Appendix G: Benefit-Cost Assumptions and Methodology

US 360/ROUTE 288 INTERCHANGE AREA STUDY – BENEFIT-COST ASSUMPTIONS AND METHODOLOGY

Assumptions

Analysis Timeframe

- Construction Year = 2021
- Analysis Period = 20 years, 365 days/year

Value of Time

Value of time was calculated to convert time savings to a monetary value. Value of time was calculated separately for autos and trucks. The assumptions and calculations for both vehicle types are described below:

Autos

The value of time for autos was calculated as the sum of the value of travel time and the value of time-related depreciation.

Value of Travel Time

- **MEDIAN HOUSEHOLD INCOME**
  (Source: http://quickfacts.census.gov)
  - Chesterfield County: $72,363
  - City of Richmond: $39,445
  - Powhatan County: $76,495
  - City of Colonial Heights: $51,612
  - City of Petersburg: $35,126
  - **Average of Chesterfield County and Surrounding Counties: $55,008**

- **MEDIAN WAGE RATES**
  (Source: http://www.bls.gov)
  - **Richmond: $17.38**

- **REASON FOR TRAVEL**
  (Source: http://nhts.ornl.gov/tables09/ae/work/Job34866.html)
  - **Personal Travel: 93.7%**
  - **Business Travel: 6.3%**

- **EMPLOYER COSTS FOR EMPLOYEE COMPENSATION**
  (Source: http://stats.bls.gov/news.release/ecec.nr0.htm)
  - **Wages: 68.7%**
  - **Benefits: 31.3%**

- **VALUE OF TRAVEL TIME (PER HOUR)**
  (Source: http://www.dot.gov/sites/dot.gov/files/docs/vot_guidance_092811c_0.pdf)
  - Personal Travel $= \frac{\text{Median Household Income}}{2080} \times 50\%$
  - Personal Travel: $13.22/hr
  - Business Travel $= \text{Median Wage Rate} \times \left(1 + \frac{\%\ \text{Benefits of Employer Costs for Employee Compensation}}{\%\ \text{Wages of Employer Costs for Employee Compensation}}\right)$
  - Business Travel: $25.30/hr
  - Combination Personal and Business Travel
    = (Personal Travel × % Personal Travel) + (Business Travel × % Business Travel)
  - **Combination Personal and Business Travel: $22.80** (rounded to the nearest $0.05)

Value of Time-Related Depreciation

- **TIME-RELATED DEPRECIATION (1995)**
  (Source: http://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech00.cfm)
  - Small autos (1995): $1.09/hr
  - Medium-sized to large autos (1995): $1.45/hr
  - Four-tire single-unit truck (1995): $1.90/hr
  - **Average auto (1995): $1.50/hr** (rounded to the nearest $0.05)

- **PRODUCER PRICE INDEX (1995)**
  (Source: http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/fhwahop12005.pdf)
  - **Passenger Cars (1995): 134.1**
  - **Trucks with GVW < 14,000 lb (1995): 159.0**

- **PRODUCER PRICE INDEX (Sep 2014)**
  (Source: http://www.bls.gov/web/ppi/ppitable09.pdf)
  - **Passenger Cars (2014): 129.3**
  - **Trucks with GVW < 14,000 lb (2014): 163.3**

- **TIME-RELATED DEPRECIATION (2014)**
  - Auto Scaled Depreciation (1995-2014)= Average $\left(\frac{\text{2014 Passenger Car PPI}}{\text{1995 Passenger Car PPI}} + \frac{\text{2014 Trucks GVW<14,000 lb PPI}}{\text{1995 Trucks GVW<14,000 lb PPI}}\right)$
  - Time-Related Depreciation (2014) = Time-Related Depreciation (1995) × Auto Scaled Depreciation
  - **Time-Related Depreciation (2014): $1.45** (rounded to the nearest $0.05)

Auto Value of Time

Auto Value of Time = Value of Travel Time + Time-Related Depreciation
Auto Value of Time: $24.25

Trucks

The value of time for trucks was calculated as the sum of the value of travel time, the value of time-related depreciation, and the value of freight inventory delay.

