Impact Study:

Converting Six Cross Intersections to Low-Speed Modern Roundabouts in Clearwater, Florida

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National Roundabout Conference
Transportation Research Board
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City of Clearwater

Cleveland Street Corridor

= *Signal controlled*

= *Stop controlled*


John F. Kennedy Middle School Roundabout
Clearwater, Florida
48 at schools
in the USA
National Roundabout Conference 2005 DRAFT
Wade-Trim

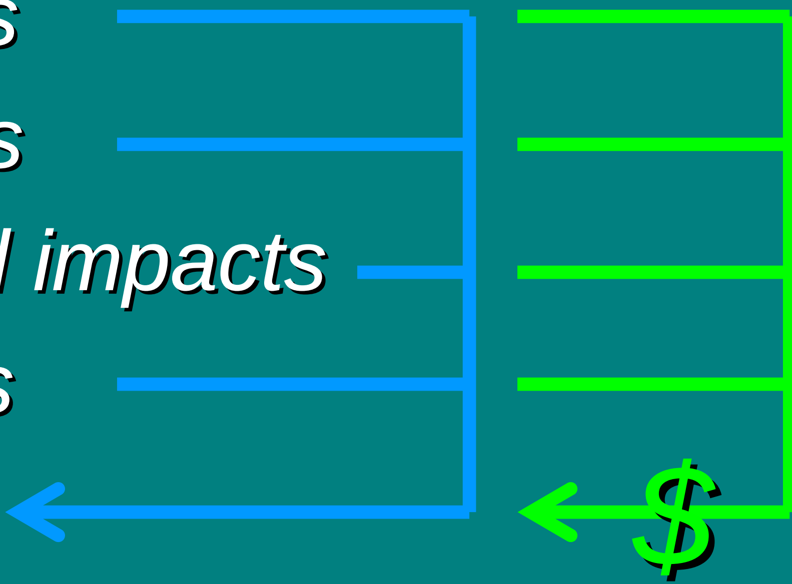
Study became more comprehensive

- *Originally a Signal Removal Study (1970 FHWA)*
- *Updated scope to encompass contemporary concerns: environment, society, etc.*
- *Considered 69 impacts*
  - *65 in non-monetary terms*
  - *5 in monetary terms*
- *Grew to 100+ pages, 200+ footnotes*

The study sets forth a comprehensive approach to evaluating the impacts of converting conventional cross intersections to modern roundabouts, provides a crash prediction methodology, and provides a template for Benefit-Cost Analysis.

Areas of Impact

1. *Traffic impacts*
2. *Safety impacts*
3. *Environmental impacts*
4. *Social impacts*
5. *Cost impacts*



Benefit Cost Analysis

Areas of Impact

1. Traffic impacts

- *Flow*
- *Trucks: fire, solid waste, WB-50's, SU*
- *Street network*
- *Future growth*
- *Non-motorized traffic flow*
- *Skycrest Elementary School*
- *Miscellaneous (8)*
- *Possible contraindications (11)*

Table 25. Traffic Impacts Expressed in Non-Monetary Terms

Area of Impact	Impact		Cost = C Benefit = B
Free flow	1	All intersections users prefer to stay in motion; prefer not to have to come to a stop; and prefer not to be stopped and waiting	B
Level of Service (LOS) (p.16)	2	Improved +0.67 grade	B
Delay (p. 8)	3	Reduced by 1/3	B
Queue length (p. 17)	4	Reduced by ¼	B
Delay to the driving public (p. 18)	5	Reduced by 5,222 person-hours	B
Truck traffic (p. 19)	6	No significant adverse affect	-
Keene Road (p. 22)	7	No impact	-
Street network (p. 23)	8	No impact	-
Future growth (p. 23)	9	No impact	-
Non-motorized traffic (p. 24)	10	Reduced delay	B
	11	Improved mobility	B
	12	Improved Level Of Service (LOS)	B
Skycrest Elementary School (p. 24)	13	Improved congestion management	B
	14	Improved 1-way operation on Corona Avenue	B
Physical and right-of-way features (p. 26)	15	No adverse impact	-
Current and planned site development features (p. 26)	16	Enhanced attractiveness of the corridor will benefit developments.	B
Certain community considerations (p. 26)	17	No adverse impact	-
Traffic management strategies (p. 26)	18	No adverse impact	-
Public transit (p. 27)	19	The low-speed environment facilitates public transit safety and environment.	B
Adjacent intersection treatments (p. 27)	20	No adverse impact	-
Public complaints (p. 27)	21	The project is responsive to the complaints.	B
Other roundabouts in the jurisdiction (p. 27)	22	No adverse impact	-
Physical or geometric features (p. 28)	23	No adverse impact	-
Land use or traffic generators (p. 28)	24	No adverse impact	-
Other traffic control devices requiring pre-emption (p. 28)	25	No adverse impact	-
Bottlenecks on intersecting roadways (p. 29)	26	No adverse impact	-
Sight distances (p. 29)	27	No adverse impact	-
Platooned arterial traffic flow (p. 29)	28	No adverse impact	-
Heavy use by persons with special needs (p. 30)	29	No adverse impact	-
Safety projects to benefit older drivers (p. 30)	30	No adverse impact	-
Emergency vehicle operations coordination requirements (p. 30)	31	No adverse impact	-
Emergency evacuation (p. 30)	32	No adverse impact	-

