Scenarios Grouped by Type I-70 Route (Changed - Hazmat Allowed)
Cumulated frequency (1/year)
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1
10
100
1000
10000
Number of fatalities + injuries
All Scenarios - EV = 0.139E2
20MW-100MW fires - EV = 0.137E2
BLEVE except propane in bulk (scenarios 3, 13) - EV = 2.761E-3
Flammable liquids - EV = 8.791E-3
Toxic Products - EV = 1.341E-1
Propane in Bulk - EV = 5.024E-2
EV = Expected Value = Fatalities (+Injuries) / year

Scenario Frequencies
Route = I-70 (Changed - Hazmat Allowed)
Time Period = Normal

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	1.60E-01	3.25E-02	2.66E-06	1.73E-05	1.73E-06	3.59E-05	1.43E-06	1.43E-06	1.43E-05	3.59E-05	9.43E-06	2.44E-06	8.03E-08
2	1.73E-01	3.53E-02	2.89E-06	1.88E-05	1.88E-06	3.90E-05	1.55E-06	1.55E-06	1.55E-05	3.90E-05	1.03E-05	2.65E-06	8.73E-08
3	8.07E-02	1.64E-02	1.34E-06	8.72E-06	8.72E-07	1.82E-05	7.22E-07	7.22E-07	7.22E-06	1.82E-05	4.77E-06	1.23E-06	4.06E-08
4	1.12E-01	2.27E-02	1.86E-06	1.21E-05	1.21E-06	2.51E-05	9.99E-07	9.99E-07	9.99E-06	2.51E-05	6.59E-06	1.71E-06	5.62E-08
5 (Tunnel)	1.16E-02	2.36E-03	5.21E-06	8.84E-06	8.84E-07	1.72E-05	8.35E-07	8.35E-07	8.35E-06	1.72E-05	4.52E-06	1.17E-06	5.49E-08
6	3.34E-01	6.81E-02	5.57E-06	3.62E-05	3.62E-06	7.52E-05	2.99E-06	2.99E-06	2.99E-05	7.52E-05	1.98E-05	5.11E-06	1.68E-07
7	2.63E-01	5.35E-02	4.38E-06	2.84E-05	2.84E-06	5.92E-05	2.36E-06	2.36E-06	2.36E-05	5.92E-05	1.55E-05	4.02E-06	1.32E-07

Scenario Frequencies
Route = I-70 (Changed - Hazmat Allowed)
Time Period = Quiet

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	1.49E-01	3.03E-02	4.03E-06	2.62E-05	2.62E-06	5.44E-05	2.17E-06	2.17E-06	2.17E-05	5.44E-05	1.43E-05	3.70E-06	1.22E-07
2	1.39E-01	2.82E-02	3.75E-06	2.44E-05	2.44E-06	5.07E-05	2.02E-06	2.02E-06	2.02E-05	5.07E-05	1.33E-05	3.45E-06	1.13E-07
3	5.60E-06	1.14E-06	1.51E-10	9.83E-10	9.83E-11	2.05E-09	8.14E-11	8.14E-11	8.14E-10	2.05E-09	5.37E-10	1.39E-10	4.58E-12
4	1.04E-01	2.12E-02	2.82E-06	1.83E-05	1.83E-06	3.81E-05	1.52E-06	1.52E-06	1.52E-05	3.81E-05	1.00E-05	2.59E-06	8.52E-08
5 (Tunnel)	8.67E-03	1.76E-03	6.32E-06	1.07E-05	1.07E-06	2.09E-05	1.01E-06	1.01E-06	1.01E-05	2.09E-05	5.49E-06	1.42E-06	6.66E-08
6	1.56E-01	3.17E-02	4.22E-06	2.74E-05	2.74E-06	5.71E-05	2.27E-06	2.27E-06	2.27E-05	5.71E-05	1.50E-05	3.88E-06	1.28E-07
7	8.20E-02	1.66E-02	2.21E-06	1.44E-05	1.44E-06	2.99E-05	1.19E-06	1.19E-06	1.19E-05	2.99E-05	7.86E-06	2.03E-06	6.70E-08

Scenario Frequencies
Route = I-70 (Changed - Hazmat Allowed)
Time Period = Peak

	Frequency per km of Route (same values for both directions of travel)												
Section #	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**	**Scenario 13**
1	9.92E-02	2.02E-02	1.94E-06	1.26E-05	1.26E-06	2.62E-05	1.04E-06	1.04E-06	1.04E-05	2.62E-05	6.88E-06	1.78E-06	5.86E-08
2	1.23E-01	2.51E-02	2.41E-06	1.56E-05	1.56E-06	3.26E-05	1.30E-06	1.30E-06	1.30E-05	3.26E-05	8.55E-06	2.21E-06	7.29E-08
3	9.99E-02	2.03E-02	1.95E-06	1.27E-05	1.27E-06	2.64E-05	1.05E-06	1.05E-06	1.05E-05	2.64E-05	6.93E-06	1.79E-06	5.90E-08
4	4.17E-01	8.47E-02	8.14E-06	5.29E-05	5.29E-06	1.10E-04	4.38E-06	4.38E-06	4.38E-05	1.10E-04	2.89E-05	7.48E-06	2.46E-07
5 (Tunnel)	1.17E-06	2.39E-07	6.19E-10	1.05E-09	1.05E-10	2.05E-09	9.92E-11	9.92E-11	9.92E-10	2.05E-09	5.37E-10	1.39E-10	6.52E-12
6	1.04E-01	2.12E-02	2.03E-06	1.32E-05	1.32E-06	2.75E-05	1.09E-06	1.09E-06	1.09E-05	2.75E-05	7.22E-06	1.87E-06	6.15E-08
7	2.18E-01	4.44E-02	4.26E-06	2.77E-05	2.77E-06	5.76E-05	2.29E-06	2.29E-06	2.29E-05	5.76E-05	1.51E-05	3.92E-06	1.29E-07

Scenario Return Periods (Scenarios 1-7)
Route = US-6 (Current) and I-70 (Changed - Hazmat Allowed)
Time Period = Normal

US 6 Route Normal Period			Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7	
Seg #	Length Miles	km	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)
1	0.291	0.468	2.55E-01	8.4	5.17E-02	41	9.51E-06	224,532	6.17E-05	34,608	6.17E-06	346,077	1.28E-04	16,682	5.11E-06	417,866
2	0.894	1.439	2.53E-01	2.7	5.09E-02	14	1.72E-05	40,410	1.11E-04	6,262	1.11E-05	62,617	2.32E-04	2,996	9.23E-06	75,303
3	0.818	1.316	3.60E-06	211,006	7.20E-07	1,055,031	3.03E-10	2,507,004,899	1.97E-09	385,595,170	1.97E-10	3,855,951,697	4.09E-09	185,726,769	1.63E-10	4,660,260,640
4	0.591	0.951	4.25E-06	247,386	8.54E-07	1,231,135	3.03E-10	3,469,932,331	1.97E-09	533,700,252	1.97E-10	5,337,002,519	4.09E-09	257,063,446	1.63E-10	6,450,242,308
5	1.878	3.022	4.25E-06	77,851	8.54E-07	387,434	5.67E-10	583,542,468	3.35E-09	98,766,740	3.35E-10	987,667,401	7.14E-09	46,340,137	2.95E-10	1,121,588,405
6	2.821	4.540	7.77E-02	2.8	1.55E-02	14	7.64E-06	28,831	4.96E-05	4,441	4.96E-06	44,409	1.03E-04	2,139	4.11E-06	53,593
7	0.388	0.624	2.30E-01	7.0	4.47E-02	36	4.78E-05	33,504	3.10E-04	5,166	3.10E-05	51,660	6.46E-04	2,479	2.57E-05	62,314
8	0.66	1.062	1.23E-01	7.7	2.22E-02	42	5.99E-05	15,717	3.89E-04	2,420	3.89E-05	24,202	8.09E-04	1,164	3.22E-05	29,238
9	0.891	1.434	5.21E-07	1,338,553	9.20E-08	7,580,286	3.03E-10	2,301,604,947	1.97E-09	354,003,197	1.97E-10	3,540,031,974	4.09E-09	170,510,098	1.63E-10	4,278,443,551
10	1.109	1.785	5.21E-07	1,075,429	9.20E-08	6,090,203	5.67E-10	988,181,024	3.35E-09	167,253,326	3.35E-10	1,672,533,255	7.14E-09	78,473,199	2.95E-10	1,899,317,425
11	1	1.609	5.21E-07	1,192,651	9.20E-08	6,754,035	5.67E-10	1,095,892,755	3.35E-09	185,483,938	3.35E-10	1,854,839,380	7.14E-09	87,026,778	2.95E-10	2,106,343,025
12	1	1.609	5.21E-07	1,192,651	9.20E-08	6,754,035	5.67E-10	1,095,892,755	3.35E-09	185,483,938	3.35E-10	1,854,839,380	7.14E-09	87,026,778	2.95E-10	2,106,343,025
13	1	1.609	4.08E-02	15.2	7.21E-03	86	4.44E-05	13,995	2.62E-04	2,372	2.62E-05	23,716	5.59E-04	1,112	2.31E-05	26,899
14	1	1.609	1.02E-01	6.1	1.80E-02	35	1.11E-04	5,598	6.56E-04	947	6.56E-05	9,472	1.40E-03	444	5.78E-05	10,750
15	1	1.609	4.08E-02	15.2	7.21E-03	86	4.44E-05	13,995	2.62E-04	2,372	2.62E-05	23,716	5.59E-04	1,112	2.31E-05	26,899
16	3	4.828	5.50E-02	3.8	9.37E-03	22	7.40E-05	2,799	4.37E-04	474	4.37E-05	4,740	9.32E-04	222	3.85E-05	5,380
17	2.242	3.608	7.36E-03	38	1.25E-03	222	9.91E-06	27,967	5.85E-05	4,738	5.85E-06	47,376	1.25E-04	2,217	5.16E-06	53,711
18	0.086	0.138	4.21E-07	17,162,106	7.18E-08	100,630,173	5.67E-10	12,742,939,015	3.35E-09	2,156,789,977	3.35E-10	21,567,899,765	7.14E-09	1,011,939,275	2.95E-10	24,492,360,750
Route TTL	**20.669**	**33.264**		**0.59**		**3.11**		**1,146.87**		**190.82**		**1,908.21**		**89.87**		**2,190.80**