Value of Travel Time

- **MEDIAN WAGE RATES**
  (Source: http://www.bls.gov/oes/current/oes_va.htm#53-0000)
  - Virginia (Heavy and Tractor-Trailer Truck Drivers): $17.58
  - Virginia (Light Truck or Delivery Services Drivers): $14.34
  - **Virginia Average: $15.96**

- **EMPLOYER COSTS FOR EMPLOYEE COMPENSATION**
  (Source: http://stats.bls.gov/news.release/ecec.t05.htm)
  - **Wages: 66.0%**
  - **Benefits: 34.0%**

- **VALUE OF TRAVEL TIME (PER HOUR)**
  - $\text{Value of Travel Time} = \text{Median Wage Rate} \times \left(1 + \frac{\%\ \text{Benefits of Employer Costs for Employee Compensation}}{\%\ \text{Wages of Employer Costs for Employee Compensation}}\right)$
  - **Value of Travel Time: $24.20** (rounded to the nearest $0.05)

Value of Time-Related Depreciation

- **TIME-RELATED DEPRECIATION (1995)**
  (Source: http://www.fhwa.dot.gov/asset/hersst/pubs/tech/tech00.cfm)
  - Six-tire trucks (1995): $2.65/hr
  - 3+ axles combination trucks (1995): $7.16/hr
  - 3 or 4 axles (1995): $6.41/hr
  - 5+ axles (1995): $6.16/hr
  - **Average truck (1995): $5.60/hr** (rounded to the nearest $0.05)

- **PRODUCER PRICE INDEX (1995)**
  (Source: http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/fhwahop12005.pdf)
  - **Trucks with GVW > 14,000 lb (1995): 144.1**
  - **Truck Trailers (1995): 124.5**

- **PRODUCER PRICE INDEX (Sep 2014)**
  (Source: http://www.bls.gov/web/ppi/ppitable09.pdf)
  - **Trucks with GVW > 14,000 lb (2014): 214.3**
  - **Truck Trailers (2014): 191.6**

- **TIME-RELATED DEPRECIATION (2014)**
  - Truck Scaled Depreciation (1995-2014)= Average $\left(\frac{\text{2014 Trucks GVW>14,000 lb PPI}}{\text{1995 Trucks GVW>14,000 lb PPI}} + \frac{\text{2014 Truck Trailers PPI}}{\text{1995 Truck Trailers PPI}}\right)$
  - Time-Related Depreciation (2014) = Time-Related Depreciation (1995) × Truck Scaled Depreciation
  - **Time-Related Depreciation (2014): $8.45** (rounded to the nearest $0.05)

Value of Freight Inventory Delay

- **AVERAGE VALUE OF FREIGHT INVENTORY DELAY (PER HOUR)**
  (Source: http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/fhwahop12005.pdf)
  - **Average Value of Freight Inventory Delay: $0.25/hr** (rounded to the nearest $0.05)

Truck Value of Time

Truck Value of Time = Value of Travel Time + Time-Related Depreciation + Value of Freight Inventory Delay
Truck Value of Time: $32.95

Crash Societal Cost

Crash societal costs were used to convert crash reductions to a monetary value. Crash societal costs were based on the FY2013-14 VDOT Highway Safety Improvement Program (HSIP) costs per crash provided below:

- **COSTS PER CRASH**
  (Source: FY2013-14 HSP Proposed Safety Improvement Form
  http://www.virginiadot.org/business/ted_app_pro.asp)

Crash Type	2014	2021*
Fatal Crash	$ 5,000,000	$ 6,100,000
Injury Crash (Type A)	$ 275,000	$ 340,000
Injury Crash (Type B)	$ 98,000	$ 120,000
Injury Crash (Type C)	$ 55,000	$ 70,000
Injury Crash (Average)	$ 142,667	$ 180,000
PDO Crash	$ 9,000	$ 10,000

* 2021 costs are calculated using 2014 cost and a 3% annual inflation rate

Occupancy Rate

Occupancy rates were used to account for multiple passengers in a vehicle.

- **OCCUPANCY RATE**
  (Source: http://nhts.ornl.gov/tables09/ae/work/Job26695.html)
  - **Trucks: 1.00 person/vehicle**
  - **Autos (Virginia): 1.63 persons/vehicle**

Repair Cost

Repair costs were not assumed in this analysis.

Crash Reduction Factors (CRF)

Crash Reduction Factors (CRFs) were used to determine the reduction in crashes after an improvement is implemented.

- **CRASH REDUCTION FACTOR**
  (Source: *FHWA's Desktop Reference for Crash Reduction Factors*)
  - **Convert signalized intersection to displaced left-turn (DLT) intersection CRF: 19 (all crash types, fatal and injury crashes)**
  - **Convert signalized intersection to a signalized superstreet configuration CRF: 56 (all crash types, all crash severities)**
  - **Convert signalized intersection to a continuous green T-intersection (CGT) CRF: 97 (angle crashes, all severities)**
  - **Increase number of lanes CRF: 31 (all crash types, all crash severities)**
  - **Change number of lanes on freeway exit ramp from 1 to 2 CRF: 42 (all crash types, all crash severities)**
  - **Convert at-grade intersection into grade-separated interchange CRF: 42 (all crash types, all crash severities)**
  - **Provide straight ramp instead of cloverleaf ramp CRF: 45 (all crash types, all crash severities)**
  - **Provide an auxiliary lane between an entrance ramp and exit ramp CRF: 20 (all crash types, all crash severities)**