Areas of Impact

2. Safety impacts

- Crashes
  - Frequency & severity
- Older users
- Non-motorized users
  - Pedestrians
  - Older pedestrians
  - Children
  - Bicyclists & skaters
  - Impaired users: mobility, visually, cognitively
  - Complexity

Crash Prediction Methodology

Alternate methodologies

1) UK safety performance prediction model
   - UK-based
   - Does not take into account individual characteristics of crashes that have actually occurred at the cross intersection
2) Apply crash rates obtained elsewhere
   - Convenient
   - US data base is small and confounded with mix of single- & multi-lane, low- & hi-speed, well- & ill-designed roundabouts

Study methodology

Examine actual crash history, determine whether each crash would have been less likely to occur at a low-speed modern roundabout

Crash Prediction Methodology

The table below gives the past three years of crash history, divided into the seven categories.

Table 8. Crash History (36 months)							
Collision Category							Total
Right-Angle	Left-Turn	Backing Vehicle (driveway)	Rear End	Side-swipe	Out of Control #1	Out of Control #2	
18	5	4	7	3	1	1	39

The table above shows a total of 39 *reported* crashes have occurred at the six intersections in the past 3 years, or more than one reported crash a month.

Applying the above determinations to the crash history results in the table below.

Table 9. Crashes That Typically Would be Prevented by a Modern Roundabout (36 mo.)

	Collision Category						
	Right-Angle	Left-Turn	Backing Vehicle (driveway)	Rear End	Side-swipe	Out of Control #1	Out of Control #2
Crash history	18	5	4	7	3	1	1
Reduction	**100%**	**100%**	**50%**	**50%**	**100%**	**50%**	**100%**
Eliminated crashes	**18**	**5**	**2**	**3.5**	**3**	**.5**	**1**

The table above shows the likely reduction in crashes had these six intersections been modern roundabouts.

Summing the injury data from the prevented crashes gives the table below.

Table 10. Injuries Associated with the Prevented Crashes (36 months)				
K	A	B	C	O
Fatalities	Incapacitating Injuries	Non-incapacitating Injuries	Possible Injuries	No Apparent Injuries (PDO)
2	0	8.5	5.5	19

The table above shows the injuries associated with the crashes that typically would be reduced had the six intersections been modern roundabouts. This table will be referred to later under *Cost Impacts* in the section on *Cost of Crashes* (p.80).

Table 26. Safety Impacts Expressed in Non-Monetary Terms

Area of Impact		Impact	Cost = C Benefit = B
Motorists (p. 32)	34	Fewer crashes	B
	35	Less severe crashes	B
	36	Most lethal crash types eliminated	B
	37	Vehicle/vehicle conflicts reduced by ¾	B
	38	Increased non-motorized travel options	B
Pedestrians (p. 45)	·	Increased comfort and mobility	B
	39	Much lower, safer vehicle speeds	B
	40	Shorter crossing exposure distance/time	B
	41	Pedestrian/vehicle conflicts reduced by 2/3	B
Older drivers (p. 39)	42	Less complexity	B
	43	No left turns in front of oncoming traffic	B
	44	Less demanding time-constrained decisions	B
	45	Lower demands on vision, flexibility and reaction time	B
	46	More time for other drivers to compensate for older drivers' errors	B
Older pedestrians (p. 50)	·	Increased comfort and mobility	B
	·	Shorter crossing exposure distance/time	B
Child pedestrians (p. 51)	·	Less complexity	B
	·	Much lower, safer vehicle speeds	B
	·	Shorter crossing exposure distance/time	B
	·	More time for drivers' to compensate for children's errors	B
Bicyclists & skaters (p. 52) Mobility impaired users (p. 52)	·	Increased comfort and mobility	B
	·	Much lower, safer vehicle speeds	B
	·	Shorter crossing exposure distance/time	B
	·	More time for drivers' to compensate for non-motorized users' errors	B
Pedestrians with impaired vision (p. 52)	·	Less complexity	B
	·	Much lower, safer vehicle speeds	B
	47	Missing aural cues sometimes available at signals	C
	·	More time for drivers to compensate for visually impaired users' errors	B
	48	Curb return pedestrian ramps, splitter island crosswalk curbs and superior installed truncated domes surfaces help wayfinding	B
Cognitively impaired pedestrians (p. 57)	·	Less complexity	B
	·	Much lower, safer vehicle speeds	B
	·	More time for drivers to compensate for cognitively impaired users' errors	B
	49	visually and texturally emphasized crosswalks make it more apparent where to cross safely	B

