

## **Travel Time Methodology**

This appendices outlines the approach to determine travel times for bus rapid transit (BRT) along State Highway 7 in three cross section scenarios: mixed traffic, managed lane, and dedicated lane. This process was also applied to determine travel times for standard buses without BRT amenities (such as off-board fare collection, transit signal priority (TSP), and queue jumps), as well as vehicular travel times for comparison.

The following equation was used in this analysis. Each input, including reference information and assumptions, is described below.

$$\text{travel time} = 2040 \text{ projected vehicular travel time} - \text{TSP time savings} \\ - \text{queue jump time savings} + \text{dwell time} + \text{acceleration \& deceleration time}$$

#### **2040 Projected Vehicular Travel Time**

- Current-day free flow and peak period travel times were identified from Google Maps.
  - 25<sup>th</sup> percentile was used to determine peak period travel time from the given range.
  - Travel times were taken from the model for 2015 and 2040, allowing current-day Google Map travel times to be scaled up to reflect 2040 traffic.
  - Dedicated and managed lanes would not be implemented within Boulder, Lafayette, or Brighton. In these scenarios, free flow travel times were applied to 60% of the corridor, while PM peak travel times were applied to the remaining 40%. This was determined by summing free-flow and peak period travel times by segment depending on the respective cross section.
- Free-flow travel time is assumed to be equivalent to travel time of a dedicated BRT lane.
- Peak period travel time is assumed to be equivalent to travel time of a mixed traffic lane.
- Managed lane travel time is assumed to be 20% higher than that of a dedicated lane.
- Travel times are calculated in both the eastbound and westbound directions.

#### **TSP Time Savings**

- TSP will be implemented in all three cross section scenarios (mixed traffic, managed lane, and dedicated lane).
- TSP saves an average of 5% of travel time along BRT corridors.<sup>1</sup>
- The assumption of 5% time savings seemed reasonable corridor-wide, given approximately 18 intersection locations where TSP could be implemented and a time savings of approximately 10 seconds per intersection.

#### **Queue Jump Time Savings**

- Queue jumps will be implemented in mixed traffic conditions only. This applies to 100% of the corridor in the mixed traffic scenario, and 40% of the corridor in the dedicated lane and managed lane scenarios.
- Maximum benefit provided by queue jumps is 10 seconds per bus per intersection.<sup>2</sup>
- It is assumed that queue jumps could be added at the same 18 intersections that would have TSP. It is also assumed that these intersections are evenly distributed along the corridor, and

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<sup>1</sup> Apex Design, 2017.

<sup>2</sup> Apex Design, 2017.

40% of the 18 intersections fall within the urban areas without dedicated and managed lane conditions.

#### **Dwell Time**

- Major outlying bus stops (non-BRT) have a dwell time of approximately 30 seconds with up to 38% time savings with off-board fare collection, leading to a dwell time of 18.6 seconds per station.<sup>3</sup>

#### **Acceleration & Deceleration Time**

- Average speed across the entire corridor was determined by travel time and distance.
- It is assumed that a BRT vehicle would have an acceleration and deceleration rate of 2 mph per second.<sup>4</sup>
- The average speed was used to determine additional time spent accelerating and decelerating at stations instead of continuing at a constant speed along that same distance.
- This value was divided by 2 to account for stations' proximity to intersections, where buses would already be accelerating and decelerating.

#### **Results**

Travel time results are displayed on the next pages.

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<sup>3</sup> [https://www.nbrti.org/docs/pdf/Characteristics\\_BRT\\_Decision-Making.pdf](https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf)

<sup>4</sup> <http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf>

	Operating Scenario 1-0	Operating Scenario 1-1	Operating Scenario 1-2	Operating Scenario 1-3	Operating Scenario 1-4	Operating Scenario 2	Operating Scenario 3	Operating Scenario 4
Auto	80	80	80	80	80	79	83	46
Mixed Traffic	76	77	77	77	77	76	80	43
Dedicated Lane	59	59	59	59	59	57	62	27
Managed Lane	64	65	65	65	65	63	68	30
Standard Bus	85	86	86	86	86	85	89	49

Note: Operating Scenario 4 only refers to the Boulder to Lafayette route. For the full Boulder to Brighton route, refer to Operating Scenario 1-0.

