



# ***Maryland's Roundabouts***

## ***Accident Experience and Economic Evaluation***



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***April 5, 2004***

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**Evaluation of Roundabouts in Maryland**

**Executive Summary**

The following report evaluates the effectiveness of Roundabouts in Maryland. Studies have found that one of the benefits of roundabout installations is the improvement of overall safety performance. Single-lane roundabouts have been found to perform better than two-way, all-way stop and signalized intersections. Although the frequency of crashes is not always lower at roundabouts, particularly multi-lane roundabouts, reduced injury rates have been reported.

This report is comprised of two distinct segments. The first segment involves general accident data (that is in our database) of all roundabouts in Maryland. This includes accident data for single-lane roundabouts; two-lane roundabouts and also data for roundabouts that have been installed at new locations where no intersection previously existed.

The second segment of this report solely concentrates on single-lane roundabouts. This segment consists of a cost effective analysis and the benefit/cost ratio analysis of those roundabouts evaluating the before construction period to the after construction period.

The analysis method utilizes the before and after approach to assess the safety affects roundabouts have on accidents. The methodology consists of data collection, comparison of data, significance testing and economic evaluation.

This report indicates the results of two techniques used in the economic evaluation. The cost effectiveness technique indicates the numbers of dollars spent to reduce a single accident. The benefit/cost technique indicates the ratio of the rate of return in safety benefits for the entire after period (Annual Benefit) as compared to the amount of dollars spent on the project taking into account the invested capital that could be recuperated over the 15-year service of the project (Equivalent Uniform Annual Cost).

***Findings:***

This analysis indicates that at locations in Maryland where single lane roundabouts have been installed there has been a 68% decrease in the total accident rate/million vehicles entering the intersection (acc/mve), 100% decrease in the fatal accident rate/mve, an 86% reduction in the injury accident rate/mve and a 41% reduction in the property damage only accident rate/mve.

The results of the cost effectiveness evaluation of the 15 single-lane roundabouts indicated that for a single accident reduced, a total of \$13,146 dollars was spent. The

weighted average accident cost for a single accident (Maryland Accident Cost figures) is estimated at approximately \$100,000. The benefit/cost analysis indicated that for every dollar spent on these projects, considering the 15 year service life of the roundabouts, there is a return of approximately \$15.00 to be realized through accident reduction. These calculations are based on the anticipated accident experience expected to occur had no roundabouts been installed compared to the actual after period accident experience of the roundabout locations.

**Segment 1**  
**Maryland Roundabout Accident Experience**

As of December 2003, Maryland has more than 40 modern roundabouts in operation at State maintained intersections. The table below shows before and after accident data for Maryland's fifteen single lane roundabouts that have been in operation long enough to obtain good after period accident data (for those built between April 1993 through December 2001). Accident data used is from the Maryland Automated Accident Reporting System (MAARS) database.

The fifteen single-lane roundabouts were all small to moderate size (outer inscribed circle diameter of 150' or less), as described in Chapter 1 of the FHWA publication "Roundabouts: An Informal Guide". Each roundabout replaced stop signs or intersection control beacons previously controlling the intersections.

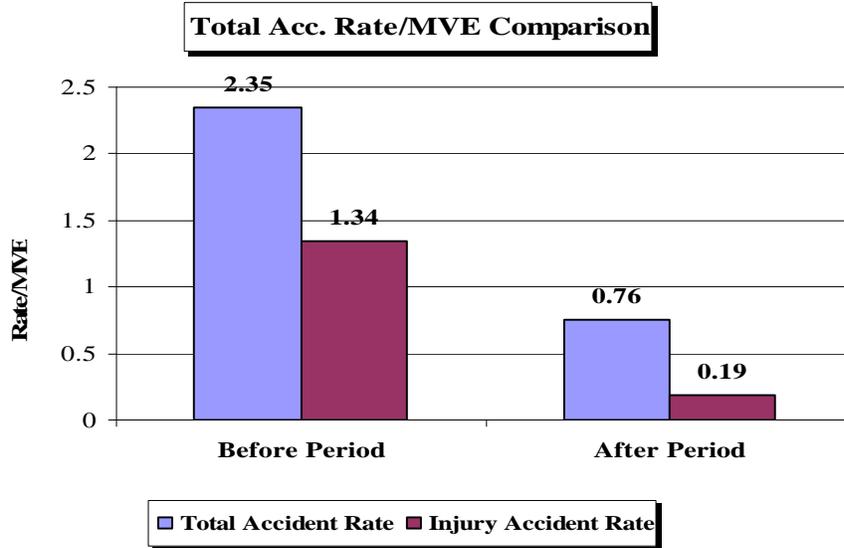
Since conversion to single-lane roundabouts, the average annual accidents for all fifteen intersections combined fell from an average of 59.5 accidents/year in the before period, to an average of 18.6 accidents/year in the after period, a 69% reduction. Accident severity also decreased, as fatal accidents show a reduction from an annual average of 1.3 fatal accidents in the before period to an annual average of 0.0 fatal accidents in the after period, a reduction of 100%. Injury accidents have shown a reduction from an annual average of 36.1 injury accidents in the before period to an annual average of 5.6 injury accidents in the after period, a reduction of 85%. The annual average property damage only accidents show a reduction from 27.9 accidents per year to 13.0 accidents per year resulting in a 69% reduction.