Interstate 70 Route Normal Period with HAZMAT			Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7	
Seg #	Length Miles	km	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)
1	0.326	0.525	1.60E-01	12	3.25E-02	59	2.66E-06	716,559	1.73E-05	110,176	1.73E-06	1,101,761	3.59E-05	53,093	1.43E-06	1,332,900
2	7.345	11.821	1.73E-01	0.49	3.53E-02	2.40	2.89E-06	29,272.61	1.88E-05	4,499.89	1.88E-06	44,998.86	3.90E-05	2,169.18	1.55E-06	54,579.26
3	0.324	0.521	8.07E-02	24	1.64E-02	117	1.34E-06	1,431,203	8.72E-06	219,933	8.72E-07	2,199,326	1.82E-05	105,374	7.22E-07	2,656,250
4	0.233	0.375	1.12E-01	24	2.27E-02	117	1.86E-06	1,433,779	1.21E-05	220,399	1.21E-06	2,203,991	2.51E-05	106,248	9.99E-07	2,669,499
5 (Tunnels)	***1.699***	***2.734***	***1.16E-02***	***32***	***2.36E-03***	***155***	***5.21E-06***	***70,197***	***8.84E-06***	***41,372***	***8.84E-07***	***413,719***	***1.72E-05***	***21,263***	***8.35E-07***	***437,997***
6	0.311	0.501	3.34E-01	6	6.81E-02	29	5.57E-06	358,703	3.62E-05	55,193	3.62E-06	551,928	7.52E-05	26,569	2.99E-06	668,220
7	0.593	0.954	5.35E-01	2	5.35E-02	20	4.38E-06	239,234	2.84E-05	36,896	2.84E-06	368,959	5.92E-05	17,700	2.36E-06	444,001
Route TTL	**10.831**	**17.431**		**0.34**		**1.84**		**17,192**		**3,228**		**32,281**		**1,563**		**38,677**

Scenario 1 *Fire, 20MW*
Scenario 2 *Fire, 100MW*
Scenario 3 *BLEVE, 50kg LPG*
Scenario 4 *Motor spirit pool fire*
Scenario 5 *VCE of motor spirit*
Scenario 6 *Chlorine release, 20T tank*
Scenario 7 *BLEVE, 18T LPG tank*
Scenario 8 *VCE, 18T LPG tank*
Scenario 9 *Torch Fire, 18T LPG tank*
Scenario 10 *Amonia Release, 18T LPG tank*
Scenario 11 *Acrolein Release, 25T tank*
Scenario 12 *Acrolein Release, 100l cylinder*
Scenario 13 *BLEVE, 20T liquid CO2 tank*

Scenario Return Periods (Scenarios 8-13)
Route = US-6 (Current) and I-70 (Changed - Hazmat Allowed)
Time Period = Normal

US 6 Route Normal Period			Scenario 8		Scenario 9		Scenario 10		Scenario 11		Scenario 12		Scenario 13	
Seg #	Length Miles	km	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)
1	0.291	0.468	5.11E-06	417,866	5.11E-05	41,787	1.28E-04	16,682	3.37E-05	63,362	8.73E-06	244,593	2.87E-07	7,440,056
2	0.894	1.439	9.23E-06	75,303	9.23E-05	7,530	2.32E-04	2,996	6.09E-05	11,413	1.58E-05	43,990	5.19E-07	1,339,202
3	0.818	1.316	1.63E-10	4,660,260,640	1.63E-09	466,026,064	4.09E-09	185,726,769	1.07E-09	709,927,556	2.78E-10	2,732,454,980	9.15E-12	83,018,850,754
4	0.591	0.951	1.63E-10	6,450,242,308	1.63E-09	645,024,231	4.09E-09	257,063,446	1.07E-09	982,607,006	2.78E-10	3,781,976,605	9.15E-12	114,905,955,866
5	1.878	3.022	2.95E-10	1,121,588,405	2.95E-09	112,158,840	7.14E-09	46,340,137	2.05E-09	161,399,307	5.69E-10	581,491,352	1.80E-11	18,381,587,748
6	2.821	4.540	4.11E-06	53,593	4.11E-05	5,359	1.03E-04	2,139	2.71E-05	8,128	7.02E-06	31,377	2.31E-07	953,534
7	0.388	0.624	2.57E-05	62,314	2.57E-04	6,231	6.46E-04	2,479	1.70E-04	9,420	4.39E-05	36,480	1.44E-06	1,112,133
8	0.66	1.062	3.22E-05	29,238	3.22E-04	2,924	8.09E-04	1,164	2.13E-04	4,420	5.50E-05	17,118	1.81E-06	520,150
9	0.891	1.434	1.63E-10	4,278,443,551	1.63E-09	427,844,355	4.09E-09	170,510,098	1.07E-09	651,762,896	2.78E-10	2,508,583,809	9.15E-12	76,217,081,837
10	1.109	1.785	2.95E-10	1,899,317,425	2.95E-09	189,931,743	7.14E-09	78,473,199	2.05E-09	273,316,410	5.69E-10	984,707,628	1.80E-11	31,127,702,246
11	1	1.609	2.95E-10	2,106,343,025	2.95E-09	210,634,302	7.14E-09	87,026,778	2.05E-09	303,107,899	5.69E-10	1,092,040,760	1.80E-11	34,520,621,791
12	1	1.609	2.95E-10	2,106,343,025	2.95E-09	210,634,302	7.14E-09	87,026,778	2.05E-09	303,107,899	5.69E-10	1,092,040,760	1.80E-11	34,520,621,791
13	1	1.609	2.31E-05	26,899	2.31E-04	2,690	5.59E-04	1,112	1.61E-04	3,859	4.45E-05	13,963	1.41E-06	440,689
14	1	1.609	5.78E-05	10,750	5.78E-04	1,075	1.40E-03	444	4.01E-04	1,550	1.11E-04	5,598	3.52E-06	176,526
15	1	1.609	2.31E-05	26,899	2.31E-04	2,690	5.59E-04	1,112	1.61E-04	3,859	4.45E-05	13,963	1.41E-06	440,689
16	3	4.828	3.85E-05	5,380	3.85E-04	538	9.32E-04	222	2.68E-04	773	7.42E-05	2,791	2.35E-06	88,138
17	2.242	3.608	5.16E-06	53,711	5.16E-05	5,371	1.25E-04	2,217	3.58E-05	7,742	9.94E-06	27,882	3.14E-07	882,645
18	0.086	0.138	2.95E-10	24,492,360,750	2.95E-09	2,449,236,075	7.14E-09	1,011,939,275	2.05E-09	3,524,510,449	5.69E-10	12,698,148,368	1.80E-11	401,402,578,965
Route TTL	**20.669**	**33.264**		**2,190.80**		**219.08**		**89.87**		**317.92**		**1,162.11**		**36,451.38**