### Operating Scenario 1: Boulder to Brighton Basic

Route distance (miles): 27.7

Stops: 10

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	47	60	77	0	0	0	20	0.0	77
	Mixed Traffic	0	60	60	47	60	77	4	3	3	20	0.8	74
	Dedicated Lane	0.6	47	52	41	46	58	3	1.2	3	30	1.1	58.2
	Managed Lane	0.6	56	58	50	55	64	3	1.2	3	25	0.9	64.0
	Standard Bus	0	60	60	47	60	77	0	0	5	20	0.8	83
Eastbound	Auto	0	60	60	56	75	80	0	0	0	20	0.0	80
	Mixed Traffic	0	60	60	56	75	80	4	3	3	20	0.8	76
	Dedicated Lane	0.6	46	52	43	48	58	3	1.2	3	30	1.1	59
	Managed Lane	0.6	55	57	51	58	65	3	1.2	3	25	0.9	64
	Standard Bus	0	60	60	56	75	80	0	0	5	20	0.8	85

### NOTES

Blue cells indicate user-input is required

White cells have equations and will auto-populate

### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampro.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampro.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>

## Operating Scenario 1-1: Boulder to Brighton Basic plus Stops at 48th Street & 63rd Street

Route distance (miles): 27.7

Stops: 12

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	47	60	77	0	0	0	20	0.0	77
	Mixed Traffic	0	60	60	47	60	77	4	3	4	20	0.9	75
	Dedicated Lane	0.6	47	52	41	46	58	3	1.2	4	30	1.4	59
	Managed Lane	0.6	56	58	50	55	64	3	1.2	4	25	1.1	65
	Standard Bus	0	60	60	47	60	77	0	0	6	20	0.9	84
Eastbound	Auto	0	60	60	56	75	80	0	0	0	20	0.0	80
	Mixed Traffic	0	60	60	56	75	80	4	3	4	20	0.9	77
	Dedicated Lane	0.6	46	52	43	48	58	3	1.2	4	30	1.4	59
	Managed Lane	0.6	55	57	51	58	65	3	1.2	4	25	1.1	65
	Standard Bus	0	60	60	56	75	80	0	0	6	20	0.9	86

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### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>

### Operating Scenario 1-2: Boulder to Brighton Basic plus Stop at New 75th Street Park-n-Ride

Route distance (miles): 27.7  
Stops: 11

		Percent of Travel Time within Corridor with Dedicated or Managed	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	47	60	77	0	0	0	20	0.0	77
	Mixed Traffic	0	60	60	47	60	77	4	3	3	20	0.8	75
	Dedicated Lane	0.6	47	52	41	46	58	3	1.2	3	30	1.3	59
	Managed Lane	0.6	56	58	50	55	64	3	1.2	3	25	1.0	64
	Standard Bus	0	60	60	47	60	77	0	0	6	20	0.8	84
Eastbound	Auto	0	60	60	56	75	80	0	0	0	20	0.0	80
	Mixed Traffic	0	60	60	56	75	80	4	3	3	20	0.8	77
	Dedicated Lane	0.6	46	52	43	48	58	3	1.2	3	30	1.3	59
	Managed Lane	0.6	55	57	51	58	65	3	1.2	3	25	1.0	65
	Standard Bus	0	60	60	56	75	80	0	0	6	20	0.8	86

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### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrii.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrii.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>

### Operating Scenario 1-3: Boulder to Brighton Basic plus Stop at Huron Street

Route distance (miles): 27.7

Stops: 11

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	47	60	77	0	0	0	20	0.0	77
	Mixed Traffic	0	60	60	47	60	77	4	3	3	20	0.8	75
	Dedicated Lane	0.6	47	52	41	46	58	3	1.2	3	30	1.3	59
	Managed Lane	0.6	56	58	50	55	64	3	1.2	3	25	1.0	64
	Standard Bus	0	60	60	47	60	77	0	0	6	20	0.8	84
Eastbound	Auto	0	60	60	56	75	80	0	0	0	20	0.0	80
	Mixed Traffic	0	60	60	56	75	80	4	3	3	20	0.8	77
	Dedicated Lane	0.6	46	52	43	48	58	3	1.2	3	30	1.3	59
	Managed Lane	0.6	55	57	51	58	65	3	1.2	3	25	1.0	65
	Standard Bus	0	60	60	56	75	80	0	0	6	20	0.8	86

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### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>



### Operating Scenario 1-4: Boulder to Brighton Basic plus Stop at Quebec Street

Route distance (miles): 27.7

Stops: 11

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model		Travel Time (mins) - 2040 Travel Demand Model		Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	47	60	77	77	0	0	0	20	0.0	77	
	Mixed Traffic	0	60	60	47	60	77	77	4	3	3	20	0.8	75	
	Dedicated Lane	0.6	47	52	41	46	58	58	3	1.2	3	30	1.3	59	
	Managed Lane	0.6	56	58	50	55	64	64	3	1.2	3	25	1.0	64	
	Standard Bus	0	60	60	47	60	77	77	0	0	6	20	0.8	84	
Eastbound	Auto	0	60	60	56	75	80	80	0	0	0	20	0.0	80	
	Mixed Traffic	0	60	60	56	75	80	80	4	3	3	20	0.8	77	
	Dedicated Lane	0.6	46	52	43	48	58	58	3	1.2	3	30	1.3	59	
	Managed Lane	0.6	55	57	51	58	65	65	3	1.2	3	25	1.0	65	
	Standard Bus	0	60	60	56	75	80	80	0	0	6	20	0.8	86	

