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Date: July 24, 2018

To: Eric Farrell, Developer
Mark Smith, Traffic Engineer Resource Systems Group
Tony Reddington, Interested Burlington Citizen
Jim Holway, Interested Burlington Citizen

C.C. Chapin Spencer, Director of Public Works

From: Norman J. Baldwin, P.E.
City Engineer/Ass't Director of Public Works

Subject: Cambrian Rise-Review of Mini-Roundabout Proposal South Road and North Avenue

In reviewing the proposal provided by Eric Farrell's Traffic Consultant, Mark Smith of RSG and the independent research regarding Roundabout Design, I have considered the following facts and I am providing my recommendation.

Here are my given assumptions; I have made use of these assumptions to render my recommendation:

- North Avenue Right of Way is a 66-foot right of way, and no other opportunities for land acquisition are available.
- Design Year 2027, PM Peak Hour Traffic-
- Assuming .5% annual growth, (CCRPC uses .6% for North Ave Corridor, Cambrian rise .47%)
- Assuming 75% of the traffic will make use of South Road, 25% North Road
- 2016 AADT-11,042 vpd
- 2018 AADT=11,042(1+.005)^2=11,042*1.010=11,152 vpd
- 2019 AADT=(11,152 vpd*1.005)+.25*4,500 vpd)=11,208 vpd+1,125 vpd=12,333 vpd, Phase I Developed
- 2020 AADT=(12,333 vpd*1.005)+.25*4,500 vpd)=12,392 vpd+1,125 vpd=13,519 vpd, Phase II Developed
- 2021 AADT=(13,519 vpd*1.005)+.25*4,500 vpd)=13,587 vpd+1,125 vpd=14,712 vpd, Phase III Developed
- 2022 AADT=(14,712 vpd*1.005)=14,785 vpd, Phase IV Developed access to North Rd. available
- 2023 AADT=(14,785 vpd*1.005)=14,858 vpd, Full Build Out Year after
- 2024 AADT=(14,858 vpd*1.005)=14,932 vpd, Full Build Out 2 Years after
- 2025 AADT=(14,932 vpd*1.005)=15,006 vpd, Full Build Out 3 years after
- 2026 AADT=(15,006 vpd*1.005)=15,081 vpd, Full Build Out 4 years after
- 2027 AADT=(15,081 vpd*1.005)=15,157 vpd, Full Build Out 5 years after

- Inscribed Circle Diameter-57'
- Circulatory Roadway Width-30'
- Cross Street Traffic 4,500 vpd
- 1% truck traffic During Peak Hour

Conclusions:

Check #1: AADT Capacity of 50' ICD Mini-Roundabout

Given the entering traffic volumes, the dimensional limitations of the Right of Way, the proposed dimensions of the roundabout proposed as a Mini-Roundabout.

Cross Street Traffic(Cambrian Rise-South Road)=3,375 vpd
Major Street Traffic(North Avenue)=11,152 vpd

% Cross Street Traffic=3,375 vpd/(11,152 vpd+3,375 vpd)
=23.2%

Referencing Transportation Research Boards, Roundabouts: An informational Guide, Second Edition, Exhibit 3-16, Page 3-25,

Assuming 30% Left Turns, 22% Cross Street Traffic, the Exhibit Indicates a Maximum AADT of 12,500 vpd for a Mini-Roundabout.

Comparing the referenced exhibit against the predicted AADT's. This suggests that capacity for the proposed Mini-Roundabout will exceed the performance capacity ratio by 2020.

Check #2: PM Peak Hour Design Year 2042

In addition to the AADT analysis above I took the opportunity to email Wei Zheng, Ph.D., P.E.,Highway Research Engineer/Program Manager, Intersection Safety R&D, FHWA Office of Safety R&D. I had asked if he had any suggested performance analysis tools that would be useful to performing an operational analysis for a mini-roundabout.

In response, Mr.Zheng provided some example mini-roundabout installations and offered the following commentary.

"We have evaluated 15 mini-roundabouts in 7 states, including snow regions in Michigan and Minnesota. In my experience, for intersections on 2-lane and 3-lane roads, a mini-roundabout has the same or higher capacity than traffic signal (especially if the left-turn volumes are high), plus less demand for ROW, and less delay during non-peak hours. If the total peak hour demand is 1,300 vph or less, a mini-roundabout will work."

He then provided me with the Roundabout Planning/Operational Analysis tool entitled "CAP-X".

2027 PM Peak Hour Demand Totals-1,754 vph(RSG TIS dated 12.21.16, PM 2027 Build) exceeds suggested 1,300 vph as suggest above.