Intersection Rules	
Roundabout	**Signalized**

1. Yield to traffic already in the roundabout
 	
Note: Vehicles in the roundabout *always* have the right-of-way
	1. If the signal is a **red ball**, come to a complete stop
	  a) After stopping, you may turn right (legal in Florida, but not in all states) but must yield to oncoming traffic; except if the sign says "NO TURN ON RED", you cannot
	  b) After stopping, you may turn left on red from a one-way street onto a one-way street (legal in Florida, but not in all states) but must yield to oncoming traffic
	2. If the signal is a **green ball**
	  a) you may go straight or turn right, but only if the way is clear – you must yield to vehicles still in the intersection
	  b) you may turn left but must yield to oncoming traffic
	3. If the signal is a [illegible]
	  a) you may go straight or turn right
	  b) you may turn left but must yield to oncoming traffic
	4. If there is one signal head for several lanes, it applies to all those lanes; if there is a signal head for each lane, each lane is governed by its own signal head; and if there are multiple heads but not as many as there are lanes, generally a head centered above a lane governs that lane, a single head located above the line dividing two lanes governs both lanes, and a single head centered above three lanes governs all three lanes
	5. If the signal for your lane is a **red arrow** pointing left or right, come to a complete stop
	  a) After stopping, you may turn right on red but must yield to oncoming traffic (legal in Florida, but not in all states); except if the sign says "NO TURN ON RED", you cannot
	  b) After stopping, you may turn left from a one-way street onto a one-way street (legal in Florida, but not in all states); except if the sign says "NO TURN ON RED", you cannot
	6. If the signal for your lane is a **red arrow** pointing up, you may not go straight
	7. If the signal for your lane is a **green arrow** pointing left or right, you may turn in the direction of the arrow, after yielding the right-of-way to vehicles within the intersection, even if the red light is burning at the same time
	8. If the signal for your lane is a **green arrow** pointing up, you may go straight, after yielding the right-of-way to vehicles within the intersection, even if the red light is burning at the same time
	9. If the signal for your lane is a [illegible], it means the same thing as the [illegible], but applies only to movement in the direction of the arrow
	10. If the signal is a **blinking red ball**, come to a complete stop and then enter the intersection, except you must yield to other vehicles already in the intersection
	11. If the signal is a [illegible], enter the intersection with caution, except you must yield to other vehicles already in the intersection
	12. If none of the bulbs on the signal head are illuminated (power outage), come to a complete stop and then enter the intersection with caution, except you must yield to other vehicles already in the intersection
	
	Note: Who has the right-of-way *changes* every few seconds as the phase sequence cycles

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Special Users

Pedestrians
Older drivers
Older pedestrians
Children
Mobility impaired
Visually impaired
Cognitively impaired

Roundabout features

- *Low vehicle speeds*
- *Reduced ped exposure*
  - *Xing 1 direction at a time*
  - *Xing fewer lanes at a time*
  - *Short crossing distance*
  - *Pedestrian refuges*
- *Reduced complexity*
  - *Fewer veh/veh conflicts*
  - *Fewer ped/veh conflicts*
  - *No phases, codes, etc.*
  - *Simpler rules of operation*
- *Truncated domes*
- *Curb return ped ramp*

Special Users

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Special Users

- *Pedestrians*
- *Older drivers*
- *Older pedestrians*
- *Children*
- *Mobility impaired*
- *Visually impaired*
- *Cognitively impaired*