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### SOURCES

TSP Time Savings

Apex Design

Accel/Decel Time Loss

Madison Area MPO

<http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf>

Queue Jumps

Apex Design

Dwell Time

NBRTI

[https://www.nbrti.org/docs/pdf/Characteristics\\_BRT\\_Decision-Making.pdf](https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf)

#### Operating Scenario 2: Boulder to Brighton Direct

Route distance (miles): 27.4  
Stops: 10

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	60	60	46	58	77	0	0	0	20	0.0	77
	Mixed Traffic	0	60	60	46	58	77	4	3	3	20	0.8	74
	Dedicated Lane	0.6	46	52	40	44	57	3	1.2	3	30	1.1	57
	Managed Lane	0.6	55.2	57	48	53	63	3	1.2	3	25	0.9	62
	Standard Bus	0	60	60	46	58	77	0	0	5	20	0.8	82
Eastbound	Auto	0	60	60	56	73	79	0	0	0	20	0.0	79
	Mixed Traffic	0	60	60	56	73	79	4	3	3	20	0.8	76
	Dedicated Lane	0.6	45	51	42	47	57	3	1.2	3	30	1.1	57
	Managed Lane	0.6	54	56	50	56	63	3	1.2	3	25	0.9	63
	Standard Bus	0	60	60	56	73	79	0	0	5	20	0.8	85

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#### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrii.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrii.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>

### Operating Scenario 3: Boulder to Brighton Basic plus Lafayette Park-n-Ride

Route distance (miles): 29.7

Stops: 11

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Travel Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	65	65	50	64	83	0	0	0	20	0.0	83
	Mixed Traffic	0	65	65	50	64	83	4	3	3	20	0.8	80
	Dedicated Lane	0.6	51	56.6	44	48	61	3	1.2	3	30	1.3	62
	Managed Lane	0.6	61	62.72	53	57	68	3	1.2	3	25	1.0	68
	Standard Bus	0	65	65	50	64	83	0	0	6	20	0.8	89
Eastbound	Auto	0	60	60	59	78	79	0	0	0	25	0.0	79
	Mixed Traffic	0	60	60	59	78	79	4	3	3	25	1.0	76
	Dedicated Lane	0.6	49	53.4	45	49	58	3	1.2	3	30	1.3	59
	Managed Lane	0.6	59	59.28	54	59	65	3	1.2	3	25	1.0	65
	Standard Bus	0	60	60	59	78	79	0	0	6	25	1.0	85

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### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareamp.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareamp.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbri.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbri.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>

### Operating Scenario 4: Boulder to Brighton Basic plus Lafayette Service

Route distance (miles): 12.3

Stops: 5

		Percent of Travel Time within Corridor with Dedicated or Managed Lanes	Travel Time (2016 Google Maps) Assuming Consistent Cross Section End-to-End	Vehicular Travel Time (mins) - 2016 Google Maps	Travel Time (mins) - 2015 Demand Model	Travel Time (mins) - 2040 Travel Demand Model	Vehicular Travel Time (mins) - 2040 Scaled Projection	TSP Time Savings (mins)	Queue Jump Time Savings (mins)	Dwell Time (mins)	Average Speed (mph)	Acceleration & Deceleration Time Loss (mins)	TOTAL TRAVEL TIME
Westbound	Auto	0	33	33	23	30	44	0	0	0	15	0.0	44
	Mixed Traffic	0	33	33	23	30	44	2	3	2	15	0.3	41
	Dedicated Lane	0.6	25	28.2	20	22	30	2	1.2	2	25	0.4	30
	Managed Lane	0.6	30	31.2	24	26	34	2	1.2	2	20	0.3	33
	Standard Bus	0	33	33	23	30	44	0	0	3	15	0.3	47
Eastbound	Auto	0	30	30	26	41	46	0	0	0	15	0.0	46
	Mixed Traffic	0	30	30	26	41	46	2	3	2	15	0.3	43
	Dedicated Lane	0.6	23	25.8	20	21	28	1	1.2	2	25	0.4	27
	Managed Lane	0.6	28	28.56	24	26	31	2	1.2	2	25	0.4	30
	Standard Bus	0	30	30	26	41	46	0	0	3	15	0.3	49

### NOTES

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This table solely analyzes travel time for the Boulder to Lafayette route. The full Boulder to Brighton route can be seen on the tab for Operating Scenario 1-0.

### SOURCES

TSP Time Savings	Apex Design	
Accel/Decel Time Loss	Madison Area MPO	<a href="http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf">http://www.madisonareampo.org/documents/DBRTTravelTimeEstimationApproach.pdf</a>
Queue Jumps	Apex Design	
Dwell Time	NBRTI	<a href="https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf">https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf</a>