2027 PM Peak+15 years (20 Year Design Life), assuming 2% Heavy Vehicle Traffic, and .5% growth for the additional 15 years, the analysis tool indicated for:

- 50' ICD Mini-Roundabout, **V/C ratio of .96**
- 75' ICD Mini-Roundabout, **V/C ratio of .93**

2027 PM Peak+5 years (10 year Design Life), assuming 2% Heavy Vehicle Traffic, and .5% growth for the additional 5 years, the analysis tool indicated for:

- 50' ICD Mini-Roundabout, **V/C ratio of .90**
- 75' ICD Mini-Roundabout, **V/C ratio of .88**

1 Transportation Research Board, NCHRP Report 672, Roundabouts An Information Guide, https://www.nap.edu/read/22914/chapter/4#67

According to reference materials at a v/c>=.85 the predicted performance of a roundabout begins to be more random and unpredictable.

RECOMMENDATION:

Given both methods operational analysis of the proposed 50' ICD Mini-Roundabout indicate exceedance prior to or shortly after full build out. It is my recommendation that we **not support** the request to consider the installation of a Mini-Roundabout. I welcome further conversations if I have in anyway misunderstood the constraint parameters.

1 Transportation Research Board, NCHRP Report 672, Roundabouts An Information Guide, https://www.nap.edu/read/22914/chapter/4#67

Capacity Analysis for Planning of Junctions

Input Worksheet

Project Name:	*Cambrian Rise Mini-Roundabout Site Evaluation*
Project Number:	*2027 North Avenue and South Road PM Peak+15 Years*
Location	*North Avenue and South Road, Burlington, Vermont*
Date	April 15, 2018

Traffic Volume Demand

	Volume (Veh/hr)				Percent (%)	
	U-Turn	**Left**	**Thru**	**Right**	Truck	Volume Growth
Eastbound	0	37	0	128	2.00%	7.50%
Westbound	0	1	0	1	2.00%	7.50%
Southbound	0	1	677	50	2.00%	7.50%
Northbound	0	158	700	1	2.00%	7.50%
Adjustment Factor	0.80	0.95		0.85		
Suggested	**0.80**	**0.95**		**0.85**		
Truck to PCE Factor				**Suggested = 2.00**	2.00	
Critical Lane Volume				1600		

Equivalent Pasenger Car Volume

	Volume (Veh/hr)			
	U-Turn	**Left**	**Thru**	**Right**
Eastbound	0	41	0	140
Westbound	0	1	0	1
Southbound	0	1	742	55
Northbound	0	173	768	1

Notes:	
Left-Turn Adjustment Factor	*Conversion of left-turning vehicles to equivalent through vehicles*
Right-turn Adjustment Factor	*Conversion of right-turning vehicles to equivalent through vehicles*
U-turn Adjustment Factor	*Conversion of U-turning vehicles to equivalent through vehicles*
Truck to PCE Factor	*1 truck = X Passenger Car Equivalents*
Critical Lane Volume Sum Limit	*Saturation Value for Critical Lane Volume Sum at an intersection*

Capacity Analysis for Planning of Junctions

Input Worksheet

Project Name:	*Cambrian Rise Mini-Roundabout Site Evaluation*
Project Number:	*2027 North Avenue and South Road PM Peak+15 Years*
Location	*North Avenue and South Road, Burlington, Vermont*
Date	April 15, 2018

Critical Lane Volume Sum			
Acceptable Configurations			
< 1200	1200 - 1399	1400 - 1599	≥ 1600
27	2	3	0

Results for Intersections

#	TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)		Overall v/c Ratio	Ranking
			CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
1	Conventional	FULL									584	0.37	0.37	7
2	Conventional Shared RT LN	CSRL									753	0.47	0.47	14
3.1	Quadrant Roadway	S-W			596	0.37			214	0.13	385	0.24	0.37	8
3.2		N-E	447	0.28			204	0.13			635	0.40	0.40	12
3.3		S-E			488	0.31	488	0.31			549	0.34	0.34	1
3.4		N-W	596	0.37					295	0.18	635	0.40	0.40	11
4.1	Partial Displaced Left Turn	N-S	406	0.25	554	0.35					406	0.25	0.35	3
4.2		E-W					1	0.00	79	0.05	575	0.36	0.36	6
5	Displaced Left Turn	FULL	406	0.25	554	0.35	1	0.00	79	0.05	406	0.25	0.35	3
6.1	Restricted Crossing U-Turn	N-S	400	0.25	497	0.31	406	0.25	554	0.35			0.35	3
6.2		E-W	1507	0.94	1592	0.99	589	0.37	555	0.35			0.99	15
7.1	Median U-Turn	N-S	508	0.32	497	0.31					683	0.43	0.43	13
7.2		E-W					135	0.08	92	0.06	550	0.34	0.34	2
8.1	Partial Median U-Turn	N-S	615	0.38	472	0.30					601	0.38	0.38	10
8.2		E-W					27	0.02	91	0.06	601	0.38	0.38	9

Capacity Analysis for Planning of Junctions

Input Worksheet

Results for Roundabouts

#	TYPE OF ROUNDABOUT	Zone 1 (North)			Zone 3 (East)			Zone 2 (South)			Zone 4 (West)			Overall v/c Ratio	Ranking
		Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3		
9.1	50 ICD	0.96			0.83			0.93			0.19			0.96	7
9.2	75 ICD	0.92			0.59			0.93			0.02			0.93	6
9.3	1 X 1	0.84			0.34			0.87			0.00			0.87	5
9.4	1 X 2	0.80			0.08	0.26		0.86			0.00	0.00		0.86	4
9.5	2 X 1	0.39	0.45		0.27			0.51	0.36		0.00			0.51	3
9.6	2 X 2	0.38	0.43		0.00	0.00		0.51	0.35		0.06	0.21		0.51	2
9.7	3 X 3	0.00	0.37	0.40	0.04	0.04	0.20	0.08	0.41	0.34	0.00	0.00	0.00	0.41	1

Results for Interchanges

#	TYPE OF INTERCHANGE	Sheet	Zone 1 (Rt Mrg)		Zone 2 (Lt Mrg)		Zone 3 (Ctr. 1)		Zone 4 (Ctr. 2)		Zone 5 (Lt Mrg)		Zone 6 (Rt Mrg)		Overall v/c Ratio	Ranking
			CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
10.1	Diamond	N-S					453	0.28	358	0.22					0.28	6
10.2		E-W					113	0.07	88	0.05					0.07	2
11.1	Partial Cloverleaf	N-S					430	0.27	315	0.20					0.27	5
11.2		E-W					42	0.28	43	0.03					0.03	1
13.1	Displaced Left Turn	N-S	406	0.25			406	0.25	425	0.27			554	0.35	0.35	7
13.2		E-W	144	0.09			88	0.05	183	0.11			2	0.00	0.11	4
14.1	Double Crossover Diamond	N-S	406	0.25	373	0.23	776	0.49	842	0.53	514	0.32	519	0.32	0.53	8
14.2		E-W	151	0.09	107	0.07	22	0.01	183	0.11	1	0.00	2	0.00	0.11	3
15.1	Single Point	N-S	271	0.17			689	0.43					412	0.26	0.43	#N/A
15.2		E-W	151	0.09			225	0.14					2	0.00	0.14	#N/A

Capacity Analysis for Planning of Junctions

Input Worksheet

Project Name:	*Cambrian Rise Mini-Roundabout Site Evaluation*
Project Number:	*2027 North Avenue and South Road PM Peak+5 Years*
Location	*North Avneue and South Road, Burlington, Vermont*
Date	April 15, 2018

Traffic Volume Demand

	Volume (Veh/hr)				Percent (%)	
	U-Turn	**Left**	**Thru**	**Right**	Truck	Volume Growth
Eastbound	0	37	0	128	2.00%	2.50%
Westbound	0	1	0	1	2.00%	2.50%
Southbound	0	1	677	50	2.00%	2.50%
Northbound	0	158	700	1	2.00%	
Adjustment Factor	0.80	0.95		0.85		
Suggested	**0.80**	**0.95**		**0.85**		
Truck to PCE Factor				**Suggested = 2.00**	2.00	
Critical Lane Volume					1600	

Equivalent Pasenger Car Volume

	Volume (Veh/hr)			
	U-Turn	**Left**	**Thru**	**Right**
Eastbound	0	39	0	134
Westbound	0	1	0	1
Southbound	0	1	708	52
Northbound	0	161	714	1

Notes:	
Left-Turn Adjustment Factor	*Conversion of left-turning vehicles to equivalent through vehicles*
Right-turn Adjustment Factor	*Conversion of right-turning vehicles to equivalent through vehicles*
U-turn Adjustment Factor	*Conversion of U-turning vehicles to equivalent through vehicles*
Truck to PCE Factor	*1 truck = X Passenger Car Equivalents*
Critical Lane Volume Sum Limit	*Saturation Value for Critical Lane Volume Sum at an intersection*

