The Tunnels that Connect Hampton Roads

THE TUNNELS THAT CONNECT HAMPTON ROADS: WONDERFUL ASSETS OR POTENTIAL ACHILLES' HEELS?

Achilles' Heel: a metaphor describing a potentially fatal weakness despite overall strength

Hampton Roads hosts the second-largest seaport on the Atlantic Coast and the largest naval base in the world. Its very existence is defined by the Atlantic Ocean and the many bodies of water that flow from many parts of Virginia into the ocean. Waterways such as the James River once profoundly divided the region. In 1930, an individual wishing to travel from downtown Hampton to downtown Norfolk faced two choices – a long and circuitous land trip that could approach 25 miles (via the James River Bridge on Route 17, which opened in 1928), or a boat ride.

The opening of the first major tunnel connecting the Peninsula with Southside (the 3.5-mile Hampton Roads Bridge-Tunnel in 1957) changed matters dramatically. Now it was possible for automobiles and trucks to travel back and forth between the Peninsula and Southside directly and with comparative ease. This cut many miles and considerable time off such a trip and might well be regarded as a definitive move in support of the notion of a region called Hampton Roads.

Four other major tunnels exist in our area: the .65-mile Downtown Tunnel (1952) and the .8-mile Midtown Tunnel (1962), connecting Norfolk and Portsmouth; the 17.6-mile Chesapeake Bay Bridge-Tunnel (1964), linking Virginia Beach to the Eastern Shore; and the 4.6-mile Monitor Merrimac Memorial Bridge-Tunnel (1992), connecting Suffolk and Newport News.

Taken together, these five bridge/tunnel complexes unite the region and stimulate commerce. Without them, the bustling Port of Hampton Roads would be a shadow of what we see today because trucks handle significant proportions of the goods that flow through the port. The bridges and tunnels also provide critical infrastructure to support the numerous Department of Defense installations and activities within the region. And, during hurricane season, they provide the promise of serving as evacuation routes.

A recitation of the positive impact of our region's bridges and tunnels on economic and social life in Hampton Roads virtually begs the question: What if they were closed, for whatever reason, or were rendered inoperable for long periods of time?

Are European Examples Relevant to Hampton Roads?

Tunnel incidents since 1995 have killed 713 people worldwide. Among the highly publicized have been:

- Mont Blanc Tunnel Fire (March 1999): The Mont Blanc Tunnel connects Italy and France. This disaster (41 deaths) occurred when a truck carrying nine tons of margarine and 12 tons of flour caught fire. All but seven of those who died stayed in their cars rather than attempt to access "escape" rooms located inside the tunnel, though it is not clear they could have survived even had they tried. The fires burned for two days. Opened in 1965, the Mont Blanc Tunnel was designed for

450,000 vehicles per year, but already was handling 1.1 million vehicles annually by 1997.

- Tauern Tunnel Accident/Fire (May 1999): The Tauern Tunnel is located near Salzburg, Austria, and was only two lanes at the time of the accident, which was caused by an early-morning collision and fire involving 60 trucks and killing 12 people.

- Gotthard Tunnel Accident/Fire (October 2001): Located in Switzerland, this tunnel is more than 10 miles long. A collision between two trucks resulted in fires that killed 12 people, primarily from smoke and heat that reached more than 1,800 degrees.

- Channel Tunnel Fires (November 1996, August 2006, September 2008): The Channel Tunnel connects the United Kingdom and France. Three significant fires aboard trains have closed the tunnel since it opened in 1994.

What lessons did Europeans learn from these accidents (none of which involved terrorism)?

- Tunnels are constantly vulnerable to accidents and mishaps that not only result in deaths, but also close them to traffic for periods of time – ranging up to three years, as was the case following the Mont Blanc Tunnel fire.

- Some fires in tunnels are virtually unavoidable and therefore are considered to be routine incidents. (The Lincoln and Holland tunnels in New York City each experience several car fires per year.) The possibility of fire requires that routine, easily implemented protocols exist to deal with such occurrences.

- Bidirectional (two-lane) tunnels are substantially more susceptible to accidents than dual (twin-tube) carriageway tunnels.

- Not surprisingly, tunnels that allow transiting vehicles to carry flammable and explosive materials are susceptible to much more destructive accidents. Convincing drivers not to carry illegal materials through tunnels is a never-ending task.

- Bad driving and unwise employee judgments have caused nearly every major tunnel accident. Terrorism might produce the same effects, but no major tunnel disaster has been the result of terrorism, although English authorities reported they foiled an attempt by Islamic terrorists to blow up the Channel Tunnel in 2006.