Roundabout features

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- *Curb return ped ramp*

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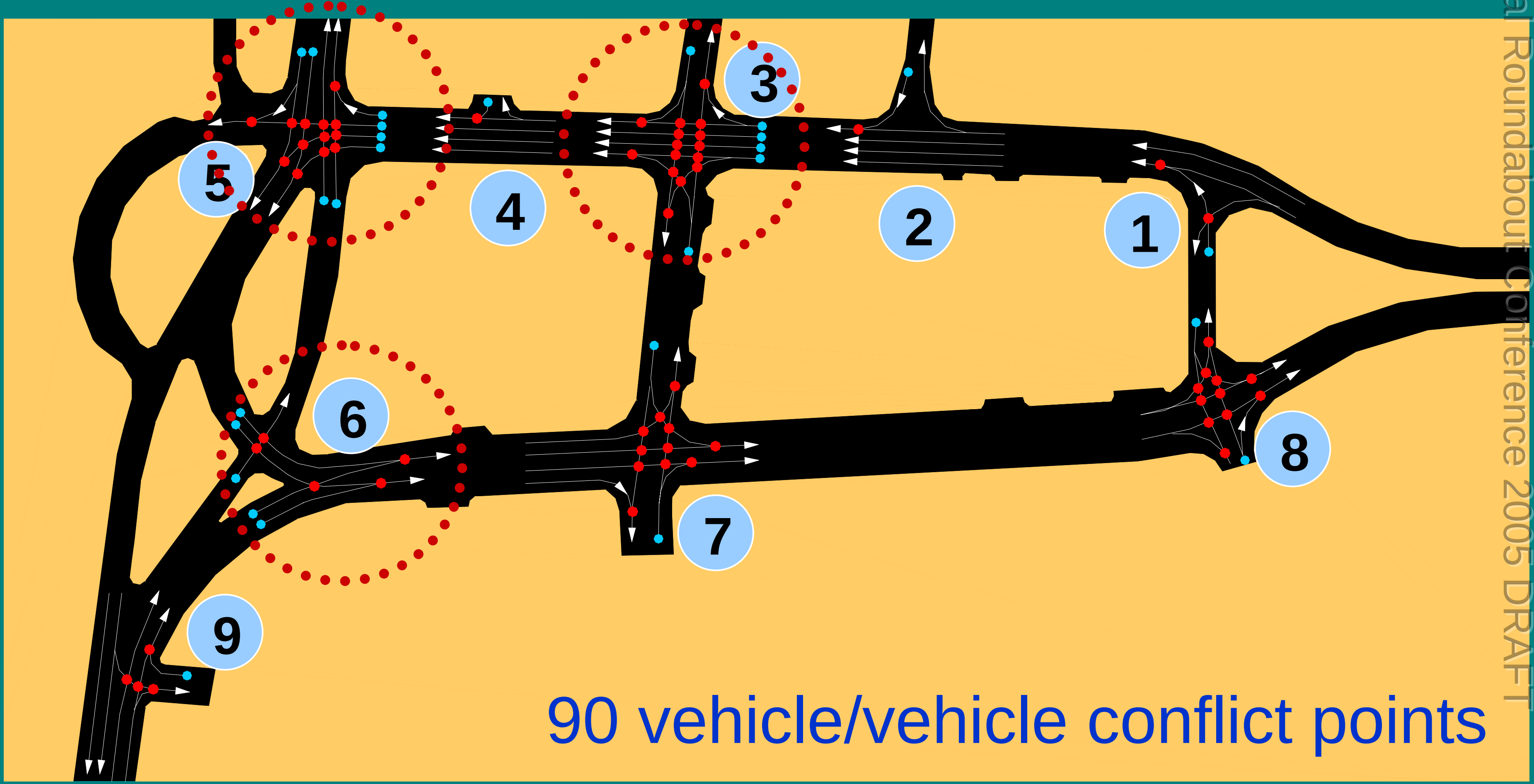
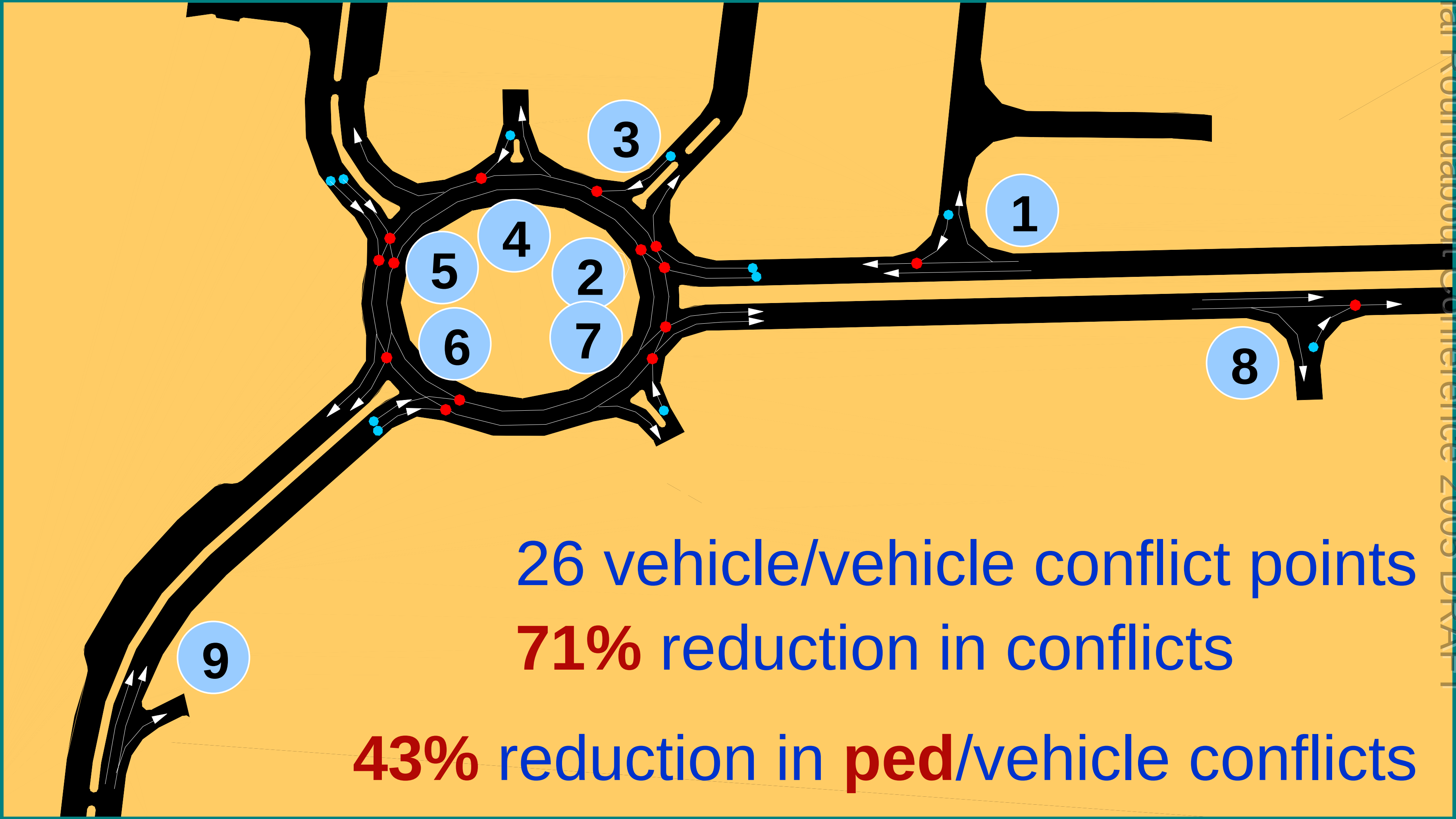
Figure 13. Independent Researchers Comment on Clearwater's First Modern Roundabout

