

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.

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

2040 Projected Vehicular Travel Time

- Current-day free flow and peak period travel times were identified from Google Maps.
 - o 25th 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.¹
- 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.²
- 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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¹ Apex Design, 2017.

² 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.³

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.⁴
- 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.

³ https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf

⁴ 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	Travel Time (2016 Google	Vehicular Travel Time	Travel Time (mins) -	Travel Time (mins) -	Vehicular Travel		Queue Jump			Acceleration &	
		Corridor with Dedicated or	Maps) Assuming Consistent	(mins) - 2016 Google	2015 Travel Demand	2040 Travel Demand	Time (mins) - 204	0 TSP Time	Time Saving	s Dwell Time	e Average	Deceleration Time	TOTAL TRAVEL
		Managed Lanes	Cross Section End-to-End	Maps	Model	Model	Scaled Projection	Savings (mins)	(mins)	(mins)	Speed (mph)	Loss (mins)	TIME
-	Auto	0	60	60	47	7 6)	77 (0 1	0 20	0.0	77
Ē	Mixed Traffic	0	60	60) 47	7 6	0	77 4		3	3 20	0.8	74
tp.	Dedicated Lane	0.6	47	52	2 4	1 4	5	58 3	1.	2 :	3 30	(1.1	58.2
/es	Managed Lane	0.6	56	58	3 50	5	5	64 3	1.	2 :	3 25	0.9	64.0
>	Standard Bus	0	60	60) 47	7 6	0	77 0		0 :	5 20	3.0	83
	Auto	0	60	60	56	5 7:	5	80 0		0 1	0 20	0.0	80
Ĕ	Mixed Traffic	0	60	60	56	7	5	80 4		3	3 20	0.8	76
g.	Dedicated Lane	0.6	46	52	2 43	3 4	В	58 3	1.	2 :	3 30	1.1	59
as	Managed Lane	0.6	55	57	7 51	5	В	65 3	1.	2 :	3 25	0.9	64
	Standard Bus	0	60	60	56	5 7	5	80 0		0 :	5 20	9.0	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 Madson Area MPO
Queue Jumps Apex Design
Dwell Time NBRTI

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

NBRTI https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf



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	,	Vehicular Travel Time (mins) - 2016 Google	Travel Time (mins) - 2015 Travel Demand	Travel Time (mins) - 2040 Travel Demand		TSP Time	Queue Jump Time Savings			Acceleration & Deceleration Time	TOTAL TRAVEL
		Managed Lanes	Cross Section End-to-End	Maps	Model	Model	Scaled Projection	Savings (mins)	(mins)	(mins)	Speed (mph)	Loss (mins)	TIME
	Auto	(60	60	47	60	77	? 0	() () 20	0.0	77
Ĕ	Mixed Traffic	(60	60	47	60	77	7 4		3 4	4 20	0.9	75
욢	Dedicated Lane	0.6	47	52	41	46	58	3	1.3	2 4	4 30	1.4	59
es	Managed Lane	0.6	56	58	50	55	64	1 3	1.3	2 4	4 25	1.1	65
>	Standard Bus	(60	60	47	60	77	7 0	() (ò 20	0.9	84
	Auto	(60	60	56	75	80) 0	() (0 20	0.0	80
e e	Mixed Traffic	0	60	60	56	75	80) 4		3 4	4 20	0.9	77
ē	Dedicated Lane	0.6	46	52	43	48	58	3	1.3	2 4	4 30	1.4	59
as	Managed Lane	0.6	55	57	51	58	65	5 3	1.3	2 4	4 25	1.1	65
ш	Standard Bus		60	60	56	75	80) 0) (3 20	0.9	86

NOTES

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SOURCES

TSP Time Savings Apex Design
Accel/Decel Time Loss Madison Area MPO
Queue Jumps Apex Design

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

Dwell Time NBRTI https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf



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

Route distance (miles): 27.7 Stops:

		Percent of Travel Time	Travel Time (2016 Google Map	os) Vehicular Travel				Vehicular Travel		Queue Jui	mp		Acceleration 8	TOTA	iL.
		within Corridor with	Assuming Consistent Cross Se	ection Time (mins) - 20	16 Tr	ravel Time (mins) - 2015	Travel Time (mins) - 2040	7 Time (mins) - 2040	TSP Time	Time Savi	ngs Dwell Tim	ne Average Sp	eed Deceleration	TRAV	/EL
		Dedicated or Managed	End-to-End	Google Maps	Tr	ravel Demand Model	Travel Demand Model	Scaled Projection	Savings (mins) (mins)	(mins)	(mph)	Time Loss (m	ns) TIME	
	Auto		0	60	60	47	60	7	7 ()	0	0	20	0.0	77
Ĕ	Mixed Traffic		0	60	60	47	60	7	7	4	3	3	20	0.8	75
흌	Dedicated Lane	0.	6	47	52	41	46	6	58 3	3	1.2	3	30	1.3	59
es	Managed Lane	0.	6	56	58	50	55	5 6	34 3	3	1.2	3	25	1.0	64
-	Standard Bus		0	60	60	47	60) 7	7 ()	0	6	20	0.8	84
_	Auto		0	60	60	56	75	5 8	30 ()	0	0	20	0.0	80
Ĕ	Mixed Traffic		0	60	60	56	75	5 8	30	4	3	3	20	0.8	77
a	Dedicated Lane	0.	6	46	52	43	48	В .	58 3	3	1.2	3	30	1.3	59
58	Managed Lane	0.	6	55	57	51	58	8 6	35 3	3	1.2	3	25	1.0	65
	Standard Bus)	0	60	60	56	75	5 8	30 ()	0	6	20	0.8	86