Interstate 70 Route Normal Period with HAZMAT			Scenario 8		Scenario 9		Scenario 10		Scenario 11		Scenario 12		Scenario 13	
Seg #	Length Miles	km	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)	Freq (/km/yr)	Return (years)
1	0.326	0.525	1.43E-06	1,332,900	1.43E-05	133,290	3.59E-05	53,093	9.43E-06	202,126	2.44E-06	781,167	8.03E-08	23,736,570
2	7.345	11.821	1.55E-06	54,579.26	1.55E-05	5,457.93	3.90E-05	2,169.18	1.03E-05	8,213.38	2.65E-06	31,923.72	8.73E-08	969,047.51
3	0.324	0.521	7.22E-07	2,656,250	7.22E-06	265,625	1.82E-05	105,374	4.77E-06	402,057	1.23E-06	1,559,197	4.06E-08	47,236,757
4	0.233	0.375	9.99E-07	2,669,499	9.99E-06	266,950	2.51E-05	106,248	6.59E-06	404,678	1.71E-06	1,559,549	5.62E-08	47,452,476
5 (Tunnels)	***1.699***	***2.734***	***8.35E-07***	***437,997***	***8.35E-06***	***43,800***	***1.72E-05***	***21,263***	***4.52E-06***	***80,913***	***1.17E-06***	***312,588***	***5.49E-08***	***6,661,705***
6	0.311	0.501	2.99E-06	668,220	2.99E-05	66,822	7.52E-05	26,569	1.98E-05	100,908	5.11E-06	390,994	1.68E-07	11,892,727
7	0.593	0.954	2.36E-06	444,001	2.36E-05	44,400	5.92E-05	17,700	1.55E-05	67,603	4.02E-06	260,658	1.32E-07	7,938,208
Route TTL	**10.831**	**17.431**		**38,677**		**3,868**		**1,562.73**		**5,927.00**		**22,998.81**		**677,284.85**

Scenario 1 *Fire, 20MW*
Scenario 2 *Fire, 100MW*
Scenario 3 *BLEVE, 50kg LPG*
Scenario 4 *Motor spirit pool fire*
Scenario 5 *VCE of motor spirit*
Scenario 6 *Chlorine release, 20T tank*
Scenario 7 *BLEVE, 18T LPG tank*
Scenario 8 *VCE, 18T LPG tank*
Scenario 9 *Torch Fire, 18T LPG tank*
Scenario 10 *Amonia Release, 18T LPG tank*
Scenario 11 *Acrolein Release, 25T tank*
Scenario 12 *Acrolein Release, 100l cylinder*
Scenario 13 *BLEVE, 20T liquid CO2 tank*

Expected Values for All Scenarios
I-70 Route (Changed – Hazmat Allowed)

Scenario	Scenario Description	Expected Value (fatalities+injuries)/year
1	HGV fire 20 MW	9.190
2	HGV fire 100 MW	4.510
3	BLEVE of a 50kg LPG cylinder	0.0026840
4	Motor spirit pool fire	0.0056090
5	VCE of motor spirit	0.0031820
6	Chlorine release from a 20 tons tank	0.1018000
7	BLEVE of an 18 tons LPG tank	0.0184500
8	VCE from an 18 tons LPG tank	0.0029860
9	Torch fire from an 18 tons LPG tank	0.0288000
10	Ammonia release from an 18 tons tank	0.0239300
11	Acrolein release from a 25 tons tank	0.0078870
12	Acrolein release from a 100 l cylinder	0.0005626
13	BLEVE of a 20 ton liquefied CO2 tank	0.0000772

Expected Values for Scenarios by Type
I-70 Route (Changed – Hazmat Allowed)

Scenario Group	Expected Value (fatalities+injuries)/year
All Scenarios	13.90
10MW-100MW fires	13.70
BLEVE except propane in bulk (scenarios 3,13)	0.0027610
Flammable liquids	0.0087910
Toxic Products	0.1341000
Propane in Bulk	0.0502400

Environmental Impact: I-70 Route
(Changed – Hazmat Allowed)

- This QRA model is designed to address principally immediate risks due to road transport of dangerous goods on human beings.
- The choice of the studied scenarios was driven by this main preoccupation.
- Transporting dangerous goods can have other and very different effects. For example: long term health effects on people, immediate or long term effects toward different medias (air, soil, water) and their biomass.
- To address long term health effects on people, a specific QRA would be necessary; to address immediate or long term environmental effects, other QRA model would be necessary. And then, the choice of representative substances would be different.
- For example, the BLEVE of a propane cylinder does not have the same effect toward the environment than a mercury pollution.
- Note that details for possible environmental effects of the selected scenarios are given in paragraph 6.5 of the reference manual
- At least one section of the described route is in a urban area
    - In a urban area, HGV fires and hydrocarbon fires can cause damages to private houses, factories...
    - In a urban area, unburnt liquid hydrocarbons can pollute sewage networks
    - In a urban area, soluble toxic products can pollute sewage networks
- At least one section of the described route is a tunnel section
    - In a tunnel, unburnt liquid hydrocarbons can contaminate drainage systems: it should be taken care of the possibility to collect and treat polluted waters, including fire fighting waters
    - In the tunnel, pay attention that unburnt polluted liquids could mainly go out of the tunnel through portal B

Damage for South/Johnson Tunnel (Changed – Hazmat Allowed)

				Damage length (m)				Cost (% of construction capital cost)				
Scenario #	DG	Title	Accident location in tunnel (% section length : 0=Portal A ; 100=Portal B)	tunnel structure	internal civil	protected equipment	unprotected equipment	tunnel structure	internal civil	protected equipment	unprotected equipment	Total
1	None	HGV fire, 20MW	17%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	7.9	18.2	0.0	0.0	0.0	0.0	0.1
			67%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
2	None	HGV fire, 100MW	17%	0.0	0.0	32.2	38.8	0.0	0.0	0.1	0.1	0.2
			33%	0.0	0.0	32.4	38.9	0.0	0.0	0.1	0.1	0.2
			50%	0.0	0.0	34.5	39.2	0.0	0.0	0.1	0.1	0.2
			67%	0.0	0.0	32.3	38.8	0.0	0.0	0.1	0.1	0.2
			83%	0.0	0.0	32.3	38.9	0.0	0.0	0.1	0.1	0.2
3	LPG	BLEVE, 50kg cylinder	17%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			33%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			50%	0.0	0.0	53.0	133.5	0.0	0.0	0.2	0.2	0.4
			67%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			83%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
4	Motor spirit	Pool fire, 28te tank	17%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			33%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			50%	0.0	0.0	89.7	98.5	0.0	0.0	0.3	0.1	0.4
			67%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			83%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
5	Motor spirit	VCE, 28te tank	17%	177.5	0.0	774.7	900.5	4.9	0.0	2.4	1.3	8.6
			33%	206.7	0.0	806.6	937.6	5.7	0.0	2.5	1.4	9.5
			50%	242.7	0.0	844.5	981.5	6.6	0.0	2.6	1.4	10.7
			67%	274.7	0.0	890.7	1035.2	7.5	0.0	2.8	1.5	11.8
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
6	Chlorine	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	LPG	BLEVE, 18te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
8	LPG	VCE, 18te tank	17%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			33%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			50%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			67%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
9	LPG	BLEVE (Torch fire), 18 te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
10	Ammonia	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Acrolein	Toxic release, 25te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Acrolein	Toxic release, 100l cylinder	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Liquefied CO2	BLEVE, 20te tank	17%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			33%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			50%	0.0	0.0	219.0	270.6	0.0	0.0	0.7	0.4	1.1
			67%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			83%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1

Damage for North/Eisenhower Tunnel (Changed – Hazmat Allowed)