- The first 10 minutes are decisive when it comes to saving people's lives and limiting material damage (e.g., in the case of the Gotthard Tunnel accident, experts were surprised by how rapidly toxic fumes spread and visibility declined; this led to the loss of life).

- Tunnel users often fail to recognize emergency signs, which has resulted in fatal consequences for those trying to escape.

- The probability of a tunnel accident increases as the volume of traffic in the tunnel increases.

- It is possible to screen many, but not all, potentially dangerous cargoes before they enter tunnels; however, the costs associated with detecting sophisticated dangers (for example, those relating to radiation) can be very high.

- Among the most efficient and low-cost means of reducing the frequency and severity of tunnel accidents are: (1) mandating smaller fuel tanks for heavy-goods vehicles; (2) providing tunnels with heat-seeking cameras; (3) restricting the amount of fuel that heavy-goods vehicles may carry into a tunnel; (4) requiring certain vehicles to carry fire-extinguishing equipment; and (5) regulating distances between vehicles.

Readers will recognize that several of the recommended precautions could be implemented immediately in our region's tunnels, but others (such as regulating distances between vehicles) would cause immediate problems. We can only wish good luck to any authority that attempts to enforce meaningful "distance between vehicles" regulations in the Downtown and Midtown tunnels during weekday rush hours.

How Vulnerable Are We in Hampton Roads?

It should come as no surprise that regional authorities are paying increased attention to Hampton Roads' bridge-tunnel vulnerabilities and are actively involved in assessing emergency preparedness and critical infrastructure protection plans. Addressing these risks and mitigating their potential impacts remain top priorities, not only among the general public, but also with Hampton Roads policy makers.

Let's look at some of the considerations. The overall level of risk to one of our tunnels due to an adverse event is a function of three primary factors:

a. **Importance Factor** (I) – This is a straightforward measure of the socioeconomic importance of a tunnel and its operation. Typically, a quantitative measure is developed to account for the following attributes of the tunnel:

   1. Financial importance to the regional economy
   2. Importance to the regional transportation network
   3. Importance as an emergency evacuation route
   4. Exposed population in the tunnel when the adverse event occurs

b. **Occurrence Factor** (O) – This variable measures the probability of an adverse event occurring. Most often, this measure takes the following into account:

   1. Level of exposure to risk events
   2. Level of security
   3. Frequency of exposure to adverse events (e.g., frequency of large-truck traffic with potentially dangerous cargoes)

c. **Vulnerability Factor** (V) – This variable measures the consequences of an adverse event to the tunnel, its occupants and neighboring populations. It usually incorporates the following measures:

   1. Expected financial damage to the tunnel
   2. Expected replacement value
   3. Expected downtime or closure of the tunnel
   4. Expected number of casualties (deaths or severe injuries)
   5. Value of reduced economic activity.

The I, O and V factors enable risk evaluators to evaluate the impact of adverse events. Let's delve into this process in more detail to get a better sense of how this occurs.

Table 1 provides an example of how the Importance, Occurrence and Vulnerability factors might be defined and developed. It uses ranges (low to high), likelihoods and expected losses (denoted by red, yellow and green, which correspond to high, medium and low severity) to describe a given adverse event in one of the region's five tunnels. A 1-5 scale is used to assign probabilities (least likely to most likely) and losses (smallest to largest) to each adverse event to which a tunnel might be exposed.

Table 2 extends this analysis to the five tunnels in Hampton Roads for 2008 to reflect the size of monetary and human losses connected to an adverse event.

The next step is to translate Table 2's values into a scale that varies between 0 and 1. The translation in Table 3 is based upon a "fuzzy" equation where the translated factor is equivalent to the average of the values for all risk events, divided by 10. The translation for the importance factor is a one-to-one mapping where an assessment of "high" corresponds to a value of 1, an assessment of "medium" corresponds to .50 and an assessment of "low" corresponds to a value of 0, etc.