NOTES

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SOURCES

TSP Time Savings Apex Design Accel/Decel Time Loss Madison Area MPO

Queue Jumps Apex Design Dwell Time NBRTI

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



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

Route distance (miles): 27.7 Stops: 11

		Corridor with Dedicated or	•	Time (mins) - 2016	- 2015 Travel	Travel Time (mins) - 2040	. ,	Savings	Savings	Dwell Tim		Acceleration & eed Deceleration T	ime TRA	AVEL
		Managed Lanes	Section End-to-End		Demand Model	Travel Demand Model	Projection	(mins)	(mins)	(mins)	(mph)	Loss (mins)	TIM	E
-	Auto	0	60	60	4	60	7	7 ()	0	0	20	0.0	77
Ē	Mixed Traffic	0	60	60	4	' 60	7	7 4	1	3	3	20	8.0	75
tp.	Dedicated Lane	0.6	47	52	4	46	5	3	3	1.2	3	30	1.3	59
es	Managed Lane	0.6	56	58	5 5	55	5 6	4 3	}	1.2	3	25	1.0	64
>	Standard Bus	0	60	60	4	7 60	77	7 ()	0	6	20	8.0	84
	Auto	0	60	60	50	75	5 80) ()	0	0	20	0.0	80
Ĕ	Mixed Traffic	0	60	60	56	75	5 80) 4	1	3	3	20	8.0	77
g	Dedicated Lane	0.6	46	52	2 43	3 48	3 58	3	3	1.2	3	30	1.3	59
Se	Managed Lane	0.6	55	57	5	58	6	5 3	3	1.2	3	25	1.0	65
ш	Standard Bus	0	60	60	50	5 75	5 80) ()	0	6	20	8.0	86

NOTES

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SOURCES

TSP Time Savings Accel/Decel Time Loss Queue Jumps Dwell Time Apex Design Madison Area MPO Apex Design NBRTI

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

https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf



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	,	Vehicular Travel Time (mins) - 2016	Travel Time (mins) - 2015 Travel	Travel Time (mins) - 2040	Vehicular Travel Time (mins) - 2040 Scaled		Queue Jump Time Savings Dwell Tim	e Average Speed		TOTAL TRAVEL
		Managed Lanes	Cross Section End-to-End	Google Maps	Demand Model	Travel Demand Model	Projection	Savings (mins)	(mins) (mins)	(mph)	Loss (mins)	TIME
	Auto	C	60	60	47	60	77	. 0	0	0 20	0.0	77
Š	Mixed Traffic	C	60	60	0 47	60	77	4	3	3 20	0.8	75
tp p	Dedicated Lane	0.6	47	52	2 41	46	5 58	3	1.2	3 30	1.3	59
/est	Managed Lane	0.6	56	58	3 50	55	5 64	3	1.2	3 25	أ.0	64
>	Standard Bus	C	60	60) 47	60	77	0	0	6 20	0.8	84
	Auto	C	60	60	56	75	5 80	0	0	0 20	0.0	80
Ĕ	Mixed Traffic	C	60	60	56	75	5 80	4	3	3 20	0.8	77
g	Dedicated Lane	0.6	46	52	2 43	48	3 58	3	1.2	3 30) 1.3	59
as	Managed Lane	0.6	55	57	7 51	58	3 65	3	1.2	3 25	أ.0	65
ш	Standard Bus	C	60	60	56	75	5 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
Queue Jumps Apex Design

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

Dwell Time NBRTI 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	Travel Time (2016 Google Maps) Assuming Consistent				Vehicular Travel Time (mins) - 2040 Scaled			Dwell Time A			OTAL RAVEL
		Managed Lanes	Cross Section End-to-End	Google Maps	Demand Model	Model	Projection	(mins)	(mins)	(mins) (m	nph) Loss (n	mins) TI	IME
	Auto	0	60	60	46	58	3 77		0	0	20	0.0	77
Ē	Mixed Traffic	0	60	60	46	58	3 77	4	3	3	20	0.8	74
ĕ	Dedicated Lane	0.6	46	52	40	44	57	3	1.2	3	30	1.1	57
les	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	3 77	. 0	0	5	20	0.8	82
	Auto	0	60	60	56	73	79		0	0	20	0.0	79
Ĕ	Mixed Traffic	0	60	60	56	73	79	4	. 3	3	20	0.8	76
율	Dedicated Lane	0.6	45	51	42	47	57	3	1.2	3	30	1.1	57
Ses	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