				Damage length (m)				Cost (% of construction capital cost)				
Scenario #	DG	Title	Accident location in tunnel (% section length : 0=Portal A ; 100=Portal B)	tunnel structure	internal civil	protected equipment	unprotected equipment	tunnel structure	internal civil	protected equipment	unprotected equipment	Total
1	None	HGV fire, 20MW	17%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	7.9	18.2	0.0	0.0	0.0	0.0	0.1
			67%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	7.3	18.1	0.0	0.0	0.0	0.0	0.0
2	None	HGV fire, 100MW	17%	0.0	0.0	32.2	38.8	0.0	0.0	0.1	0.1	0.2
			33%	0.0	0.0	32.4	38.9	0.0	0.0	0.1	0.1	0.2
			50%	0.0	0.0	34.5	39.2	0.0	0.0	0.1	0.1	0.2
			67%	0.0	0.0	32.3	38.8	0.0	0.0	0.1	0.1	0.2
			83%	0.0	0.0	32.3	38.9	0.0	0.0	0.1	0.1	0.2
3	LPG	BLEVE, 50kg cylinder	17%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			33%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			50%	0.0	0.0	53.0	133.5	0.0	0.0	0.2	0.2	0.4
			67%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
			83%	0.0	0.0	52.8	133.5	0.0	0.0	0.2	0.2	0.4
4	Motor spirit	Pool fire, 28te tank	17%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			33%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			50%	0.0	0.0	89.7	98.5	0.0	0.0	0.3	0.1	0.4
			67%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
			83%	0.0	0.0	82.4	88.9	0.0	0.0	0.3	0.1	0.4
5	Motor spirit	VCE, 28te tank	17%	177.5	0.0	774.7	900.5	4.9	0.0	2.4	1.3	8.6
			33%	206.7	0.0	806.6	937.6	5.7	0.0	2.5	1.4	9.5
			50%	242.7	0.0	844.5	981.5	6.6	0.0	2.6	1.4	10.7
			67%	274.7	0.0	890.7	1035.2	7.5	0.0	2.8	1.5	11.8
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
6	Chlorine	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	LPG	BLEVE, 18te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
8	LPG	VCE, 18te tank	17%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			33%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			50%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			67%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
			83%	0.0	0.0	2740.0	2740.0	0.0	0.0	8.5	4.0	12.5
9	LPG	BLEVE (Torch fire), 18 te tank	17%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
			33%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			50%	243.8	0.0	849.9	987.8	6.7	0.0	2.6	1.4	10.8
			67%	243.5	0.0	849.8	987.7	6.7	0.0	2.6	1.4	10.7
			83%	243.5	0.0	849.8	950.5	6.7	0.0	2.6	1.4	10.7
10	Ammonia	Toxic release, 20te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Acrolein	Toxic release, 25te tank	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Acrolein	Toxic release, 100l cylinder	17%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			33%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			67%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			83%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Liquefied CO2	BLEVE, 20te tank	17%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			33%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			50%	0.0	0.0	219.0	270.6	0.0	0.0	0.7	0.4	1.1
			67%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1
			83%	0.0	0.0	218.0	270.2	0.0	0.0	0.7	0.4	1.1

Appendix G Minutes of Teleconferences with Colorado Motor Carriers Association and Colorado State Patrol

<u>1/19/05 12:00pm CDOT, CMCA, PB Telephone Conference</u>

<u>Attendees:</u>
PB-New York
Rama Kanthan - Project Manager
Andrew Louie - Mechanical Engineer
Jim Guinan - Chief Mechanical Engineer
PB-Colorado
John Guenther - Deputy PM
CDOT
Bernie Guevara - Regional Traffic Engineer
Mike Salomon - Director of Maintenance
Ina Zisman - Resident Engineer
Colorado Motor Carriers Association
Greg Fulton - President of CMCA
Weidlinger Associates
Stephanie King - Risk Analysis

<u>Purpose of teleconference:</u> Engage the Colorado Motor Carrier Association (CMCA) in the Hazmat Risk Study.

-Greg from the CMCA started the meeting with the viewpoint of the Carriers represented by the CMCA of the Loveland pass situation.
- Main concern he expressed is safety for the drivers and trucks.

-Hazardous Materials Transport:
Greg estimates that 10-15% of all shipments are placarded shipments. He also recognizes that some placarded shipments are more dangerous than others, yet all placarded shipments are treated the same at the EJMT tunnel. Most of the Hazmat shipments that make use the I-70/US-6 route are fuel deliveries with some traffic coming from cross country shipments. Most Fuel shipments originate in Denver and are delivered regionally around the area.

- Issues affecting safety are:
Load shifting of cargo as trucks navigate steep grades and winding roads of US-6 as they head over Loveland pass, Challenging road conditions, especially in the winter time. Delivery restrictions to the hours of 12-5am put drivers under additional stress. Tight delivery timetables also put additional stress on drivers. US-6 is generally a very difficult route for trucks to navigate.

- Cost issues involving the I-70 US-6 route:
Greg expressed that there is difficulty in finding drivers willing to drive the US-6 route and also highlighted the fact that there have been several bad accidents on US-6 with trucks

running off the road. For Fuel tankers, drivers must pass very stringent background checks, and undergo constant fitness evaluations. The CMCA has a zero tolerance rule, and constantly check their drivers for fatigue, and impose driving limits, as a result drivers are better paid. The trucks themselves also undergo constant inspections and maintenance. Because of the difficulty of the route, higher pay has to be offered to drivers to drive that route. Greg has also noted that the CMCA pays 35% of the US Highway trust fund yet only contributes 8% of the vehicle miles used on it. In regards to an increased operations cost of the tunnel if trucks were allowed through it, escorted, ultimately any additional costs will have to be passed onto the customer, but Greg re-iterated that the issue was not about cost but about safety.

- Issues truck drivers have with US-6:
Greg expressed that a major issue is delivery timing. most towns impose strict regulations as to when fuel deliveries can be made, 12am-5am. As a consequence truck drivers have to make their runs in the dead of night where road conditions are much more difficult due to the lowered visibility and the lower road maintenance cycle. Also, some trucks have to make their trips hours in advance and wait until they can deliver in the 12 - 5am window. Also the delivery timetables are very tight and don't allow much room for delays due to weather or any other road condition. Greg has also expressed that truck drivers fear the US-6 route because they know it would take a while for emergency responders to reach them in the event of an incident. Truck drivers would even be willing to wait at the EJMT to be escorted rather than have to travel the US-6 route, even if it may take an hour. Navigating twisting steep grades of US-6 forces drivers to be more alert than normal which fatigues them much faster, and combined with having to drive between 12 and 5am, places even more stress on the drivers.

- Use of the EJMT and I-70 corridor
The CMCA does not want to open the EJMT to trucks all year round, just the winter months between Oct-March. They feel that escorted trucks through the tunnel will be much safer for everyone than to run trucks over US-6. Greg pretty much sought any solution that did not involve going over the Loveland pass. Ideally he would like to see the EJMT escort trucks every half hour, but Mike pointed out that it could take 15 min. to clear the tunnels for escort, which means the tunnels would have to be closed to other traffic most of the time if trucks were escorted every half hour. The CMCA doesn't even need to run trucks 24 hours a day, just the hours between 10pm and 5 am, as deliveries are restricted to 12am and 5am anyway. In those hours, as confirmed by Mike, traffic dies down rather abruptly, to about 200 cars an hour by Mike's estimates. Any kind of system where trucks can travel through tunnel and not US-6 is something truckers would be in favor of. No clear answers were given to the questions about how a tunnel incident that would lose the tunnel for any extended period of time would affect the trucking industry. Greg also did not know if fuel tanker trucks had compartments. He also noted that 75% of all truck accidents involve other automobiles and escorting trucks though the tunnel would eliminate a large portion of the risk. Jim Guinan mentioned that tunnels in Virginia and Washington allow Hazardous Materials Transport, but that these tunnels have advanced fire suppression systems like foam/deluge sprinkler systems.

-Final remarks

Greg re-iterates that safety is the primary concern. He has also offered that someone from CDOT and/or PB come ride with one of the truck drivers on US-6 just to see how difficult it is. He does not want to impact the day-to-day operations or place extra burden anywhere unless absolutely necessary. A window from 10pm-5am only during the winter months, with 1 hour escort intervals is all that is being asked. Greg feels that such a system would greatly benefit everyone as his drivers would no longer face the dangers of US-6 and the impact to traffic would be minimal. Ina brings up a point that in that closing the tunnel to escort trucks through it, would make people in regular auto's irritated, and they would tend to speed on I-70, through the tunnels at 70-75 mph, and then meet up with the trucks doing 20-25 outside of the tunnel, it has the potential to cause accidents outside of the tunnel. There is also concern with trucks on the westbound downhill portion of I-70 not going 20-25 mph, and perhaps allowing themselves to coast at a much higher speed and thus encountering brake failure.

Another conference call is scheduled next week, Wednesday 1 pm Denver time, with the Colorado State Patrol, which Bernie will arrange.