Finally, let's take the values of Table 3 and translate them into an overall risk prioritization score (RPS) that takes into account all three factors (importance, fre-

TABLE 1

CONNECTING RISK FACTORS TO AN EVENT'S IMPORTANCE

Risk Scale Example

	Importance Factor	Occurrence Factor	Vulnerability Factor	
			Monetary Loss	Human Loss
Scales	Low / High	Likelihood	Severity (Dollars)	Severity (Deaths)
1	Low	<1%		
2	Low to Medium	1-5%		
3	Medium	5-10%		
4	Medium to High	10-50%		
5	High	>50%		

quency of occurrence and vulnerability). The risk prioritization scores in Table 4 are the product of the equation **RPS = I • O • V**. These scores enable us to say that, all things considered, the Hampton Roads Bridge-Tunnel (HRBT) merits our greatest attention if and when we worry about adverse events. **Taking into account the HRBT's importance, the likelihood of an adverse event occurring there, and its potential vulnerability, the HRBT receives the highest risk ranking. The lowest risk ranking belongs to the Chesapeake Bay Bridge-Tunnel (CBBT) and hence it merits the least attention of any of the five tunnels when we consider how to deal with adverse events.** Note that "least attention" is not equivalent to "no attention." Adverse events (e.g., car and truck accidents, flooding, fire) are fully capable of causing significant problems at the CBBT. However, all things considered, these problems are much smaller for the CBBT than is the case for the HRBT and MMBT.

TABLE 2

ADVERSE EVENT EXAMPLES FOR THE FIVE HAMPTON ROADS TUNNELS

2008 Factor Translation Example

Risk Events	Importance Factor	Occurrence Factor	Vulnerability Factor	
	Low – High	Likelihood	Monetary Loss (Dollars)	Human Loss (Deaths/Injuries)
HRBT				
Car Accident	High	5	1	2
Flooding		3	3	2
Fire		2	2	2
MMBT				
Car Accident	High	4	1	1
Flooding		3	3	1
Fire		2	2	1
Midtown Tunnel				
Car Accident	Medium	5	1	2
Flooding		4	3	2
Fire		2	2	2
Downtown Tunnel				
Car Accident	Medium	5	1	2
Flooding		4	3	2
Fire		2	2	2
CBBT				
Car Accident	Medium to High	3	1	1
Flooding		3	4	1
Fire		1	2	1

TABLE 3 A SCALE FOR ADVERSE EVENTS: THE FIVE HAMPTON ROADS TUNNELS		
Importance Factor	**Occurrence Factor**	**Vulnerability Factor**
	HRBT	
1	.33	.20
	MMBT	
1	.30	.15
	Midtown Tunnel	
.5	.37	.20
	Downtown Tunnel	
.5	.37	.20
	CBBT	
.75	.23	.17

TABLE 4 RELATIVE RISK RANKINGS: THE FIVE HAMPTON ROADS TUNNELS		
Tunnel	**Risk Prioritization Score**	**Risk Rank**
HRBT	.0670	
MMBT	.0450	
Midtown Tunnel	.0370	
Downtown Tunnel	.0370	
CBBT	.0293	

Regional Infrastructure Independence

The tragic events of Sept. 11, 2001, in New York City and at the Pentagon served to re-emphasize what often is termed the "cascade" effect. The major building blocks of a modern urban civilization are interrelated and interdependent. When one part of New York City's infrastructure was destroyed or failed, this rippled into other parts of the city and knocked out other vital functions as well.

Suppose a destructive hurricane were to hit Hampton Roads. Likely, it would knock out electricity, disrupt natural gas delivery, diminish our ability to communicate, limit our ability to access television and radio, and perhaps flood or block off one or more tunnels. Clearly, our ability to deal with any one of these calamities depends at least partially upon the continuing operation of the remaining pieces of infrastructure.

Unfortunately, somewhat like a domino effect, the destruction of one piece of infrastructure (electrical service) often does impede or even knock down other pieces of infrastructure (television and radio reception and, in the case of New York City, subways). Hence, any analysis of the impact of adverse events upon our region's tunnels must be approached from an overall systems point of view. Everything is related and the experience of 9/11 reveals that infrastructure failures often cascade. Both foresight and wise planning are required to minimize the probability that infrastructure failures spread like a contagious disease.

Final Reflection: Accidents and Terrorism

All of the major European tunnel episodes that we described earlier were accidents and not the result of terrorist actions. Even so, a terrorist, especially a suicidal terrorist, could replicate the tragic results of these accidents. **In fact, Hampton Roads is vulnerable to terrorist attacks directed against many different key components of its infrastructure – not just bridges and tunnels, but also electrical, natural gas and water supplies, and tall buildings. The possibility of chemical and radiation attacks on the region, or even the detonation of small atomic weapons, cannot be discarded due to the overriding importance of the military installations located in our midst. Prudence requires that we be mindful of and prepare for such possibilities.**