UTC Spotlight

University Transportation Centers Program

Colorado School of Mines

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

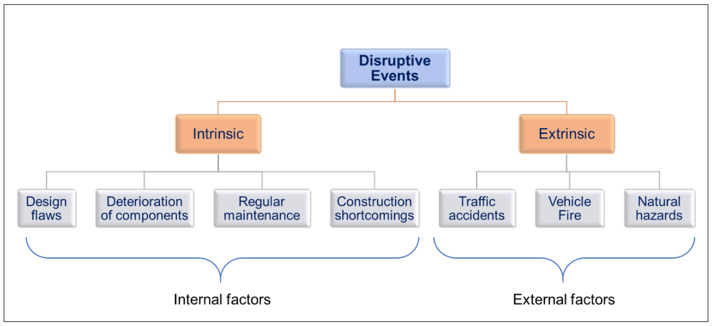
Quarterly
Issue 2
April 2020

Improving the Functionality and Resilience of Roadway Tunnels

Road tunnels are an important component of transportation infrastructure. Increased urbanization, population density and traffic congestion demand greater investments in underground transportation infrastructure. Underground transportation offers better traffic efficiency and long-term sustainability, but it also poses special design, operation and maintenance challenges. Public safety and traffic efficiency can be severely affected when hazardous events cause a major tunnel in a high capacity road network to partly or fully lose its functionality and resilience.

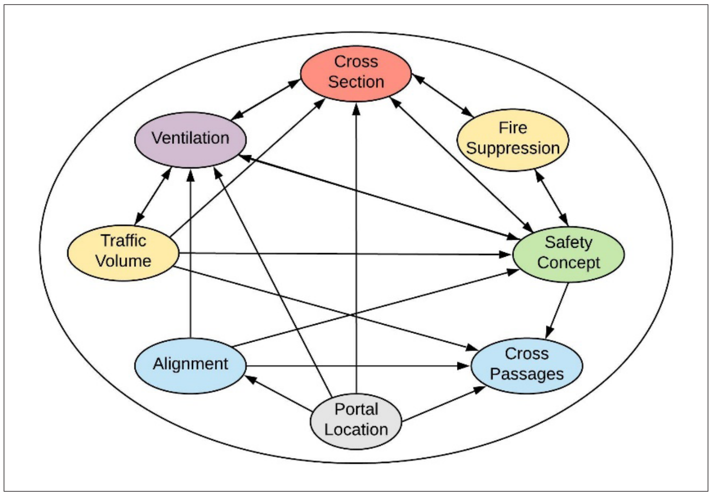
There are many issues and operational parameters unique to tunnels that are not encountered in open traffic networks. For instance, fire in tunnels behaves differently from typical fires in open space due to limited intake of oxygen, large amounts of smoke, potential toxic gases and a high level of heat. Moreover, the impacts of hazardous events are more severe in tunnels than in roads, highways and bridges. Collateral damage to a tunnel's structure and equipment can lead to lengthy tunnel closures. Alternate routes used during closures tend to be narrower roads with lower speed limits, causing traffic delays and congestion. More importantly, existing methods to analyze, predict and mitigate the occurrence and impact of hazardous events for road traffic cannot be applied to tunnels.

The University Transportation Center for Underground Transportation Infrastructure (UTC-UTI) at Colorado School of Mines is conducting a study to improve the functionality and resilience of road tunnels to achieve a more efficient traffic flow. **Functionality** of a tunnel is defined as its through-pass capacity over time. **Resilience** is defined as the ability of the tunnel to recover from disruptive and hazardous events to which the tunnel is subjected. As shown in Figure 1, disruptive events can be intrinsic, i.e. due to internal factors, like design flaws, construction shortcomings, deterioration of components and regular maintenance, as well as extrinsic, i.e. events caused by external factors (traffic accidents, fire, and natural hazards) not directly related to the construction/ design of the tunnels. These issues and operational parameters can be interdependent in often complicated ways, as illustrated in Figure 2.



Sandeep Khetwal

Figure 1. Intrinsic and extrinsic events that can impact the functionality and resilience of road tunnels.



Sandeep Khetwal

Figure 2. Main operational parameters that affect tunnel functionality and resilience, and their interrelationships.

This study aims to: 1) identify different operational parameters and events that affect tunnel functionality and resilience, the nature of their impact on tunnel operation and their interrelationships; 2) develop models and tools to predict tunnel performance and resilience under different events; and 3) test and validate the models and tools using the data from road tunnels in Colorado. Historical data from various tunnel operations were statistically analyzed, with machine-learning techniques used to uncover patterns and correlations, generate probabilistic relationships between the different operational parameters and events, and inform understanding of their impact on tunnel functionality and resilience. Researchers developed a data-driven stochastic simulation model to simulate different events associated with tunnel performance and resilience based on their locations, sizes and traffic data.

UTC-UTI researchers initiated the project by developing a standardized digital framework to collect operational data from road tunnels. Using the data collection system, extensive review and analysis were conducted on historical and paper-based data that have been gathered during more than 10 years of operation of the Eisenhower–Johnson Memorial Tunnels (EJMT). The EJMT consists of a pair of dual-bore, four-lane vehicular tunnels located approximately 97 km west of Denver, Colorado. The EJMT is the highest vehicular tunnel in the United States (at 3,390 m above mean sea level] and it carries I-70 from one side of the continental divide to the other. The EJMT is the main thoroughfare for vehicles travelling between Denver and the major cities in the West, with several world-class ski destinations nearby. While the tunnel greatly reduces the travel time over the Continental Divide and the hazard of crossing mountain passes in winter, it also carries a large volume of traffic which continues to increase


Marte Gutierrez

Figure 3. Vehicular pile up at the eastern portal of the Eisenhower–Johnson Memorial Tunnels (EJMT) due to temporary closure of the tunnel.

and exceed its designed capacity every year (Colorado DOT, 2018). This congestion delays the movement of commuters, passengers, goods and services through the tunnel, resulting in significant economic losses. Other issues in the tunnels, such as accidents, inspection, maintenance and repair, result in vehicular pile up at the entrance to the tunnel and on I-70, as shown in Figure 3.

UTC-UTI believes that knowledge and insights gained from this study will help improve the operation and management of road tunnels everywhere and make them more efficient and resilient against disruptive events.

References

Colorado Department of Transportation (2018). Eisenhower Tunnel Traffic Counts. Eisenhower Tunnel Traffic Counts. https://www.codot.gov/travel/eisenhower-tunnel/eisenhower-tunnel-traffic-counts.html. Accessed on Sep. 25, 2018.

About This Project

The University Transportation Center for Underground Transportation Infrastructure (UTC-UTI) is a Tier 1 University Transportation Center (UTC), housed at Colorado School of Mines (underground.mines.edu/utc-uti.html), that focuses on improving the durability and extending the life of transportation infrastructure. UTC-UTI is a consortium of transportation researchers and educators from California State University Los Angeles (CSULA), Colorado School of Mines (CSM) and Lehigh University (LU). Marte Gutierrez (mgutierr@mines.edu) is the Director of UTC-UTI.