1/25/06 12:00pm CDOT, CSP, PB Telephone Conference

Subject: Colorado Depart of Transportation – Hazmat Risk study for Eisenhower Johnson Memorial Tunnel vs. Loveland pass.

-Meeting and Teleconference with the Colorado State Patrol comments and coordination.

Date: 25 January 2006

Attendees:

Mike Salamon	Director of Tunnel Operations	Colorado DOT	
Bernie Guevara	Regional Traffic Engineer	Colorado DOT	
Ina Zisman	Resident Engineer	Colorado DOT	
Rama Kathan	Project Manager	Parsons Brinkerhoff	212-465-5156 (Teleconference)
John Guenther	Deputy Project Manager	Parsons Brinkerhoff	303-390-5840
Jim Davis	PB Denver Office Manager	Parsons Brinkerhoff	303-390-5911
Jim Guinan	Director of Tunnel Ventilation	Parsons Brinkerhoff	212-465-5533 (Teleconference)
Andrew Louie	Mechanical Engineer	Parsons Brinkerhoff	212-631-3767 (Teleconference)
Stephanie King	Director of Risk Analysis	Weidlinger Associates	650-230-0295 (Teleconference)
Allan Turner	Captain – Hazmat	Colorado State Patrol	303-239-4552
Ron Prater	Captain -Troop 6B	Colorado State Patrol	970-668-6852
Scott Hernandez	Major -OSB	Colorado State Patrol	303-273-1679
Doyles S. Eicher	Major - District 6	Colorado State Patrol	303-273-1626

Summary of Colorado State Patrol Concerns:

- The Colorado State Patrol (CSP) feels that the status quo be maintained.
- All placarded trucks should use US-6 and only in the event when US-6 is closed should Hazmat trucks be escorted through the EJMT every hour on the hour.
- It is CSP opinion that the I-70 corridor and EJMT infrastructure is too important to risk allowing a major Hazmat incident.
- CSP has also stated that even if they wanted to allow routine Hazmat traffic through the EJMT, there would be difficulty as public hearings would have to be held.
-CSP feels that any Hazmat incident on US-6 would not be as bad as one in the EJMT.

Discussion:

Guevara: Purpose of the meeting is to brief Colorado State Patrol (CSP) on the current Hazmat risk study. Project is an update to the 15-year old study on Hazmat transport through the EJMT as opposed to over Loveland Pass. PB team has visited tunnel and pass, gathered all data, and also had teleconference with Colorado Motor Carriers Association (CMCA). The team will submit their final report in February-March time frame. Study was not prompted by any specific issue – just the desire to re-visit the alternative route comparison.

Regulations concerning Hazmat Transportation:

Captain Turner states that the Colorado State Patrol has the sole authority to designate a "hazardous materials route" (in the state of Colorado) He also states that local governments cannot restrict delivery access on designated routes. CDOT can restrict delivery times but CSP cannot. Captain Turner cites section 397.67 of the Federal Motor Carrier Safety Administration regulations:
397.67 Motor carrier responsibility for routing.
(a) A motor carrier transporting NRHM *(Non-Radioactive Hazardous Materials)* shall comply with NRHM routing designations of a State or Indian tribe pursuant to this subpart.
(b) A motor carrier carrying hazardous materials required to be placarded or marked in accordance with 49 CFR §177.823 and not subject to a NRHM routing designations pursuant to this subpart, shall operate the vehicle over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys, except where the motor carrier determines that:
(b)(1) There is no practicable alternative;
(b)(2) A reasonable deviation is necessary to reach terminals, points of loading and unloading, facilities for food, fuel, repairs, rest, or a safe haven; or
(b)(3) A reasonable deviation is required by emergency conditions, such as a detour that has been established by a highway authority, or a situation exists where a law enforcement official requires the driver to take an alternative route.
(c) Operating convenience is not a basis for determining whether it is practicable to operate a motor vehicle in accordance with paragraph (b) of this section.
(d) Before a motor carrier requires or permits a motor vehicle containing explosives in Class 1, Divisions 1.1, 1.2, 1.3, as defined in 49 CFR §173.50 and §173.53 respectively, to be operated, the carrier or its agent shall prepare a written route plan that complies with this

section and shall furnish a copy to the driver. However, the driver may prepare the written plan as agent for the motor carrier when the trip begins at a location other than the carrier's terminal.

He notes that subsection (b) prohibits use of the EJMT to transport Hazardous Materials unless; no practicable alternative, or emergency condition where CSP has set up a detour. The reason why Hanging Lakes tunnel allows Hazmat trucks through it is because there is no practical alternative. Allowing Hazmat trucks through the EJMT when US-6 is closed is in compliance with subsection (b)(3). Major Hernandez brings up the point, that the findings of the Hazmat risk study could change the classification of US-6 from “practicable” to “not-practicable” if it is found that driving trucks up US-6 puts trucks at a much higher risk of accident. It is also noted that there are tunnels in the state of Washington and Virginia that allow Hazmat trucks through them.
Captain Turner also notes that only trucks that carry more than 500 gallons of Hazmat are required to use the NRHM route designations. But Tunnel policy prohibits all placarded Hazmat vehicles from entering the EJMT anyway. If CDOT decides that they would allow Hazmat trucks through the tunnel, then they would have to petition the CSP to change the route designation which would require public hearings and have to involve the state attorney general.

Major Hernandez notes that relatively new restrictions in towns on the western slope (Vail, Aspen, etc.) that Hazmat trucks can travel at any time, but can only deliver in 3-6AM time window (Dillon and Keystone are 12-5AM). The resorts do not want the trucks there when the tourist population is highest (during the day and evening).

Current route difficulties:

The CSP recognizes that US-6 is very difficult for truck traffic. Major Hernandez feels that US-6 was never designed for commercial vehicles. He notes that accident repots on US-6 involving trucks show that the trucks were not speeding when the accident occurred. It seems that the movement of the cargo/load is what pushes the trucks off the road. Mr. Guinan brings up the point that all tanker trucks in NY and NJ at least, are required to be compartmentalized, to prevent “sloshing” of the product. Captain Turner confirms that tanker trucks in Colorado are also compartmentalized but that the design of the baffles that make up the compartments are only designed to prevent the back and forth movement of the product and not side to side. The geometry of US-6 makes tanker trucks susceptible to the sideways sloshing of product and thus causing instability. He also notes that the sloshing effect is only really pronounced for half-full tankers, as full or empty tankers do not experience the slosh effect as much as half full ones.

Major Hernandez also notes there are more challenges on US-6 than just route geometry and road conditions. He has observed an increase in people who travel up along route 6 to ski at night. This influx of people crowd the roadway and Hazmat truck drivers trying to make deliveries have called the CSP to report such issues. Major Hernandez has also noted that people camp out along Route-6 and build fires right along the roadside.

Although US-6 is rather treacherous, the I-70 corridor presents its own challenges. The CSP has had numerous problems with regular commercial traffic on the I-70 corridor west of the EJMT. The biggest problems the CSP faces with regular truck traffic are drivers who are untrained in mountain driving. When asked about the statements made by the CMCA (Colorado Motor Carriers Association) that their drivers undergo rigorous background checks, the CSP agrees that the CMCA regulates its drivers far better than the Airline pilots. And although the CSP never cites CMCA drivers as being under qualified, they feel that their fatigue regulations are only on par with the industry country wide. Though the CSP has no problems with the CMCA, it's those drivers coming from another state that are not trained in mountain driving that present problems. The most common problems with trucks on I-70 are overheated brake failures and untrained drivers who don't know to slow down. Also, the steep grade of I-70 puts a lot of stress on the trucks themselves. No hard numbers were on hand for the truck runaway ramp usage, but the CSP stated that it was an important safety feature, and that sometimes it was difficult for trucks to make it to the ramp due to automobile traffic. Ms. Zisman also notes that truck escape ramps on downhill portion of I-70 are used heavily. An issue to consider is the impact of having Hazmat trucks using these ramps. Summit County is concerned with having potential of Hazmat pollution of Clear Creek. The CSP has also had times where they stopped trucks because there weren't any snow chains on the trucks, and the out-of-state drivers didn't even know how to put them on sometimes.

Political and Social-economic issues:

The CSP expressed that the I-70 corridor is a very important route for towns west of EJMT like Dillon and Silverthorne. A closure of I-70 would be very devastating to local economies. Plus, a lot of the ski villages near there would also be hurt very bad by the closure, thus holding a public hearing to allow Hazmat trucks through the tunnel would most likely not fare well at all with the surrounding towns. In addition, the CSP has expressed security concerns with allowing Hazmat vehicles through the tunnel even on a controlled, every hour, on the hour basis for any set period of time, no matter how small. Captain Turner's concern was that if the EJMT is open to Hazmat vehicles, it could potentially become a more attractive target for terrorists. The Tunnel is also of interest to Homeland security as Homeland security has an interest in protecting infrastructure in the US. Major Hernandez questioned exactly how the risk analysis would be carried out, whether all the risk factors were combined into one element or if it will be presented as many different types of risk. Dr. King, responds that certain risks, like dollar value of the highway and replacement costs will be presented quantifiably, while things like economic and social impact will be presented qualitatively.

Captain Turner touched on environmental impacts and his greatest concern was endangerment of protected wildlife. He felt that any Hazmat release on I-70 had a chance of harming local endangered wildlife. As for the Dillon reservoir, a Hazmat release on US-6 would dilute by the time it reached the Dillon Reservoir, and that fuel spills are cleanable from the water.

Possible regulations to lower the risk of an incident in the EJMT and on I-70:

The CSP has given suggestions should Hazmat trucks be allowed through the EJMT. These suggestions include: Mandatory brake checks, cargo inspections before entering the tunnel, Driver evaluations and other additional safeguards. Even with an escort or convoy policy, it takes anywhere from 15 to 20 minutes for a convoy to pass through the tunnel, and on the other side of the tunnel the trucks are still doing 20-25, while cars, that were held up, are going as fast as 85 mph and then encountering the slow 20-25mph trucks just outside the tunnel. It still presents a problem.

It should be noted that a security risk analysis is not part of the scope, nor are security mitigation options. The earlier report by Homeland Security concluded that the highest risk was explosion at the portal.

Final Remarks:

It is the CSP's final opinion that the consequences of a serious Hazmat incident in the tunnel or I-70 would be too great to afford any risk of Hazmat trucks through the tunnel. Captain Turner, feels that any incident on US-6 would be much easier to take care of than one on I-70 or the tunnel. Ms. Zisman feels that people will be able to adapt, whether tunnel access is restricted at night for convoying, or if it had to be closed sometime for repair, people will adjust. She cited an example from the past when one of the tunnel bores was closed for repairs, people adjusted their schedules so to reduce time spent waiting in traffic. Captain Turner feels that the effect of an extended closure of US-6 is minor compared to the effect of an extended closure of I-70. The CSP feels that maintaining the status quo would best option.

2/22/06 1:30pm CDOT, CSP, PB Meeting

Attendees:

Greg Fulton with CMCA hosted the meeting.
See Sign in Sheet on next page for attendees

Discussion:

Purpose of the meeting is for members of the Colorado Motor Carriers Association (CMCA) to provide their perspective on risk associated with hazardous materials vehicles traveling over Loveland Pass and through the Eisenhower Johnson Memorial Tunnels (EJMT).

Greg Fulton (CMCA) opened meeting and introductions were made.

Guevara: Project is an update to the 15-year old study on Hazmat transport through the EJMT as opposed to over Loveland Pass. PB has been given the task of analyzing the risk associated with hazardous material being transported over the pass vs. through EJMT.

Guenther: PB is performing a risk analysis and has been tasked with evaluating each route and providing a recommendation to CDOT as to which carries the least risk to the traveling public. The draft report is being finalized and will be delivered to CDOT within a few weeks.

The floor was then opened to comments for CMCA members in attendance. The following comments were provided by CMCA members unless designate otherwise.

1. With current policy, drivers are forced to go over the pass at night in white out conditions. Inadequate attention is given to snow removal and the pass remains open too long. Someone should be able to make the call and "close it" as soon as necessary.
2. Drivers are forced to stop on the pass due to white out conditions.
3. Carriers would like to see more closures of the pass before conditions become too extreme.
4. Fifteen years ago drivers would cross pass 4 times a day and have to chain up each time. Today, fewer drivers tolerate having to chain up that often and refuse to drive the route.
5. It is becoming so hard to find drivers. They don't want to get on board because of hazards having to drive up Loveland Pass.
6. Emergency response to incidents on the pass during extreme conditions requires too much time.
7. Spills on the pass are complex. "I don't want to drive it myself", said the Hazmat Clean up Contractor.
8. Companies outside of Colorado which are unfamiliar with the winter conditions at Loveland Pass believe that it is lucrative to pick up extra work by driving these routes. Their lack of experience makes it more dangerous.
9. Long delays at EJMT cost carriers money. Waiting is extra cost. Drivers are paid by the hour.
10. Drivers experience fatigue due to spending a couple of hours negotiating difficult driving conditions over the pass, making traveling on I-70 more dangerous once the re-enter the corridor.
11. The question was asked "What is the biggest fear of CDOT?" in allowing Haz Mat vehicles through EJMT. CDOT responded with the number one fear is a major loss of life and the second fear is the loss of the facility (tunnel itself).
12. Carriers want the change (ability to drive through the tunnel) only during winter time. Not all year.
13. "It appears, I70 has to be open for skiers and with less consideration for tankers."
14. CDOT stated there are a total of 13 representative scenarios that will be analyzed for degree of risk separately.
15. CSP stated, "There are no good choices. Damn if you do, damn if you don't".
16. CSP stated that they have authority over the designation of Haz Mat routes. CDOT was grandfathered in as having decision power for time of day, day of the week type restrictions at the tunnel.
17. CSP stated that the pass is the designated route and that the laws only allow vehicles through the tunnel when the pass is closed due to adverse weather conditions.
18. CSP stated that in order for the designated Haz Mat route to be through EJMT will require a public involvement process.
19. CSP reiterated the concern for the tunnel walls and ventilation system. They'll not withstand the extreme heat. The tunnel is key to the economic life of the western slope.
20. CSP stated that they see that there is no good solution. They best that can be hoped for is the lesser of two evils.
21. Carriers would like to see improved monitoring of the conditions along the pass and earlier closures. Drivers are forced to use the pass right up until it is closed.

22. CDOT responded by stating that a new camera is being installed at the pass to monitor conditions. More VMS's are being added to provide more up to date information.
23. Carrier proposes 10PM to 6AM time period to allow tankers through the tunnel (based on experience). Safety precautions shall also be in place during this time.
24. Time of day delivery restrictions are being imposed by west slope communities. Aspen requires that trucks be out of city limits by 6:00 am. Issues are compounding as more west slope communities are imposing restrictions.
25. More restriction on gasoline carriers results in higher gas prices in these regions.
26. CSP noted that communities are not allowed to impose restrictions on designated Haz Mat routes. If this is happening, carriers need to inform CSP.
27. The recommendation was made that a pilot program for a few months be implemented for allowing restricted access through EJMT to determine and work out issues. Carriers would like to see a common ground. Use safety records as screening, And train all drivers in "Highway Watch".
28. There are more demands for fuel. The challenges are ever becoming greater. "If we don't do anything, this would get worse. More increased fuel cost.
29. More sand be utilized on pass. It has been noted that traction is becoming more of an issue as less sand is used. Magnesium chloride results in more "black ice" and a decrease in traction for climbing and descending the pass. Loveland Pass should not be allowed during winter.
30. Ray Chamberlain (PB) stated that the problem has no solution. With population growth of Colorado, the problem is also growing. We can only optimize management. Possible strategies, even experimental strategies need to be explored. Revising current laws, no matter how difficult the process is, always remains an option. He recommended a long term solution of a future bore at EJMT that can be designated for Haz Mat vehicles. In the mean time, experiment for solutions.
31. The comment has been made that a fire in the tunnel may damage the existing ventilation system to the point that it is inoperable. The question was asked as to the cost of upgrading the fan system. $20-30 million was suggested. That's under estimated, said another.
32. The issue of environmental impact to water supply due to a spill on the pass was raised. A spill on the east side of the divide affects the Denver metro water supply. CDOT responded that there is an impact no matter where a spill occurs. A spill on I-70 west of EJMT affects Straight Creek and Silverthorne & Dillon's water supply. A spill on I-70 east of the tunnel affects Clear Creek and Denver. A spill on Loveland pass affects Clear Creek east of the pass and the Snake River west of the pass.
33. CMCA asked about a system that allows carriers with a good record be allowed through EJMT in some fashion. CDOT responded stating that such a system is difficult to enforce and asked if CMCA would post personnel at the tunnel to check drivers. CMCA stated that they believe that it would be better to post trained CDOT personnel rather than rotating CMCA personnel.
34. CDOT asked for CMCA's preference as to access to the tunnel. Be it 24 hrs a day or restricted access at designated intervals. During extreme weather conditions only –i.e. winter time, said another.. CMCA will come up with proposal(s) for their preferences and plan to present to them to CDOT within next two weeks.
35. CDOT expressed that there is no solution and that the best we can expect is to "manage the problem" vs. "solving the problem".
36. CMCA asked if CDOT has any HazMat containment systems on either rout. CDOT responded that there no such systems are in place on either pass with the exception of the truck escape ramps.