Capacity Analysis for Planning of Junctions

Input Worksheet

Project Name:	*Cambrian Rise Mini-Roundabout Site Evaluation*
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Critical Lane Volume Sum			
Acceptable Configurations			
< 1200	1200 - 1399	1400 - 1599	≥ 1600
27	3	2	0

Results for Intersections

#	TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)		Overall v/c Ratio	Ranking
			CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
1	Conventional	FULL									553	*0.35*	0.35	7
2	Conventional Shared RT LN	CSRL									714	*0.45*	0.45	14
3.1	Quadrant Roadway	S-W			565	*0.35*			205	*0.13*	358	*0.22*	0.35	8
3.2		N-E	426	*0.27*			190	*0.12*			595	*0.37*	0.37	12
3.3		S-E			466	*0.29*	466	*0.29*			515	*0.32*	0.32	1
3.4		N-W	565	*0.35*					277	*0.17*	595	*0.37*	0.37	11
4.1	Partial Displaced Left Turn	N-S	378	*0.24*	524	*0.33*					378	*0.24*	0.33	3
4.2		E-W					1	*0.00*	74	*0.05*	544	*0.34*	0.34	6
5	Displaced Left Turn	FULL	378	*0.24*	524	*0.33*	1	*0.00*	74	*0.05*	378	*0.24*	0.33	3
6.1	Restricted Crossing U-Turn	N-S	381	*0.24*	462	*0.29*	378	*0.24*	524	*0.33*			0.33	3
6.2		E-W	1438	*0.90*	1506	*0.94*	548	*0.34*	530	*0.33*			0.94	15
7.1	Median U-Turn	N-S	482	*0.30*	463	*0.29*					641	*0.40*	0.40	13
7.2		E-W					126	*0.08*	88	*0.05*	516	*0.32*	0.32	2
8.1	Partial Median U-Turn	N-S	582	*0.36*	439	*0.27*					569	*0.36*	0.36	10
8.2		E-W					25	*0.02*	87	*0.05*	569	*0.36*	0.36	9

Capacity Analysis for Planning of Junctions

Input Worksheet

Results for Roundabouts

#	TYPE OF ROUNDABOUT	Zone 1 (North)			Zone 3 (East)			Zone 2 (South)			Zone 4 (West)			Overall v/c Ratio	Ranking
		Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3		
9.1	50 ICD	0.90			0.70			0.86			0.03			0.90	7
9.2	75 ICD	0.87			0.51			0.86			0.01			0.87	6
9.3	1 X 1	0.79			0.31			0.81			0.00			0.81	5
9.4	1 X 2	0.75			0.07	0.24		0.80			0.00	0.00		0.80	4
9.5	2 X 1	0.37	0.42		0.25			0.48	0.33		0.00			0.48	3
9.6	2 X 2	0.35	0.40		0.00	0.00		0.47	0.33		0.06	0.19		0.47	2
9.7	3 X 3	0.00	0.35	0.38	0.03	0.03	0.18	0.07	0.38	0.31	0.00	0.00	0.00	0.38	1

Results for Interchanges

#	TYPE OF INTERCHANGE	Sheet	Zone 1 (Rt Mrg)		Zone 2 (Lt Mrg)		Zone 3 (Ctr. 1)		Zone 4 (Ctr. 2)		Zone 5 (Lt Mrg)		Zone 6 (Rt Mrg)		Overall v/c Ratio	Ranking
			CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
10.1	Diamond	N-S					422	0.26	334	0.21					0.26	6
10.2		E-W					106	0.07	82	0.05					0.07	2
11.1	Partial Cloverleaf	N-S					406	0.25	293	0.18					0.25	5
11.2		E-W					40	0.27	41	0.03					0.03	1
13.1	Displaced Left Turn	N-S	378	0.24			378	0.24	396	0.25			524	0.33	0.33	7
13.2		E-W	135	0.08			82	0.05	171	0.11			2	0.00	0.11	4
14.1	Double Crossover Diamond	N-S	378	0.24	356	0.22	731	0.46	792	0.50	479	0.30	496	0.31	0.50	8
14.2		E-W	142	0.09	100	0.06	21	0.01	170	0.11	1	0.00	2	0.00	0.11	3
15.1	Single Point	N-S	252	0.16			651	0.41					394	0.25	0.41	#N/A
15.2		E-W	142	0.09			211	0.13					2	0.00	0.13	#N/A