Methodology

The following sections outline the equations used to calculate the benefit-cost (B/C) for each improvement concept:

Operational Benefit

$$Operational\ Benefit = \sum_{Year=2020}^{2040} \Delta Truck\ Delay_{Year} \times Truck\ Value\ of\ Time + \Delta Auto\ Delay_{Year} \times Auto\ Value\ of\ Time$$

$$\begin{aligned}\Delta Truck\ Delay = {} & (No\ Build\ AM\ Travel\ Time \times No\ Build\ AM\ Trucks - Build\ AM\ Travel\ Time \times Build\ AM\ Trucks \\ & + No\ Build\ PM\ Travel\ Time \times No\ Build\ PM\ Trucks - Build\ PM\ Travel\ Time \times Build\ PM\ Trucks) \\ & \times \left(\frac{365\ days}{1\ year}\right) \times \left(\frac{1\ hr}{3600\ sec}\right) \times (Truck\ Occupancy\ Rate)\end{aligned}$$

$$\begin{aligned}\Delta Auto\ Delay = {} & (No\ Build\ AM\ Travel\ Time \times No\ Build\ AM\ Autos - Build\ AM\ Travel\ Time \times Build\ AM\ Autos \\ & + No\ Build\ PM\ Travel\ Time \times No\ Build\ PM\ Autos - Build\ PM\ Travel\ Time \times Build\ PM\ Autos) \\ & \times \left(\frac{365\ days}{1\ year}\right) \times \left(\frac{1\ hr}{3600\ sec}\right) \times (Auto\ Occupancy\ Rate)\end{aligned}$$

Safety Benefit

$$Safety\ Benefit = \sum_{Year=2020}^{2040} \Delta Fatals_{Year} \times Fatal\ Cost + \Delta Injuries_{Year} \times Injury\ Cost + \Delta PDOs_{Year} \times PDO\ Cost$$

$$\Delta Fatals = No\ Build\ Fatal\ Crashes \times \frac{Fatal\ CRF}{100}$$

$$\Delta Injuries = No\ Build\ Injury\ Crashes \times \frac{Injury\ CRF}{100}$$

$$\Delta Fatals = No\ Build\ PDO\ Crashes \times \frac{PDO\ CRF}{100}$$

Total Cost

$$Total\ Cost = Construction\ Cost + PE\ Cost + ROW\ Cost + \sum_{Year=2020}^{2040} Maintenance\ cost_{Year}$$

Benefit-Cost

$$Benefit/Cost = \frac{Operational\ Benefit + Safety\ Benefit}{Total\ Cost}$$

US 360/Route 288 Interchange Area Study
Summary of Benefit-Cost Analysis

	Improvement	Operational Benefit (2021 $)	Safety Benefit (2021 $)	Total Benefit (2021 $)	Total 20-Year Cost (2021 $)	Benefit-Cost Ratio Weekday Peak Hour	Rank
1	US 360 at Old Hundred Road/Commonwealth Centre Parkway - At-Grade DLT Intersection - Maximum	$ 156,732,307	$ 9,798,213	$ 166,530,520	$ 75,100,000	2.2	8
2	US 360 at Old Hundred Road/Commonwealth Centre Parkway - Grade-Deparated Diverging Diamond Interchange (DDI)	$ 227,745,761	$ 21,659,208	$ 249,404,969	$ 111,900,000	2.2	7
3	SB Route 288 to WB US 360 Off-Ramp Improvements	$ 88,501,515	$ 19,758,213	$ 108,259,727	$ 11,600,000	9.3	1
4	Bailey Bridge Connector Improvements	$ 441,435,051.59	$ -	$ 441,435,052	$ 79,400,000	5.6	4
5	US 360 Superstreets - 5 Intersections	$ 333,282,491	$ 15,273,758	$ 348,556,249	$ 46,400,000	7.5	2
6	US 360 at Brad McNeer Parkway - Continuous Green T-Intersection	$ 57,196,773	$ 3,820,987	$ 61,017,760	$ 9,300,000	6.6	3
7	Widen NB and SB Route 288 - from 4 Lanes to 6 Lanes	$ 135,259,458	$ 45,309,087	$ 180,568,545	$ 36,700,000	4.9	5
8	SB Route 288 Construct CD Road (2 Lanes)	$ 95,576,659	$ 6,220,154	$ 101,796,813	$ 37,600,000	2.7	6
9	EB US 360 to NB Route 288 Directional On-Ramp (2 Lanes)	$ 9,114,190	$ 2,609,075	$ 11,723,266	$ 25,400,000	0.5	9