Feb 22 EJMT Hazmat Study mtg
location: CMCA office

Attendees:

Name	Company	Tel. No.
Bernie Guevara, PE	CDOT Traffic	303-757-9122
John Guenther, PE	Parsons Brinckerhoff	303 390 ~~5840~~
Ray Chamberlain, P.E.	" "	303-832-9091
Greg Miller	AU H Transportation	303-292-3656
[illegible] Rumage	Sinclair Trucking	303 287-3392
[illegible]	Denver Newspaper Agcy	303-820-5563
Matt Wetzel	RMCAT Environmental	303/425-7526
Ralph Coates	East Transp.	303-534-6376
Jeff Rhinehart	STL	303-227-1272
David Newberry	Groendyke Transport	719-391-9855
Jim Mackin	Groendyke Transport	303-289-3373
Jerry Wedek	Wedek Systems	707-287-2674
Dan Coleman	D.G. Coleman	303-321-5708
Ken Campbell	Roadway	972 790 3611
Brian Morris	Roadway Exp	3/340-2371
Bill Copley	FMCSA	720-963-3150
Dave Fuggit	P.O.E.	303-205-5681
Allan Turner	CSP/HMTSR	(303)239-4546
John Oxley	Yellow Driver	303 717 6939
[illegible] Anson	Yellow	303 361 7067
Christi Krenke	CWPMA	303-422-7805
Chris E. Mann	Great West Casualty Company	303/989-2673
Mike Salamon	CDOT	303-573-5301

Appendix H Proposal Submitted by Colorado Motor Carriers Association (CMCA) and Letter Report by PB Team Summarizing Evaluation of Proposal

Proposal for Pilot Program for
Movement of Hazardous Materials through the Eisenhower Tunnel
by the Colorado Motor Carriers Association

The Colorado Motor Carriers Association proposes a Pilot Program to study the feasibility of moving commercial vehicles carrying hazardous materials (hereafter HazMat Carriers) through the Eisenhower Tunnel.

This Pilot Program would run from June 1, 2006 – November 30, 2006, in order to gauge the effectiveness and risks of altering the current process of forcing hazardous materials carriers to drive over Loveland Pass.

The Colorado Motor Carriers Association recommends these parameters for the Pilot Program.

- All commercial vehicles carrying any placarded amounts of hazardous materials would be allowed to move through the Eisenhower Tunnel.
- HazMat carriers would be allowed to drive unescorted through the Eisenhower Tunnel any day of the week under the following restrictions:
    - HazMat carriers would be restricted to the right lane of the Eisenhower Tunnel.
    - HazMat carriers would be restricted from traveling through the Eisenhower Tunnel between the hours of 6am to 10pm.
    - HazMat carriers would be assessed maximum fines for violating any of these restrictions (i.e. speeding, lane changes, disobeying a traffic control device).

These parameters were developed based on the following assumptions:

- Separating specific loads for travel through the Eisenhower Tunnel (i.e. corrosive vs. flammable) would be difficult and put added responsibility on CDOT personnel to distinguish individual loads.
- All drivers of vehicles carrying hazardous materials must have completed specific training in transporting and handling of hazmat, safety procedures, security awareness and security plans and emergency communication protocols.
- All vehicles must have Personal Protective Equipment on board, in addition to fire fighting equipment, an Emergency Response Guide / Material Safety Data Sheet or equivalent, and emergency contact information as required under Federal law.
- All companies transporting placarded hazardous materials must have completed an in-depth security plan, including terminal and en-route security plans, communication protocols, emergency response programs and training requirements.
- All drivers of vehicles carrying placarded hazardous materials must have a specific hazardous materials endorsement on his / her Commercial Drivers License. As of May 31, 2005, all current HM endorsement holders (January 1, 2005 for new applicants) must go through a federal background check as part of renewing their HM endorsement. This background check is conducted by the Department of Justice and results are vetted through the Transportation Security Administration.

- The hours of operation were selected based on times with low traffic volume. In addition, the 10pm through 6am will provide local HazMat carriers the opportunity to deliver loads and return to their terminal in a safe and efficient manner.
- Reduced speed is recommended in order to provide CDOT, law enforcement and local citizens an increased comfort level with the new process. This will also decrease the risk exposure to the traveling public, and should alleviate problems associated with icy or snow packed conditions at the entrance / exit to the Eisenhower Tunnel.
- The right lane restriction is also recommended in order to provide CDOT, law enforcement and local citizens an increased comfort level with the new process. This will decrease the risk exposure to the commercial vehicles from passenger vehicles traveling at higher speeds, and will also help alleviate problems associated with icy or snow packed conditions at the entrance / exit to the Eisenhower Tunnel.

The Colorado Motor Carriers Association (CMCA) will work to support this process in any way possible. CMCA is dedicated to highway safety, and would not allow efficiency to overshadow safety in any circumstances. CMCA will develop a brochure describing this Pilot Program, detailing the restrictions, penalties and process. Brochures and letters can be mailed to all HazMat Carriers (which can be easily accessed because all carriers must register for a hazardous materials permit to transport within the state), and can also be disseminated through the Ports of Entry, truck stops and other appropriate locations. Formal training sessions / focus groups can also be scheduled to educate managers and drivers of the specific restrictions of the Pilot Program, to ensure compliance and understanding.

The Colorado Motor Carriers Association will also work with the Colorado Department of Transportation and the Colorado State Patrol to educate and assure local communities of the safety and viability of this Pilot Program. In addition, the Colorado Motor Carriers Association will assist in the evaluation of the Pilot Program and help develop any necessary changes to the process to better meet everyone's needs.

This Pilot Program has many advantages. For the Colorado Department of Transportation, the benefits include decreased maintenance costs (for maintaining Loveland Pass through the overnight hours), decreased personnel costs (again, for maintaining Loveland Pass throughout the night), decreased congestion on I-70, and most importantly, increased safety for the traveling public.

Local communities will also benefit in a number of ways. First, allowing HazMat Carriers to use the Eisenhower Tunnel is the safest and most efficient manner to traverse the mountain corridor. Local deliveries will be made more quickly, allowing trucks to get in and out of communities before local traffic volumes increase. Additionally, by allowing HazMat Carriers the opportunity to drive through the Eisenhower Tunnel under the proposed time restriction, may encourage companies to change delivery times and remove themselves from the general traffic flow. This would be most beneficial on weekends with high volumes of ski traffic already on the highway.

For the HazMat Carriers, the benefits include a more efficient and much safer route. By traveling through the Eisenhower Tunnel and bypassing Loveland Pass, drivers will be faced with far less stress and fatigue-inducing factors. Drivers will be more alert while traveling through the mountains, which will lead to increased safety for everyone involved. In addition, drivers will no longer be faced with a strict time table. The route through the Eisenhower Tunnel is less time-consuming, leaving drivers with more time to reach their destination. This will allow drivers to better adapt to changing weather patterns, and make adjustments when necessary, without running up against delivery schedules or hours of service issues.

Regardless of the tangible benefits to the trucking industry, CDOT, and local communities, the major benefit to everyone involved is safety. Traveling through the Eisenhower Tunnel is the safest, least stressful, least fatiguing, and most efficient route along I-70. Requiring HazMat carriers to take Loveland Pass places drivers into one of the most dangerous and stressful stretches of highway in the state. This route is full of blind spots, shallow or non-existent shoulders, steep grades and sharp corners. There is little or no room for error, which only increases the stress on drivers. There is little room to maneuver should a truck come across a disabled vehicle, pedestrians or bicycle riders, animals moving across the road or rock slides / snow slides cover the road. Because of these factors the Loveland Pass route has a much higher accident rate for trucks than the segment of I-70 through the Eisenhower Tunnel.

Of further concern are the seriousness of the accidents on Loveland Pass and the ability of emergency personnel to respond in a timely manner. In many cases truck accidents have proven fatal for drivers and in other cases injuries have become more serious because of the time delay in responders becoming aware of the accident as well as reaching the scene by ambulance. In addition, clean up of hazmat spills on Loveland Pass poses a much more dangerous situation for cleanup crews as well as taking a greater amount of time due to the difficult conditions. As time passes, spills of hazardous materials become difficult and expensive to remediate.

Adverse weather conditions merely heighten the danger. Weather conditions change rapidly, and a driver may find whiteout conditions along the route, even though weather is clear at the Eisenhower Tunnel. Safety for all parties starts with providing a safe route for the truck driver. To date, there have been multiple fatalities and injuries on Loveland Pass. There have been no such issues in the Eisenhower Tunnel.

May 5, 2006

Colorado Department of Transportation
Region 1
18500 East Colfax Avenue
Aurora, CO 80011

Attn: Mr. Bernie Guevara

RE: CDOT Statewide Tunnel Engineering Contract
Task Order #10
Risk Analysis Study of HAZMAT Trucks through EJMT

Dear Mr. Guevara:

Per our telecom with you last week, we are enclosing our Evaluation Report of the "Proposal for Pilot Program for Movement of Hazardous Materials through the Eisenhower Tunnel" submitted by the Colorado Motor Carriers Association (CMCA) in March 2006.

We have also submitted to you our preliminary report for the Risk Analysis Study of HAZMAT Trucks through EJMT last week.

We very much appreciate your comments on the above reports as soon as possible.

Thank You.

Sincerely,

Parsons Brinckerhoff Quade & Douglas, Inc.

Rama Kanthan, Ph. D, P.E.
Project Manager

Cc: Ina Zisman, Resident Engineer
Mike Salamon, Tunnel Superintendent

Colorado Department of Transportation Statewide Tunnel Engineering Contract
Task Order Number #10

Risk Analysis Study of Hazardous Material Trucks
through Eisenhower/Johnson Memorial Tunnels (EJMT)

EVALUATION OF PILOT PROGRAM PROPOSAL SUBMITTED BY CMCA

The Colorado Motor Carriers Association (CMCA) has submitted in March 2006 to the Colorado Department of Transportation (CDOT) a "Proposal for Pilot Program for Movement of Hazardous Materials through the Eisenhower Tunnel." This proposal outlines a six-month study in which commercial vehicles carrying hazardous materials (Hazmat carriers) would be allowed to pass through the Eisenhower/Johnson Memorial Tunnels (EJMT) with restrictions as noted below. Currently all Hazmat carriers are prohibited from using the EJMT by the Colorado State Patrol policy, requiring them to use Loveland Pass instead unless the Loveland Pass route is closed to traffic. The proposed pilot program would run from June 1, 2006 to November 30, 2006, and include the following parameters:

- All commercial vehicles carrying any placarded amounts of hazardous materials would be allowed to move through the EJMT.
- Hazmat carriers would be allowed to drive unescorted through the EJMT any day of the week under the following restrictions:
    - Hazmat carriers would be restricted to the right lane of the EJMT.
    - Hazmat carriers would be prohibited from traveling through the EJMT between the hours of 6am to 10pm.
    - Hazmat carriers would be assessed maximum fines for violating any of these restrictions (i.e. speeding, lane changes, disobeying a traffic control device).

The PB team has evaluated the CMCA proposal with regard to its suitability in relation to the recommendations contained in the preliminary report, "Risk Analysis Study of Hazardous Materials Trucks through Eisenhower/Johnson Memorial Tunnels" submitted by the PB team to CDOT in April, 2006. The PB team identified several issues in the CMCA proposal; these issues are summarized below.

1. A six-month pilot program may "gauge the effectiveness … of altering the current process" in terms of providing an empirical basis as to the occurrence or non-occurrence of an incident involving a Hazmat carrier in the EJMT during this six-month trial period; however, it does not adequately "gauge the … risks of altering the current process". Risk, in simple terms, is the likelihood of a future adverse outcome – it combines the probability of an event occurring with the consequences of the event should it occur. In this case, the risk of Hazmat transport through the tunnel is computed from several years of statistical data on accident rates and rates of Hazmat incidents given an accident occurs, population and economic data, and consequence modeling of the impacts on the exposed population, tunnel infrastructure, and environment given an incident occurs. It would not be correct to use the observed data from this six-month trial period in the same process to compute risk – this would

only characterize what has happened in the past six months; it would not correctly characterize the risk, i.e., the probabilistically-derived expected consequences on an annual basis, as is done in the report, "Risk Analysis Study of Hazardous Materials Trucks through Eisenhower/Johnson Memorial Tunnels" submitted by the PB team to CDOT in April, 2006.

2. The CMCA proposal states that, "All drivers of vehicles carrying hazardous materials must have completed specific training in transporting and handling of hazmat, safety procedures, security awareness and security plans and emergency communication protocols." The proposal includes other requirements for driver screening, training, and carrying of emergency equipment. The PB team recognizes the importance of these requirements; however, several Hazmat carrier accidents (e.g., the Caldecott Tunnel in California) have been caused by passenger vehicle behavior. In these cases, Hazmat carrier driver requirements have little impact on reducing the occurrence of an accident and subsequent Hazmat incident.
3. The CMCA proposal states that, "Reduced speed is recommended in order to provide CDOT, law enforcement and local citizens an increased comfort level with the new process. This will also decrease the risk exposure to the traveling public." The exact reduction in speed is not included in the CMCA proposal. It is not clear to the PB team that local citizens will feel "an increased comfort level with the new process," regardless of the speed of the Hazmat carrier. It is unlikely that local citizens in a passenger car traveling through the EJMT in a lane adjacent to a Hazmat carrier will feel any level of comfort. Additionally, it is not clear to the PB team that the reduced speed will decrease the risk exposure to the traveling public.
4. The CMCA proposal states that, "The right lane restriction is also recommended in order to provide CDOT, law enforcement and local citizens an increased comfort level with the new process. This will decrease the risk exposure to the commercial vehicles from passenger vehicles traveling at higher speeds." Similar to the issue above related to speed, it is not clear to the PB team that there would be an "increased comfort level" or a measurable "decrease in risk exposure" associated with this lane restriction requirement.
5. The CMCA proposal states that, "For the Colorado Department of Transportation, the benefits include decreased maintenance costs (for maintaining Loveland Pass through the overnight hours), decreased personnel costs (again, for maintaining Loveland Pass throughout the night), decreased congestion on I-70, and most importantly, increased safety for the traveling public." The PB team agrees that the lack of Hazmat carrier traffic during the night-time hours on Loveland Pass (U.S. Route 6) would reduce long-term maintenance needs. In addition, the PB team does not understand how allowing Hazmat carriers through the EJMT will result in "decreased congestion on I-70, and most importantly, increased safety for the traveling public." Besides, allowing the HAZMAT trucks through the EJMT will increase tunnel operating costs for CDOT due to the additional manpower needs to regulate the HAZMAT traffic at the tunnel entrances.
6. The CMCA proposal states that, "… allowing HazMat Carriers to use the Eisenhower Tunnel is the safest and most efficient manner to traverse the mountain corridor."

> The PB team agrees that the proposed change is a more efficient and safer route for the Hazmat carriers themselves; however, the PB team does not agree that, "the major benefit to everyone involved is safety", as stated in the CMCA proposal, especially when "everyone" is assumed to include the local communities (as indicated in the CMCA proposal) as well as the traveling public using the EJMT.

Even though this proposal a pilot program, CDOT may have to hold public hearings to change the status of HAZMAT tunnel traffic through EJMT.

Based on the evaluation of the CMCA proposal, summarized in the issues outlined above, the PB team recommends to CDOT that the six-month pilot program not be implemented. The results of the comparative risk assessment carried out by the PB team lead to the recommendations in the report, "Risk Analysis Study of Hazardous Materials Trucks through Eisenhower/Johnson Memorial Tunnels" submitted by the PB team in April, 2006. The primary recommendation is summarized as, "The current policy of routing Hazmat trucks on the U.S. 6 route over Loveland Pass should be maintained. The risk of Hazmat truck transport through the EJMT is too great in terms of potential for catastrophic loss of life, extensive infrastructure damage, environmental impact to Clear Creek, and economic impact to the areas on the western slope to warrant a change in the current policy." Implementing the six-month pilot program would be a change in the current policy and would result in an unacceptable level of risk; thus, the PB team cannot recommend the CMCA proposal be implemented by CDOT.

The PB team presented our professional opinion above. However, CDOT may have more insight into other areas which are not readily apparent to us including other extenuating circumstances. Therefore, CDOT is at liberty to take a different course of action.