NOTES

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SOURCES

TSP Time Savings Apex Design
Accel/Decel Time Loss Madison Area MPO
Queue Jumps Apex Design
Dwell Time NBRTI

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

well Time NBRTI https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf



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

 Route distance (miles):
 29.7

 Stops:
 11

		Percent of Travel Time within	Travel Time (2016 Google Maps)				Vehicular Travel Time				1	Acceleration & TOTAL
		Corridor with Dedicated or	Assuming Consistent Cross Section	n Time (mins) - 2016	2015 Travel Demand	2040 Travel Demand	(mins) - 2040 Scaled	TSP Time	Queue Jump Time	Dwell Time	Average Speed [Deceleration Time TRAVEL
		Managed Lanes	End-to-End	Google Maps	Model	Model	Projection	Savings (mins)	Savings (mins)	(mins)	(mph) L	Loss (mins) TIME
-	Auto	0	6	5 6	5) 6-	4 83	3 0	C) 0	20	0.0 83
Ē	Mixed Traffic	0	6	5 6	5 50) 6	4 83	3 4	3	3	20	0.8 80
Vestbo	Dedicated Lane	0.6	5	1 56.6	6 44	4 4	6	1 3	1.2	2 3	30	1.3 62
	Managed Lane	0.6	6	1 62.73	2 50	5	7 68	3	1.2	2 3	. 25	1.0 68
_ >	Standard Bus	0	6	5 6	5 50) 6-	4 83	3 0	C) 6	20	0.8 89
	Auto	0	6	0 6) 59	9 78	3 79	9 0	C) 0	25	0.0 79
Ĕ	Mixed Traffic	0	6	0 6	59	9 70	3 79	9 4	3	3	25	1.0 76
ĝ	Dedicated Lane	0.6	4	9 53.4	4:	5 49	9 58	3	1.2	2 3	30	1.3 59
05	Managed Lane	0.6	5	9 59.2	5-	1 59	9 65	5 3	1.2	2 3	25	1.0 65
	Standard Bus	0	6	0 6	55	70	3 79	9 0	C) 6	25	1.0 85

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SOURCES

TSP Time Savings Apex Design
Accel/Decel Time Loss Madison Area MPO
Queue Jumps Apex Design

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Dwell Time NBRTI https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf



Operating Scenario 4: Boulder to Brighton Basic plus Lafayette Service

Route distance (miles): Stops:

		Percent of Travel Time within	Travel Time (2016 Google	Vehicular Travel	Travel Time (mins) -	Travel Time (mins) -	Vehicular Travel					Acceleration &	TOTAL	
		Corridor with Dedicated or	Maps) Assuming Consistent	Time (mins) - 2016	2015 Travel	2040 Travel Demand	Time (mins) - 2040	TSP Time	Queue Jump Time	Dwell Time	e Average Speed	Deceleration Tim	e TRAVE	:L
		Managed Lanes	Cross Section End-to-End	Google Maps	Demand Model	Model	Scaled Projection	Savings (mins)	Savings (mins)	(mins)	(mph)	Loss (mins)	TIME	
77	Auto	(33	33	23	30	44	4 0	()	0 1	5 0	.0	44
Š	Mixed Traffic		33	33	23	30	44	1 2	3	1	2 1	5 0	.3	41
₽ P	Dedicated Lane	0.6	25	28.2	20	22	30	2	1.2	2	2 2	5 0	.4	30
Ves	Managed Lane	0.6	30	31.2	24	26	34	1 2	1.2	2	2 2	0 0	.3	33
>	Standard Bus	(33	33	23	30	44	1 0	()	3 1	5 0	.3	47
	Auto	(30	30	26	41	46	6 0	()	0 1:	5 0	.0	46
Ĕ	Mixed Traffic		30	30	26	41	46	3 2	3	1	2 1	5 0	.3	43
g	Dedicated Lane	0.6	23	25.8	20	21	28	3 1	1.2		2 2	5 0	.4	27
Se	Managed Lane	0.6	28	28.56	24	26	3	1 2	1.2		2 2	5 0	.4	30
ш	Standard Bus	(30) 30	26	41	46	6 0	()	3 1	5 0	.3	49

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

NOTES

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White cells have equations and will auto-populate

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 Queue Jumps

Apex Design

Dwell Time NBRTI https://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf