EVALUATING CAPACITY OF THE
ZION – MT. CARMEL TUNNEL IN ZION NATIONAL PARK

Jonathan Upchurch
ITE Western District Annual Meeting
June 21, 2017
Time zones
Nevada is on Pacific Time.
Utah is on Mountain Time.
Arizona is on Mountain Time (Daylight saving time not observed).

Save as
SITE SCHEMATIC

A. Framework for Upper Pine Creek Bridge
B. 200’ Stope
C. Powder and Tool Shed
D. Pioneer Construction Trail Blasted into Cliff Face
E. 235’ Incline Tramway, Powder and Tool Shed
F. Excavated Material Dumped out of Galleries
G. Blacksmith, Compressor and Transformer Shops
H. Nevada Contracting Company Camp
I. Aerial Tramway
J. Machine Shop
K. Start of Pioneer Construction Trail, October 23, 1927
L. Derrick for Lifting Stone
M. Dynamite and Material Storage
N. Warehouse Near Pioneer Construction Road
O. Construction Quarters of George and John Shea, Subcontractors of Rock Retaining Walls on Switchbacks

Drawing based on field survey, historical photographs and original design documents.
NATIONAL HISTORIC CIVIL ENGINEERING LANDMARK

AMERICAN SOCIETY OF CIVIL ENGINEERS
1852

ZION MT. CARMEL TUNNEL AND HIGHWAY, UTAH

This 5,613-foot-long tunnel, the longest vehicular tunnel in the National Park System, was blasted through the towering sandstone cliffs above Pine Creek Canyon. Construction required extraordinary access through cliff-face galleries for blasting and excavation. The tunnel and the 25-mile-long highway, completed between 1927 and 1930, promoted the "NPS-Rustic" style of engineering and landscape architecture used throughout the National Park System.

Constructed: 1927 - 1930

Designated: 2011
Vehicles over 11’4” (3.4 m) tall or 7’10” (2.4 m) wide, including mirrors, awnings, and jacks, will require traffic control in the tunnel. Single-axle vehicles may not exceed 40’ in length.
AVERAGE TRAVEL TIME:

LARGE VEHICLES - 3 MINUTES 45 SECONDS
FREE-FLOWING SMALL VEHICLES - 2 MINUTES 57 SECONDS

AVERAGE TRAVEL SPEED:

LARGE VEHICLES - 19 MPH
FREE-FLOWING SMALL VEHICLES - 24 MPH
HEADWAY IN A PLATOON: 5 SECONDS
HEADWAY FOR LARGE VEHICLES: 27 SECONDS
TURNAROUND TIME: 34 SECONDS
TWO-LANE RURAL HIGHWAY  3,200 PASSENGER CARS PER HOUR

TUNNEL THEORETICAL CAPACITY  1,440 PASSENGER CARS PER HOUR
Hourly Two-way Tunnel Capacity as a Function of Number of Arriving Large Vehicles

<table>
<thead>
<tr>
<th>Number of Arriving Large Vehicles per Hour</th>
<th>Capacity (vehicles per hour)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>2</td>
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</tr>
<tr>
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</table>
CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES
WAITING TIME AS A FUNCTION OF INTERVAL BETWEEN RELEASERS

- **Waiting Time for First Vehicle (minutes)**
- **Interval Between Releases (minutes)**

The graph shows a positive correlation between the interval between releases and the waiting time for the first vehicle. As the interval increases, so does the waiting time.
1 day with a 28:10 waiting time

5 days with a 22:40 waiting time

23 days with a 18:20 waiting time

118 days with a 13:35 waiting time
CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES

![Graph showing capacity as a function of interval between releases. The x-axis represents the interval between releases in minutes, ranging from 0 to 40. The y-axis represents capacity in vehicles per hour, ranging from 0 to 600. The graph shows a positive correlation between the interval and capacity.]
AUGUST 6 TO SEPTEMBER 23

ON AN AVERAGE DAY,
ONE-WAY OPERATION FOR AT LEAST
41 MINUTES OUT OF EVERY HOUR

ON THE WORST DAY,
ONE-WAY OPERATION FOR AT LEAST
52 MINUTES OUT OF EVERY HOUR
CONCLUSIONS
RECOMMENDATIONS

- Dark Tunnel
  - Remove Sunglasses
  - Watch For Slow Moving Vehicles

- TURN LIGHTS ON IN TUNNEL

- NO STOPS IN TUNNEL
WHAT IS A TOLERABLE WAITING TIME?
CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES
Alternatives for Addressing the Capacity-related Issues

1. Enlarge the existing tunnel
2. Construct a parallel tunnel
3. Ban large vehicles 24/7/365
4. Ban large vehicles on a temporal basis
5. Restrict large vehicles to smaller time periods
6. Restrict large vehicles to only certain portions of each hour
7. Construct pulloffs to serve as large vehicle holding areas
8. Automate tunnel operation
9. Always use a “stick”, rather than a timer, to clear the tunnel
10. Increase staffing level

11. Avoid management decisions that would encourage more traffic through tunnel

12. Publicize that there will be (may be) long waiting times and otherwise do nothing

13. Utilize congestion pricing. Charge a higher fee for passage during high-volume hours

14. Other