"We appreciate the commitment of the City of Clearwater to provide an exemplary roundabout including features that make it accessible to and usable by persons with disabilities. The design includes a number of excellent features, including separation of the pedestrian and vehicular way and landscaping which prevents persons who are blind from inadvertently crossing the streets entering the roundabout at locations other than the crosswalks."	*"The greatest roundabout ever built in the United States is on Clearwater Beach, Florida."*
Letter to the principal author from Lukas Franck, Chair, Janet Barlow and Billie Louise Bentzen, Environmental Access Committee, Association for the Education and Rehabilitation of the Blind and Visually Impaired, Division Nine – Orientation and Mobility, July, 1999	*Roundabouts and Pedestrians with Visual Disabilities: How Can We Make Them Safer?*, Lal C. Wadwa, Ph.D., Head, Civil and Environmental Engineering, James Cook University, Australia, Transportation Research Baord,82nd Annual Meeting, January 2003, Washington, D.C.

Before Construction



Entryway Roundabout



26 vehicle/vehicle conflict points

71% reduction in conflicts

43% reduction in **ped**/vehicle conflicts

Areas of Impact

3. *Environmental impacts*
   - *Fuel consumption*
   - *Pollutants*
   - *Trees*
   - *Landscaping*
   - *Aesthetics*
   - *Street character*
   - *Noise*
   - *Neighborhood and city*

Table 27. Environmental Impacts Expressed in Non-Monetary Terms

Area of Impact	Impact		Cost = C Benefit = B
Fuel Consumption (p.)	50	Save 17,739 gallons over 20 years	B
Emissions (p.61)	51	Reduced by 3,746,444 Kg over 20 years. Reduction of global warming gases	B
Trees and plants (p.64)	52	Lose 19, gain 6 (plus 1,390 LF of 10' median for more trees)[195]	B
	53	Increased shade and habitat	B
Stormwater (p.)	54	3,932 SF of impermeable surface replaced with planting area in central islands (plus another 13,920 SF in medians)	B
Noise (p.)	55	Reduced noise	B

Areas of Impact

4. Social impacts

- *Social origins of the project: Design charrette*
- *Public acceptance: 65% of property owners*
    - *Session 8B, Wednesday morning*
- *Equity impacts: Vertical & horizontal equity*
- *Travel impacts*
- *Health impacts*
- *Impacts on residents' health*
- *Long-range impacts*

Table 28. Social Impacts Expressed in Non-Monetary Terms

Area of Impact	Impact		Cost = C Benefit = B
Aesthetics	56	Gain six attractive roundabouts	B
	57	Enhance character of Cleveland street	B
	58	Compatible with character of Cleveland Street	B
Landscaping	59	3,932 SF of asphalt replaced with planting area in central islands (plus another 13,920 SF in medians)	B
Community	60	Improved mobility for all users	B
	61	Increased neighborhood interaction	B
	62	Improved urban environment encourages urban infill that reduces sprawl	B
	63	More hospitable streets encourage street activities and community interaction	B
Crashes	64	Reduction in injuries, trauma, suffering, pain, emotional anguish, and emotional and mental disorders	B

The preceding four tables list 64 impacts expressed in non-monetary terms: 44 providing a net benefit, 19 having no adverse impact, and one being a cost.

Areas of Impact

4. Cost impacts

- Costs to the City
  - Capital costs: Design & construction
  - Operations & maintenance
- Costs to society
  - Fuel, delay
  - Costs of crashes
- Benefit-Cost Analysis

The five impacts expressed and evaluated in monetary terms are listed in the table below.

Table 29. Impacts Expressed in Monetary Terms

Area of Impact	Impact (2004 dollars)		Cost = C Benefit = B	
Costs to the City of Clearwater	65	Capital costs (design + ROW + construction)	$ 1,740,398	C
	66	Annual Operations and Maintenance (O & M) Costs	$ 3,780	C
Reduced Costs to Society	67	Annual fuel costs	$ 26,609	B
	68	Annual cost of delay	$ 58,486	B
	69	Annual comprehensive costs of crashes	$ 2,656,989	B

The table above lists five impacts expressed in monetary terms. Construction costs are historical and have been adjusted to base year 2004 dollars using the formulas below.

$$\text{Current year cost} = (\text{historical year cost}) \times (1 + k)^{(\text{current year})-(\text{historic year})}$$

Where k = 3.5%[197] annual adjustment factor for construction costs

The same formula was used to adjust the other historical cost data, using j as the adjustment factor,

where i = 3% annual adjustment factor for consumer costs

Future benefits are inflated, discounted and summed to arrive at a present value.

Future benefits are inflated for each year of the project life cycle according to the standard geometric cash flow series formula below.

$$A_k = A_{k-1}(1+r)^{k-1} \qquad k=1,\ldots,n$$

Where $r = r_i + r_{TG}$

$r_i = 3\%$ = inflation rate

$r_{TG} = 0.45\%$ = rate of traffic growth

The standard formula for discounting was used to discount the series of life-cycle costs and benefits to present value,[198]

$$PV = \sum_{t=1}^{N} A_t [1/(1+j)^t]$$

Where PV = Present Value
t = year of life-cycle analysis period
A = amount of benefit or cost in year t
N = 20 = length of life cycle (years)
j = 7%[199] = discount rate

Perhaps the most straightforward way to compare monetary benefits and costs over the life cycle is with the Net Present Value[200] (NPV), as follows

Monetary NPV= (benefits) – (costs) = $ 39,492,884

The other most widely used measure to compare benefits and costs is the Benefit/Cost Ratio,[201] as follows

$$\text{Monetary Benefit/Cost Ratio} = \frac{\text{Present Value of benefits}}{\text{Present Value of costs}} = 34.5$$

The monetary Benefit/Cost Ratio shown above is substantially greater than unity, or one.

BCA Inputs

A. COSTS TO THE CITY

(1) Capital Costs: One-time Cost of Rbts.

Year of construction cost data		2002
Construction cost per rbt.	$	173,726
Number of roundabouts		6
Design cost (2003)	$	55,398
ROW acquisition (2004)	$	5,000

(2) O&M Costs, year		2002
Ann. cost to maint. 3 signals	$	6,000
Annual cost to maint. 6 rbts.	$	2,220

B. COSTS TO SOCIETY

(3) Fuel

Fuel cost (per gallon)	$	1.50
Annual fuel savings (gallons)		17,739

(4) Delay

Cost data for year		2002
Hourly cost of travel delay	$	11.20
Travel delay reductn. (hrs/yr)		5,222

(5) Crashes

Comprehensive Costs of Crashes		
NSC data for year		2002
K Death	$	3,470,000
A Incapacitating Injury	$	172,000
B Non-incapacitating Injury	$	44,200
C Possible Injury	$	21,000
O No Injury	$	2,000

Annual Factors for Adjusting Historic Costs to	
Current Year	2004
Consumer Inflation Rate (i)	3.00%
Construction Inflation Rate (k)	3.50%

Factors to calculate PV of Total Ann. Benefits	
Year of Construction	2005
Project service life (N) (yrs.)	20
Annual Inflation Rate (r_i)	3.00%
Annual Traffic Growth (r_{tg})	0.45%
Annual Inflation Factor (r)	3.45%
Annual Discount Rate (j)	7.00%

BCA Calculations

Construction cost of 6 rbts. adj. to current yr. by (k)	$	1,116,595
Design cost adjusted by (r_i)	$	57,060
Right-of-Way acquisition	$	5,000
PV cost of 6 roundabouts	**$**	**1,178,655**

Adjusted to current year by (i)		
Annual O&M benefit	**$**	**4,010**

Adjusted to current year by (i)		
Annual Fuel Cost savings	$	26,609
Annual Travel Delay savings	$	62,048.22
Total annual preventable delay benefit	**$**	**88,657**

Comprehensive costs of crashes, adjusted to current year by (r_i)		
K Death	$	3,681,323
A Incapacitating Injury	$	182,475
B Non-incap. Injury	$	46,892
C Possible Injury	$	22,279
O No Injury	$	2,122

Crash History worksheet

Total crash prevention benefit (current year)	**$**	**2,656,989**

Annual O&M benefit	$	4,010
Tot. Ann. Prev. Delay Bene.	$	88,657
Ann. Crash Prevn. Benefit	$	2,656,989
Total annual benefits	**$**	**2,749,656**

Amortize Over Life Cycle worksheet

PV benefit of 6 rbts.	**$ 40,671,539**

Benefit Cost Analysis Outputs

Net Present Value (NPV)	**$**	**39,492,884**
Benefit/Cost Ratio		**34.5**

PV benefit of 6 rbts.	$ 40,671,539
PV cost of 6 roundabouts	$ 1,178,655

Skyored rbts BCA rev17.xls - Inputs & Outputs

BCA Inputs | BCA Calculations

A. COSTS TO THE CITY

(1) Capital Costs: One-time Cost of Rbts.

Year of costruction cost data		2002
Construction cost per rbt.	$	173,726
Number of roundabouts		6
Design cost (2003)	$	55,398
ROW acquisition (2004)	$	5,000

Construction cost of 6 rbts. adj. to current yr. by (k)	$	1,116,595
Design cost adjusted by (r_i)	$	57,060
Right-of-Way acquisition	$	5,000
PV cost of 6 roundabouts	**$**	**1,178,655**

(2) O&M Costs, year 2002

(2) O&M Costs, year		2002
Ann. cost to maint. 3 signals	$	6,000
Annual cost to maint. 6 rbts.	$	2,220

Adjusted to current year by (i)		
Annual O&M benefit	**$**	**4,010**

B. COSTS TO SOCIETY

(3) Fuel

Fuel cost (per gallon)	$	1.50
Annual fuel savings (gallons)		17,739

(4) Delay

Cost data for year		2002
Hourly cost of travel delay	$	11.20
Travel delay reductn. (hrs/yr)		5,222

Adjusted to current year by (i)		
Annual Fuel Cost savings	$	26,609
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Crash History worksheet

Total crash prevention benefit (current year)	**$**	**2,656,989**

Annual Factors for Adjusting Historic Costs to Current Year		2004
Consumer Inflation Rate (i)		3.00%
Construction Inflation Rate (k)		3.50%

Factors to calculate PV of Total Ann. Benefits	
Year of Construction	2005
Project service life (N) (yrs.)	20
Annual Inflation Rate (r_i)	3.00%
Annual Traffic Growth (r_{tg})	0.45%
Annual Inflation Factor (r)	3.45%
Annual Discount Rate (j)	7.00%

Annual O&M benefit	$	4,010
Tot. Ann. Prev. Delay Bene.	$	88,657
Ann. Crash Prevn. Benefit	$	2,656,989
Total annual benefits	**$**	**2,749,656**

Amortize Over Life Cycle worksheet

PV benefit of 6 rbts.	**$ 40,671,539**

Benefit Cost Analysis Outputs

Net Present Value (NPV)	**$**	**39,492,884**
Benefit/Cost Ratio		**34.5**

PV benefit of 6 rbts.	$	40,671,539
PV cost of 6 roundabouts	$	1,178,655

BCA Inputs

BCA Calculations

A. COSTS TO THE CITY

(1) Capital Costs: One-time Cost of Rbts.

Year of costruction cost data		2002
Construction cost per rbt.	$	173,726
Number of roundabouts		6
Design cost (2003)	$	55,398
ROW acquisition (2004)	$	5,000

Construction cost of 6 rbts. adj. to *current yr.* by (k)	$	1,116,595
Design cost adjusted by (r_i)	$	57,060
Right-of-Way acquisition	$	5,000
PV cost of 6 roundabouts	**$**	**1,178,655**

(2) O&M Costs, year		2002
Ann. cost to maint. 3 signals	$	6,000
Annual cost to maint. 6 rbts.	$	2,220

Adjusted to *current year* by (i)		
Annual O&M benefit	**$**	**4,010**

BCA Inputs

A. COSTS TO THE CITY

(1) Capital Costs: One-time Cost of Rbts.

Year of costruction cost data		2002
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BCA Calculations

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Design cost adjusted by (r_i)	$	57,060
Right-of-Way acquisition	$	5,000
PV cost of 6 roundabouts	**$**	**1,178,655**

Adjusted to *current year* by (*i*)		
Annual O&M benefit	**$**	**4,010**

Benefits

Costs

BCA Inputs | BCA Calculations

A. COSTS TO THE CITY

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PV cost of 6 roundabouts	**$**	**1,178,655**

(2) O&M Costs, year 2002

Ann. cost to maint. 3 signals	$	6,000
Annual cost to maint. 6 rbts.	$	2,220

Adjusted to current year by (i)		
Annual O&M benefit	**$**	**4,010**

B. COSTS TO SOCIETY

(3) Fuel

Fuel cost (per gallon)	$	1.50
Annual fuel savings (gallons)		17,739

(4) Delay

Cost data for year		2002
Hourly cost of travel delay	$	11.20
Travel delay reductn. (hrs/yr)		5,222

Adjusted to current year by (i)		
Annual Fuel Cost savings	$	26,609
Annual Travel Delay savings	$	62,048.22
Total annual preventable delay benefit	**$**	**88,657**

(5) Crashes

Comprehensive Costs of Crashes		
NSC data for year		2002
K Death	$	3,470,000
A Incapacitating Injury	$	172,000
B Non-incapacitating Injury	$	44,200
C Possible Injury	$	21,000
O No Injury	$	2,000

Comprehensive costs of crashes, adjusted to current year by (r_i)		
K Death	$	3,681,323
A Incapacitating Injury	$	182,475
B Non-incap. Injury	$	46,892
C Possible Injury	$	22,279
O No Injury	$	2,122

Crash History worksheet

Total crash prevention benefit (current year)	**$**	**2,656,989**

Annual Factors for Adjusting Historic Costs to	
Current Year	2004
Consumer Inflation Rate (i)	3.00%
Construction Inflation Rate (k)	3.50%

Factors to calculate PV of Total Ann. Benefits	
Year of Construction	2005
Project service life (N) (yrs.)	20
Annual Inflation Rate (r_i)	3.00%
Annual Traffic Growth (r_{tg})	0.45%
Annual Inflation Factor (r)	3.45%
Annual Discount Rate (j)	7.00%

Annual O&M benefit	$	4,010
Tot. Ann. Prev. Delay Bene.	$	88,657
Ann. Crash Prevn. Benefit	$	2,656,989
Total annual benefits	**$**	**2,749,656**

Amortize Over Life Cycle worksheet

PV benefit of 6 rbts.	**$ 40,671,539**

Benefit Cost Analysis Outputs

Net Present Value (NPV)	**$**	**39,492,884**
Benefit/Cost Ratio		**34.5**

PV benefit of 6 rbts.	$ 40,671,539
PV cost of 6 roundabouts	$ 1,178,655

Skycrest rbts BCA rev17.xls - Inputs & Outputs

B. COSTS TO SOCIETY

(3) Fuel

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Annual fuel savings (gallons)	17,739

(4) Delay

Cost data for year	2002
Hourly cost of travel delay	$ 11.20
Travel delay reductn. (hrs/yr)	5,222

(5) Crashes

Comprehensive Costs of Crashes	
NSC data for year	2002
K Death	$ 3,470,000
A Incapacitating Injury	$ 172,000
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C Possible Injury	$ 21,000
O No Injury	$ 2,000

Annual Factors for Adjusting Historic Costs to	
Current Year	2004
Consumer Inflation Rate (*i*)	3.00%
Construction Inflation Rate (*k*)	3.50%

Adjusted to *current year* by (*i*)	
Annual Fuel Cost savings	$ 26,609
Annual Travel Delay savings	$ 62,048.22
Total annual preventable delay benefit	**$ 88,657**

Comprehensive costs of crashes, adjusted to *current year* by (r_j)	
K Death	$ 3,681,323
A Incapacitating Injury	$ 182,475
B Non-incap. Injury	$ 46,892
C Possible Injury	$ 22,279
O No Injury	$ 2,122

Crash History worksheet

Total crash prevention benefit (current year)	**$ 2,656,989**

Benefits

Costs

The National Safety Council (NSC) classifies crashes into five categories for the purpose of assigning comprehensive costs. The most recent NSC comprehensive crash costs are given in the table below.

Table 24. Average Comprehensive Crash Cost per Injured Person[191]

Death	Incapacitating Injury	Non-incapacitating Injury	Possible Injury	No Injury (PDO)
$3,470,000	$172,000	$44,200	$21,000	$2,000

The table above gives the comprehensive costs according to the severity of the injuries as classified by the KABCO system described earlier under *Safety Impacts* in the section on *Impact of Crash Severity* (p. 38).

Classification of Crashes at Six Intersections in the Cleveland Street Corridor for 36 Month Period									
Date of Crash	Cleveland &	Type of Collision	Pre-ventable Crash?	NSC Comprehensive Cost ($)					Crash Prevention Benefit
				K	A	B	C	O	
				3,681,323	182,475	46,892	22,279	2,122	
07/08/00	Meteor	Right Angle	100%			1			$ 46,892
08/08/00	Corona	Rear End	50%					1	$ 1,061
08/12/00	Saturn	Right Angle	100%				1		$ 22,279
08/31/00	Saturn	Right Angle	100%				1		$ 22,279
11/02/00	Aurora	Right Angle	100%			1			$ 46,892
12/14/00	Corona	Left Turn	100%					1	$ 2,122
02/03/01	Saturn	Left Turn	100%					1	$ 2,122
02/17/01	Duncan	Left Turn	100%			1			$ 46,892
04/09/01	Saturn	Right Angle	100%					1	$ 2,122
06/14/01	Corona	Right Angle	100%					1	$ 2,122
08/07/01	Aurora	Out of Control	100%	2		1			$ 7,409,538
10/03/01	Lake	Right Angle	100%			1			$ 46,892
10/09/01	Lake	Right Angle	100%					1	$ 2,122
10/09/01	Saturn	Right Angle	100%					1	$ 2,122
01/22/02	Corona	Right Angle	100%			2			$ 93,784
02/10/02	Duncan	Left Turn	100%					1	$ 2,122
02/20/02	Corona	Backing Vehicle	50%					1	$ 1,061
02/28/02	Aurora	Right Angle	100%					1	$ 2,122
04/03/02	Duncan	Right Angle	100%					1	$ 2,122
04/15/02	Saturn	Right Angle	100%					1	$ 2,122
04/27/02	Saturn	Sideswipe	100%					1	$ 2,122
06/19/02	Duncan	Rear End	50%				1		$ 11,139
06/20/02	Lake	Backing Vehicle	50%					1	$ 1,061
06/25/02	Saturn	Right Angle	100%					1	$ 2,122
08/08/02	Aurora	Backing Vehicle	50%					1	$ 1,061
08/20/02	Corona	Out of Control	50%					1	$ 1,061
09/28/02	Aurora	Backing Vehicle	50%					1	$ 1,061
10/17/02	Corona	Right Angle	100%			1			$ 46,892
10/17/02	Corona	Sideswipe	100%			1			$ 46,892
11/09/02	Aurora	Right Angle	100%					1	$ 2,122
12/28/02	Corona	Right Angle	100%					1	$ 2,122
01/23/03	Aurora	Right Angle	100%				1		$ 22,279
01/30/03	Lake	Rear End	50%				1		$ 11,139
02/21/03	Aurora	Left Turn	100%				1		$ 22,279
03/05/03	Lake	Rear End	50%			1			$ 23,446
03/17/03	Saturn	Rear End	50%					1	$ 1,061
04/12/03	Duncan	Rear End	50%				1		$ 11,139
05/22/03	Aurora	Sideswipe	100%					1	$ 2,122
06/05/03	Lake	Rear End	50%					1	$ 1,061
	Total	39		2	0	10	7	23	

Total for 36 months	$ 7,970,966
Annual benefit	**$ 2,656,989**

Factors to calculate PV of Total Ann. Benefits	
Year of Construction	2005
Project service life (N) (yrs.)	20
Annual Inflation Rate (r_I)	3.00%
Annual Traffic Growth (r_{TG})	0.45%
Annual Inflation Factor (r)	3.45%
Annual Discount Rate (i)	7.00%

Annual O&M benefit	$	4,010
Tot. Ann. Prev. Delay Bene.	$	88,657
Ann. Crash Prevn. Benefit	$	2,656,989
Total annual benefits	**$**	**2,749,656**

Amortize Over Life Cycle worksheet

PV benefit of 6 rbts.	**$**	**40,671,539**

Benefits

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Construction Inflation Rate (k)	3.50%

Crash History worksheet

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Benefit Cost Analysis Outputs

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Costs

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Benefit Cost Analysis Outputs

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