**Figure 1. Average Accident Data and Total Accident Rate  
Single Lane Roundabouts**

	Before						After					
	Years	Avg. Annual Acc.	Avg. Annual Injury Acc.	Total Acc. Rate /MVE	Total Injury Rate /MVE	MVE	Years	Avg. Annual Acc.	Avg. Annual Injury Acc.	Total Acc. Rate /MVE	Total Injury Rate /MVE	MVE
MD 94@ Old Frederick	4.0	5.0	3.5	4.41	3.09	4.5	4.0	1.0	0.0	0.80	0.00	5.0
MD 24@ MD165	5.0	6.4	4.0	5.31	3.32	6.0	2.3	0.4	0.4	0.27	0.27	3.7
MD193@Oak Grove	3.0	0.3	0.0	0.15	0.00	6.5	2.0	1.0	1.0	0.43	0.43	4.7
MD18A@ MD18H	3.0	1.4	0.7	0.54	0.27	7.4	3.0	0.3	0.0	0.12	0.00	8.1
MD 17@MD180	3.0	5.7	3.0	2.31	1.22	7.4	2.0	0.0	0.0	0.00	0.00	5.5
MD17@"B"St	3.0	0.3	0.3	0.49	0.49	2.0	4.0	0.5	0.3	0.66	0.33	3.0
MD140@Antrim	5.0	6.0	5.8	2.68	1.34	11.2	6.4	1.4	0.5	0.53	0.18	16.8
MD94@MD144A	5.0	8.4	3.8	6.75	3.05	6.2	9.7	1.9	0.4	1.20	0.27	15.1
MD213@Leeds	5.0	4.0	2.8	3.07	2.15	6.5	7.4	2.2	0.1	1.38	0.09	11.6
MD2@MD408/MD422	5.0	7.8	5.2	3.21	2.14	12.2	7.2	4.4	1.2	1.62	0.43	20.9
MD637@Oxen Run	3.0	1.7	0.7	0.45	0.18	11.0	2.0	1.0	0.0	0.24	0.00	8.2
MD637@Good Hope	3.0	1.0	0.7	0.27	0.18	11.0	2.0	1.5	1.0	0.37	0.24	8.2
MD63@MD58	5.0	3.8	1.6	3.30	1.39	5.8	7.0	0.7	0.1	0.52	0.10	9.7
MD372@Hilltop	3.0	3.7	1.3	1.67	0.61	6.6	4.0	1.3	0.3	0.51	0.10	9.7
MD307@MD313/MD318	3.8	4.2	3.2	2.48	1.86	6.5	4.0	0.8	0.3	0.39	0.13	7.6

Using Donald A. Morin application of statistical concepts to accident data (Morin Lower Control Limit Test) indicate that both total and injury accident reductions are significant reductions at a 95% confidence interval. Total and injury accident rates in the following graph and table are per million vehicles entering (MVE). The *total* accident rate for the roundabouts in the **before** period was 2.35 reported accidents/MVE. The *total* accident rate in the **after** period was 0.76 accidents/MVE. The *injury* rate in the **before** period was 1.34 accidents/MVE. The **after** period mean *injury* rate was 0.19 accidents/MVE.

Figure 2



**Single-lane Roundabouts having no before period**

***MD 100 @ MD 103 Interchange  
(2 Separate Single Lane Roundabouts)  
Howard County***

This is a new interchange along MD 100 at MD 103 that opened to traffic in late November 1998. Since these intersections are new, there is no before period accident data to report. The outside diameter of both of these roundabouts is 120'. **Since opening there have been five police reported accidents at Meadow Ridge Road (north roundabout) and six police reported accidents at the south roundabout from January 1, 1999 to December 31, 2002.**

**MD 100 @ MD 103 North – January 1, 1999 to December 31, 2002.**

<b>Angle</b>	<b>1</b>
<b>Rear end</b>	<b>1</b>
<b>Fixed object</b>	<b>3</b>
<b>Injury accident</b>	<b>0</b>
<b>Property damage only accident</b>	<b>5</b>

**MD 100 @ MD 103 South – January 1, 1999 to December 31, 2002.**

<b>Angle</b>	<b>1</b>
<b>Rear end</b>	<b>3</b>
<b>Fixed Object</b>	<b>1</b>
<b>Backing</b>	<b>1</b>
<b>Injury accident</b>	<b>1</b>
<b>Property damage only accident</b>	<b>5</b>

***MD 100 @ Snowden River Parkway***

*(1 Single Lane Roundabout)*

***Howard County***

This is a new interchange along MD 100 at Snowden River Parkway that opened to traffic in late November 1998. Since this intersection is new, there is no before period accident data to report. There were 7 accidents reported in the 3-year after period. Below are the police reported accidents that have occurred since the opening of the roundabout. The outside diameter of this roundabout is 100'. **Study period 1/1/99 to 12/31/02.**

<b>Angle</b>	<b>3</b>
<b>Rear end</b>	<b>1</b>
<b>Fixed object</b>	<b>3</b>
<b>Injury accidents</b>	<b>2</b>
<b>Property damage only accident</b>	<b>5</b>

***MD 7 @ Holly Oaks Drive***

*(1 Single Lane Roundabout)*

***Harford County***

This is a new roundabout opened to traffic in September 1999. Since this is a new location there is no before period accident data to report. Since September of 1999, there have been 7 accidents at this location. The outer diameter of this roundabout is 120'. The study period is from 1/1/99 to 12/31/02.

<b>Rear end</b>	<b>1</b>
<b>Fixed object</b>	<b>4</b>
<b>Other/unknown</b>	<b>2</b>
<b>Injury Accident</b>	<b>3</b>
<b>Property damage only accident</b>	<b>4</b>

***MD 291 @ US 301 Interchange***  
 (2 Separate Single Lane Roundabouts)

***Kent County***

These are new roundabouts that opened to traffic in August 1999 as part of a new interchange project. Since the improvement is actually an interchange with roundabouts providing access to and from the ramps, there is no before period accident data. The outside diameter for both roundabouts is 110'. **Since September 1, 1999, there have been no reported accidents through 2002.**

***Two-lane Roundabouts***

Maryland has also constructed eight 2-lane roundabouts: MD45 @ MD146 /Joppa Road (Towson Roundabout) in Baltimore County, MD450 @ Taylor Avenue/Spa Road in Anne Arundel County, MD100 @ MD104 in Howard County and MD139 @ Bellona Avenue in Baltimore County, US1 @ 34<sup>th</sup> St. /Perry St. in Prince Georges County, MD80 @ Sugarloaf Pkwy in Frederick County, MD 216 @ US 29 (East) and MD216 @ US29 (west) in Howard County. Listed below are the roundabouts that currently have before and after period accident data.

**Figure 3.**  
***Two-Lane Roundabouts***

	Before					After						
	Years	Avg. Annual Acc.	Avg. Annual Injury Acc.	Total Acc. Rate /MVE	Total Injury Rate /MVE	MVE	Years	Avg. Annual Acc.	Avg. Annual Injury Acc.	Total Acc. Rate /MVE	Total Injury Rate /MVE	MVE
US1 @ Perry St./34St.	3.0	0.3	0.0	0.09	0.00	11.3	1.0	9.0	1.0	2.25	0.25	4.0
MD450@MD435/MD387	5.0	6.0	2.5	1.52	0.63	7.9	3.0	3.0	0.3	0.66	0.07	13.6
MD139@ Bellona Ave.	2.0	1.7	0.7	0.36	0.15	13.7	4.0	0.0	0.0	0.00	0.00	20.3
MD45 Towson	5.0	6.8	4.2	0.83	0.51	41.0	5.0	15.4	2.8	1.62	0.29	47.5

***MD 45 @ MD 146 / Joppa Road (Towson Roundabout)***  
***Baltimore County***

The Towson Roundabout was opened to traffic in October of 1998. The configuration of this roundabout is oval in design and has an outer/inner diameter ranges from 140' x 260' / 58' x 188'. Prior to the construction of the roundabout, this intersection initially was controlled by two separate traffic signals. This roundabout is in a very urbanized area having five approach legs. The average ADT for the 5-year before period of 1993 through 1997 was approximately 44,900 and for the 4-year after period of 1999 and 2002 it was 52,000.

Although the total accident rate in the after period resulted in an increase of 95%, the injury accident rate decreased by 43%. From 2001 to 2002, the total accident frequency decreased from 20 accidents to 10 accidents. With the installation of the roundabout, the a.m. peak period improved from a Level of Service (LOS) B to LOS A, the p.m. peak period went from a LOS E to LOS B. Furthermore, the roundabout resulted in a 70% delay reduction in the a.m. peak hour and a 58% delay reduction in the p.m. peak hour.

***MD 450 @ Taylor Avenue/Spa Road (Annapolis Gateway)***  
***Anne Arundel County***

The MD 450 roundabout was opened to traffic in December of 1999. The outer diameter ranges from 168' to 188' with an inner diameter from 104' to 124'. Our records indicate that this roundabout was under construction during 1998 and most of 1999. After construction, the total accident rate decreased by 57% and the injury accident rate decreased by almost 90%.

***MD 139 @ Bellona Avenue***  
***Baltimore County***

The MD 139 @ Bellona Avenue roundabout opened in May of 1999. The outer diameter of the roundabout is 85'. There have been no police reported accidents at this location since it became an operational roundabout in July of 1999.

***US 1 @ 34<sup>th</sup> Street/Perry Street***  
***Prince Georges County***

The US 1 @ 34<sup>th</sup> Street/Perry Street Roundabout completion date was February 2002. The outer diameter is 140'. During the before period of 1998 through 2000, there was 1 police reported accident at this intersection. After construction of the roundabout, for the approximate 1-year after period, there was a 2900% increase in the average accidents per year, with the collision frequency increasing to 9 police reported accidents. These accidents varied by collision type, but 3 of the 9 were sideswipe type collisions.

***Two-lane Roundabouts having no before period***

***MD 80 @ Sugarloaf Pkwy.***  
***Frederick County***

This roundabout was constructed as part of a new intersection in 2000 and therefore no before period data exist. This roundabout has an outer diameter of 240'. **There have been no reported accidents during the after period of 2001 through 2002.**

***MD 100 @ MD 104***  
***Howard County***

This is a new interchange along MD 100 at MD 104 that opened to traffic in late November 1998. Since this location is new there is no before period accident data to report. The outside diameter of this roundabout is 150'.

There have been 12 police reported accidents at this location since the opening of the roundabout. There were 6 accidents at this location during the year 2002. The accident frequencies have consistently increased over the last 3 years. The major collision types are rear end and fixed object type collisions. Only 1 of the 12 accidents is injury related.

***MD 216 @ US 29 Interchange (East and West Two Roundabouts)  
Howard County***

These are new roundabouts that opened to traffic in the spring 2001 as part of a new interchange project. Since the improvement is actually an interchange with roundabouts providing access to and from the ramps, there is no before period accident data. The outside diameter for both roundabouts is 230’.

Thus far the **east roundabout** has experienced 6 accidents during the 1-year and 10 months after period. Only 1 accident was injury related. There were 2 rear end collisions, 2 right angle collisions, 1 struck fixed object and 1 sideswipe collision. The accident frequencies have doubled from the 10 months period of 2001 (2 accidents) to the entire year of 2002 (4 accidents).

The **west** roundabout has experienced 4 total accidents during the after period. All 4 accidents were property damage only type collisions. During the year 2001 there were 2 accidents and 2 accidents during 2002. There 2 struck fixed object collisions and 2 sideswipe collisions.

**Segment 2**  
**Benefit/Cost Analysis and Cost effectiveness**  
**Of 15 Single-lane Roundabouts**

The following segment evaluates the effectiveness of the 15 single lane roundabouts installed throughout the State of Maryland. The analysis method utilized the before and after approach to assess the safety effects of single-lane roundabouts and their cost effectiveness. The methodology consisted of data collection, comparison of data, significance testing and economic evaluation.

The cost effectiveness technique indicates the number of dollars spent to reduce 1 accident. The benefit/cost technique indicates the ratio of the anticipated rate of return in safety benefits (accident reduction) for the entire 15-year service life of the roundabouts – (Equivalent Uniform Annual Benefit) as compared to the amount of dollars spent on these projects taking into account the invested capital that can be recuperated over the same 15-year service life – (Equivalent Uniform Annual Cost).

***Accident Data:***

Accident data used is from the Maryland State Highway Administration accident database. This database consists of all accidents for which an official accident report

form was completed using the Maryland Automatic Accident Reporting System (MAARS). Accident data was collected for 15 single-lane mini roundabouts. The before and after period vary depending on completion dates of the roundabouts. As indicated in the introduction, approximately 1-year of accident data for each roundabout was deleted from the accident information presented in segment 1 to account for the construction/adjustment period.

### ***Analysis Method:***

The comparison of data consists of using the before accident frequency to determine what the existing accident condition would have been had no roundabouts been installed. Based on the before period accident rate per every million vehicle entering (MVE) and the after period traffic volumes, **expected** accident frequencies are calculated had no roundabouts been installed. The expected accident frequency is then used for comparison to the actual after period accident frequency. The significance testing utilizes the percent change of the expected accident frequency to the actual after period accident frequency. Using Poisson Distribution at a confidence interval of 95%, significant % changes can be determined between the expected accident frequency and the actual after period accident frequency.

The final step is the economic analysis. Both the benefit/cost and the cost/effectiveness techniques are utilized. The benefit/cost analysis utilizes the Annual Benefit (AB) to the Equivalent Uniform Annual Cost (EUAC) over the entire service life of the roundabouts. Any project that has a benefit/cost ratio greater than 1.0 is considered economically successful. Use of this method requires that the dollar value is placed on all cost and benefit elements related to the project. Maryland has developed its own average accident cost figures that have been stratified by severity. These figures are used in this study. An alternate method is the cost/effectiveness technique. This method is to determine the cost in preventing a single accident and then deciding whether the project cost was justified. Benefits are not priced using this technique, but are used to determine the cost of reducing accidents by severity.

### ***Comparison of Measures of Effectiveness:***

The Measure of Effectiveness (MOE) data comparison worksheet below indicates the total accident experience for all 15 single-lane mini roundabouts. The worksheet indicates the accident frequency by severity, collision type, and rate per million vehicles entering the intersections. Also indicated is the percent change from the **expected** after period accident rate (ER) had the roundabouts not been implemented to the actual after period accident rate (APR) with roundabouts.

Although all accidents are indicated for the study locations in this report, it is important to stress that this study only evaluates the effectiveness of roundabouts in relationship to severity of accidents. From the before period (3.9 years) to the after period (4.5 years) the overall accident rate decreased from 2.35 accidents/million vehicles entering (acc./MVE) to 0.76 accidents/MVE. Fatal accidents decreased from 0.05 acc./MVE to

0.0 acc./MVE, injury accidents decreased from 1.34 acc./MVE to 0.19 acc./MVE and the property damage only accident rate decrease from 0.97 acc./MVE to 0.57 acc./MVE. There was a 68% decrease in the total accident rate, a 100% decrease in the fatal accident rate, 86% decrease in the injury accident rate and a 41 decrease in the property damage only accident rate.

Concerning collision types, the right-angle accident rate decrease by 93%, the rear end accident rate decreased by 27%, opposite direction rate decreased by 100%, sideswipe accident rate decreased by 52%, left turn accident rate decreased by 97%. Conversely, the fixed object accidents increased 474%.

The accident rate occurring during darkness hours also showed a decrease (27%) and the accident rate occurring during wet roadway surface condition indicate a 51% decrease.

**Figure 4.**

MARYLAND STATE HIGHWAY ADMINISTRATION  
Office of Traffic and Safety  
Traffic Safety Analysis Division

NAME: R. CUNNINGHAM  
DATE: March 19, 2004

( MOE ) DATA COMPARISON WORKSHEET  
INTERSECTION

LOCATION: 15 SINGLE LANE ROUNDABOUTS

COUNTY: VARIOUS LOGMILES: VARIOUS

Before Period	1/2 COMBINED ADT		Before ADT	5186	# Days Before	21495
After Period	1/2 COMBINED ADT		After ADT	5425	# Days After	24493
MOE DATA SUMMARY	CONTROL		PROJECT		EXPECTED AFTER RATE	PERCENT (%) REDUCTION
	BEFORE	AFTER	BEFORE	AFTER		
ACCIDENTS:						
TOTAL ACCIDENTS			260	105		
FATAL ACCIDENTS			5	0		
INJURY ACCIDENTS			148	36		
PROP. DAMAGE ONLY			107	79		
ANGLE COLLISION			177	15		
REAR END			31	28		
FIXED OBJECT			7	60		
OPP. DIRECTION			13	0		
SIDESWIPE			5	3		
LEFT TURN			25	1		
PEDESTRIAN			0	1		
PARKED VEHICLE			0	0		
OTHER COLLISION			2	7		
NIGHTTIME ACC.			45	41		
WET SURFACE ACC.			52	32		
EXPOSURE			310.781818	337.773125		
MOE COMPARISON	BCR	ACR	BPR	APR	ER	(%)
TOTAL ACCIDENTS			2.35	0.76	2.35	68
FATAL ACCIDENTS			0.06	0.00	0.05	100
INJURY ACCIDENTS			1.34	0.19	1.34	86
PROP. DAMAGE ONLY			0.97	0.57	0.97	41
ANGLE COLLISION			1.60	0.11	1.60	93
REAR END			0.28	0.20	0.28	27
FIXED OBJECT			0.06	0.36	0.08	-174
OPP. DIRECTION			0.12	0.00	0.12	100
SIDESWIPE			0.06	0.02	0.05	52
LEFT TURN			0.23	0.01	0.23	97
PEDESTRIAN			0.00	0.01	0.00	N/A
PARKED VEHICLE			0.00	0.00	0.00	N/A
OTHER COLLISION			0.02	0.08	0.02	-151
NIGHTTIME ACC.			0.41	0.30	0.41	27
WET SURFACE ACC.			0.47	0.23	0.47	51

It should be noted that the expected accident rate (ER) assumes the same rate as the before period rate (BPR). This is based on the assumption that if no changes are made the accident rate will remain essentially the same. Accidents and volumes would be expected to increase and decrease proportionately, thereby allowing the accident rate to remain somewhat consistent.

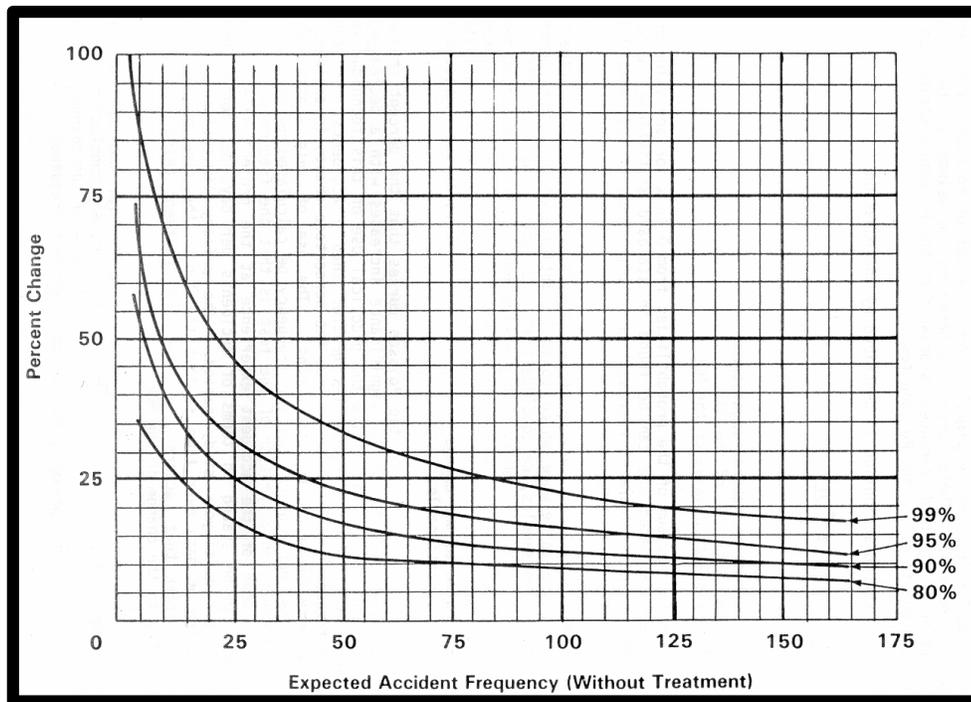
The percent reduction is calculated by using the formula:

$$\% \text{ Reduction} = ((ER-APR)/ER) 100$$

***Significance Testing***

Significance testing utilizes the percent change of the expected accident frequency (had no installation taken place) to the actual after period accident frequency. Using Poisson Distribution, at a confidence interval of 95%, significant percent changes can be determined between the expected after period accident frequency and the actual after period accident frequency.

**Figure 5. Accident Reduction Statistical Confidence Intervals**



The Statistical Test Worksheet below shows the actual after period accident frequency, the expected after period accident frequency, the percent change and finally the % change needed for a specific category to be deemed significant. The critical value line used is at 95% confidence interval.

**Figure 6.**

MARYLAND STATE HIGHWAY ADMINISTRATION  
Office of Traffic and Safety  
Traffic Safety Analysis Division

NAME: E. CUNNINGHAM  
DATE: March 26, 2004

STATISTICAL TEST WORKSHEET  
INTERSECTION

LOCATION: 16 SINGLE LANE ROUNDABOUTS

COUNTY: VARIOUS LOGMILES: VARIOUS

EVALUATION OBJECTIVE ( FUNDAMENTAL )	AFTER FREQUENCY		PERCENT REDUCTION		SIGNIFICANT YES or NO
	OBSERVED	EXPECTED	OBSERVED	EXPECTED	
TOTAL ACCIDENTS	106	323	66	10	YES
FATAL ACCIDENTS	0	6	100	60	YES
INJURY ACCIDENTS	26	164	86	12	YES
PROP. DAMAGE ONLY	79	133	41	15	YES
ANGLE COLLISION	15	220	93	10	YES
REAR END	28	39	27	25	YES
FIXED OBJECT	50	9	-474	51	NO
OPP. DIRECTION	0	14	100	40	YES
SIDESWIPE	3	6	52	60	NO
LEFT TURN	1	31	97	26	YES
PEDESTRIAN	1	0	N/A	#N/A	#N/A
PARKED VEHICLE	0	0	N/A	#N/A	#N/A
OTHER COLLISION	7	2	-101	too small	NO
NIGHTTIME ACCIDENTS	41	54	27	22	YES
WET SURFACE ACCIDENTS	32	65	51	21	YES

\*\*\* -- TO SMALL TO TEST

As indicated above, there were significant reductions in total, fatal, injury, and property damage only accidents. Rear end, right-angle, opposite direction and left turn accidents indicate significant reductions by collision type. Accidents occurring during nighttime and wet surface conditions also had significant reductions.

Vehicles striking fixed objects indicate a significant increase at a 474%. We would have expected 9 fixed object collisions had no roundabouts been installed, but there were 50 fixed object accidents observed during the actual after period of roundabout installations.

During the after period, 39 of the 50 fixed object accidents occurred at 4 of the 15 roundabout sites. These are listed below by location and year to show the fixed object trends during each year of the after period.

### Struck Fixed Objects

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
MD 94 @ MD 144A	0	2	1	1	2	3	0	1	1	1	12
MD 2 @ MD 408/MD 422	n/a	n/a	0	3	0	0	1	3	1	4	12
MD 213 @ Leeds	n/a	n/a	2	4	1	0	0	0	1	1	9
MD 140 @ Antrim	n/a	n/a	n/a	n/a	1	2	0	0	3	0	6
Total	0	2	3	8	4	5	1	4	6	6	39

There were 25 fixed object accidents that occurred during darkness hours. MD 94 @ MD 144A experienced 7 nighttime fixed object accidents and MD 2 @ MD 408/MD 422 experienced 8 nighttime fixed object accidents. MD 213 @ Leeds and MD 140 @ Antrim had 4 nighttime fixed object accidents each. Of the 25 nighttime fixed object accidents, 11 of these occurred during wet roadway surface conditions. There were 14 total wet surface fixed object collisions at these 4 roundabout locations.

### Recorded Primary Causes of Fixed Object Accidents

Listed below are the primary causes of the 39 fixed object accidents as recorded by the attending police officer.

Driving too fast for conditions	20
Alcohol/Drugs	11
Weather	3
Medication	1
Physical ailment	1
Sun Glare	1
Ran-off-road by other vehicle	1
Animal	1

MD 94 @ MD 144A experienced 7 fixed object accidents involving driving too fast for conditions. MD 213 @ Leeds experienced 6 fixed object accidents involving driving too fast for conditions. MD 94 @ MD 144A also experienced the highest number (5) of vehicles striking fixed objects involving drivers under the influence of alcohol.

The majority of fixed objects struck were curbs (27 accidents). There were 7 accidents involving vehicles striking sign support poles, 4 accidents striking utility poles and 1 vehicle striking a guard rail. These accidents are listed in the chart below by location and object struck.

Location	Curb	Sign Support	Utility Pole	Guard Rail
MD 94 @ MD 144A	5	4	3	0
MD 2 @ MD 408/ MD 422	10	1	1	0
MD 213 @ Leeds	6	2	0	1
MD 140 @ Antrim	6	0	0	0
Total	27	7	4	1

As previously stated the object of a cost/effectiveness evaluation is to determine the amount of dollars spent to reduce 1 accident. The initial total cost of the roundabouts is \$6,219,505. There is no before and after annual operating and maintenance cost or salvage value for these projects. As indicated on the chart below, 49 per year accidents were prevented as a result of the roundabout installations. The capital recovery factor (CRF) was determined using 6% interest rate for the 15-year service life of the project. At these parameters the CRF is 0.1030. Based on the calculations below, it was determined that for every accident reduced \$ 13,146 was spent. Comparing this to the average accident cost for 1 accident at approximately \$100,000, roundabout installations appear to be having a very positive impact.

**Figure 7. Cost Effectiveness & Benefit/Cost Ratio Worksheet**

MARYLAND STATE HIGHWAY ADMINISTRATION  
Office of Traffic and Safety  
Traffic Safety Analysis Division

NAME : P. CUNNINGHAM  
DATE : March 29, 2004

**COST EFFECTIVENESS WORKSHEET & BENEFIT/COST ANALYSIS**

**INTERSECTION**

LOCATION : 15 SINGLE LANE ROUNDABOUTS

COUNTY : VARIOUS LOGMILES : VARIOUS

INITIAL IMPLEMENTATION COST : \$6,219,505

ANNUAL OPERATING AND MAINTENANCE COST (BEFORE IMPLEMENTATION) : \$0

ANNUAL OPERATING AND MAINTENANCE COST (AFTER IMPLEMENTATION) : \$0

NET ANNUAL OPERATING AND MAINTENANCE COST : \$0

( NUMBER OF ACCIDENTS PREVENTED PER YEAR ) : 49

After period Years 4.47

ANNUAL SAFETY BENEFITS :					
ACCIDENT TYPE	EXPECTED	ACTUAL	BENEFIT	ACC. COST	ANNUAL BENEFIT
FATAL ACC	1	0	1.34	\$4,167,062	\$5,588,882
INJURY ACC	41	6	35.32	\$110,584	\$3,905,634
PROP. DAM. ACC.	30	18	12.07	\$20,156	\$315,724
			0		
			0		
			0		
<b>TOTAL</b>	<b>72</b>	<b>23</b>	<b>48</b>		<b>\$9,810,219</b>

SERVICE LIFE (YEARS) : 15

SALVAGE VALUE : \$0.00

INTEREST RATE : 6% = CAP RECOVERY FACTOR 0.1030

SINKING FUND FACTOR : 0.0000

ANNUAL BENEFIT (AB): \$9,810,219

EUAC : \$540,509

Benefit/Cost 15.3

COST / EFFECTIVENESS \$13,146

SPENT PER ACC REDUCED

The final action in this report is to determine the economic impact of the roundabout installations brought about by accident prevention. Using Maryland's own accident cost figures for severity, it is determined that the average cost of a fatal accident is \$4,167,062. The average injury accident cost is at \$110,584 and average property damage only accident cost is at \$26,156.

Unlike the cost effectiveness evaluation, which determines how many dollars are spent to reduce 1 accident, the benefit/cost analysis considers the initial cost of the projects for the entire service life (15-years) of the roundabouts. In doing a benefit/cost analysis, the initial cost is converted into an Equivalent Uniform Annual Cost (EUAC). The EUAC is then divided into the Annual Benefit (AB). Again, this is done to calculate the amount of money spent over the 15-year service life for roundabout installations as opposed to the dollar value realized through the annual safety benefits in accident prevention during the actual after period of the roundabouts.

The worksheet above indicates that **for every dollar spent** on the roundabout installations over the entire 15-year service life, **approximately \$15 is anticipated to be realized in benefit through accident reduction.**

#### *Conclusion:*

The analysis indicates that at locations where roundabouts have been installed there has been a 68% decrease in the total accident rate and a 100% decrease in the fatal accident rate. There was also an 86% reduction in the injury accident rate and a 41% reduction in the property damage only accident rate. These calculations are based on the anticipated accident experience expected to occur had no roundabouts been installed compared to the actual after period accident experience of the roundabout locations.

The results of the cost/effectiveness evaluation of the 15 single-lane mini roundabouts indicated that for every accident reduced, a total of \$ 13,146 was spent. The weighted average accident cost for a single accident is estimated at approximately \$100,000. The benefit/cost analysis indicated that for every dollar spent on these projects, considering the 15-year service life of the roundabouts, there is a return of approximately \$ 15.00 to be realized through accident reduction.

The reasons for increased safety levels at roundabouts appear to be:

- Roundabouts have fewer conflict points in comparison to other conventional intersections. The potential for right-angle, left turn and head-on accidents is eliminated with roundabout use. Pedestrian accidents are also affected because crossing distances are shorter.
- Low absolute speeds associated with roundabouts allow drivers more time to react to potential conflicts, also helping to improve the safety performance of roundabouts.

- Since most road users travel at similar speeds through roundabouts, i.e., have low relative speeds, accident severity can be reduced compared to some traditionally controlled intersections.

# Appendix A

## ROUNDABOUTS ACCIDENTS

Total Accidents	MD 94 @ Old Frederick		MD 24 @ MD 165		MD 193 @ Oak Grove		MD 18A @ MD 18H		MD 17 @ MD 180	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0	0	2	0	0	0	0	0	0	0
Injury	14	0	20	1	0	2	2	0	9	0
PDO	6	4	10	0	1	0	2	1	8	0
Total	20	4	32	1	1	2	4	1	17	0
1/2 ADT(Avg.)	3106	3424	3300	4279	5968	6429	6794	7428	6728	7468
VMT (mill)	4.5	5.0	6.0	3.7	6.5	4.7	7.4	8.1	7.4	5.5
Rate/mve	4.44	0.80	5.33	0.27	0.15	0.43	0.54	0.12	2.30	0.00
Angle	17	1	14	0	0	0	2	1	14	0
Rear End	1	0	8	1	0	1	0	0	2	0
Fixed Obj.	0	2	0	0	0	1	0	0	0	0
Opp. Dir.	0	0	8	0	0	0	0	0	0	0
Sideswipe	0	0	1	0	0	0	2	0	0	0
Left turn	2	0	1	0	1	0	0	0	1	0
Pedestrian	0	0	0	0	0	0	0	0	0	0
Parked veh.	0	0	0	0	0	0	0	0	0	0
Other	0	1	0	0	0	0	0	0	0	0
Nighttime	2	1	7	0	0	0	0	0	4	0
Wet Surface	1	1	3	0	0	0	0	0	3	0
Alcohol use	0	1	2	0	0	0	1	0	1	0
Trucks	0	0	2	1	0	1	1	0	2	0

## ROUNDABOUTS ACCIDENTS

Total Accidents	MD 17 @ "B" Street		MD 140 @ Antrim Blvd.		MD 94 @ MD 144A		MD 213 @ Leeds Road		MD 2 @ MD 408/MD 422	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0	0	0	0	0	0	1	0	1	0
Injury	1	1	15	3	19	4	14	1	26	9
PDO	0	1	15	6	23	14	5	15	12	25
Total	1	2	30	9	42	18	20	16	39	34
1/2 ADT(Avg.)	1869	2074	6094	7173	3430	4227	3561	4256	6595	7884
VMT (mill)	2.0	3.0	11.2	16.8	6.2	15.1	6.5	11.6	12.2	20.9
Rate/mve	0.50	0.67	2.68	0.54	6.77	1.19	3.08	1.38	3.20	1.63
Angle	1	1	19	1	39	4	16	3	22	1
Rear End	0	0	5	2	2	1	1	1	3	17
Fixed Obj.	0	0	2	6	0	12	0	9	1	12
Opp. Dir.	0	0	1	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	1	0	0	1	0	0
Left turn	0	0	3	0	0	1	3	0	12	0
Pedestrian	0	1	0	0	0	0	0	0	0	0
Parked veh.	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	2	1	4
Nighttime	0	1	8	3	3	9	4	8	7	10
Wet Surface	0	0	5	4	5	9	4	2	9	10
Alcohol use	0	0	1	3	1	5	3	4	2	3
Trucks	0	0	2	0	6	2	0	1	3	2

**ROUNDABOUTS ACCIDENTS**

Total Accidents	MD 637 @ Oxen Run Road		MD 637 @ Good Hope Road		MD 63 @ MD 58		MD 372 @ Hilltop Road		MD 307 @ MD 313/MD 318	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0	0	0	0	1	0	0	0	0	0
Injury	2	0	2	2	8	1	4	1	12	1
PDO	3	2	1	1	10	4	7	4	4	2
Total	5	2	3	3	19	5	11	5	16	3
1/2 ADT(Avg.)	10088	11187	10088	11187	3112	3719	6002	6658	4621	5201
VMT (mill)	11.0	8.2	11.0	8.2	5.8	9.7	6.6	9.7	6.5	7.6
Rate/mve	0.45	0.24	0.27	0.37	3.28	0.52	1.67	0.52	2.46	0.39
Angle	1	0	2	0	12	3	7	0	11	0
Rear End	1	0	0	2	2	0	4	2	2	1
Fixed Obj.	0	0	0	1	3	2	0	3	1	2
Opp. Dir.	2	0	0	0	0	0	0	0	2	0
Sideswipe	1	2	0	0	0	0	0	0	0	0
Left turn	0	0	1	0	1	0	0	0	0	0
Pedestrian	0	0	0	0	0	0	0	0	0	0
Parked veh.	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	1	0	0	0	0	0
Nighttime	3	1	1	2	2	1	1	4	3	1
Wet Surface	2	0	2	0	7	1	6	4	5	1
Alcohol use	0	0	0	0	1	0	0	2	0	1
Trucks	2	0	0	0	1	0	0	0	1	0

Total Accidents	Total		Rate		% Reduc.
	Before	After	Before	After	
Fatal	5	0	0.05	0.00	100
Injury	148	26	1.34	0.19	86
PDO	107	79	0.97	0.57	41
Total	260	105	2.35	0.76	68
Days/study	21486	24493			
VMT (mill)	110.8	137.8	110.8	137.8	-24
Rate/mve	2.35	0.76			
Angle	177	15	1.60	0.11	93
Rear End	31	28	0.28	0.20	27
Fixed Obj.	7	50	0.06	0.36	-474
Opp. Dir.	13	0	0.12	0.00	100
Sideswipe	5	3	0.05	0.02	52
Left turn	25	1	0.23	0.01	97
Pedestrian	0	1	0.00	0.01	#DIV/0!
Parked veh.	0	0	0.00	0.00	#DIV/0!
Other	2	7	0.02	0.05	-181
Nighttime	45	41	0.41	0.30	27
Wet Surface	52	32	0.47	0.23	51
Alcohol use	12	19	0.11	0.14	-27
Trucks	20	7	0.18	0.05	72

## Appendix B

### ROUNDAABOUTS RATES

Rate/MVE	MD 94 @ Old Frederick			MD 24 @ MD 165			MD 193 @ Old Grove			MD 18A @ MD 18H			MD 17 @ MD 180		
	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.
Fatal	0.00	0.00	#DIV/0!	0.33	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Injury	3.11	0.00	100%	3.33	0.27	92%	0.00	0.43	#DIV/0!	0.27	0.00	100%	1.22	0.00	100%
PDO	1.33	0.80	40%	1.67	0.00	100%	0.15	0.00	100%	0.27	0.12	54%	1.08	0.00	100%
Total	4.44	0.80	82%	5.33	0.27	95%	0.15	0.43	-177%	0.54	0.12	77%	2.30	0.00	100%
VMT (mill)	4.5	5.0	-11%	6.0	3.7	38%	6.5	4.7	28%	7.4	8.1	-9%	7.4	5.5	26%
Angle	3.78	0.20	95%	2.33	0.00	100%	0.00	0.00	#DIV/0!	0.27	0.12	54%	1.89	0.00	100%
Rear End	0.22	0.00	100%	1.33	0.27	80%	0.00	0.21	#DIV/0!	0.00	0.00	#DIV/0!	0.27	0.00	100%
Fixed Obj.	0.00	0.40	-100%	0.00	0.00	#DIV/0!	0.00	0.21	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Opp. Dir.	0.00	0.00	#DIV/0!	1.33	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Sideswipe	0.00	0.00	#DIV/0!	0.17	0.00	100%	0.00	0.00	#DIV/0!	0.27	0.00	100%	0.00	0.00	#DIV/0!
Left turn	0.44	0.00	100%	0.17	0.00	100%	0.15	0.00	100%	0.00	0.00	#DIV/0!	0.14	0.00	100%
Pedestrian	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Parked veh	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Other	0.00	0.20	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Nighttime	10%	25%	-150%	19%	0%	100%	0%	0%	#DIV/0!	0%	0%	#DIV/0!	18%	0.0	100%
Wet Surfac	5%	25%	-400%	6%	0%	100%	0%	0%	#DIV/0!	0%	0%	#DIV/0!	18%	0.0	100%
Alcohol use	0%	25%	#DIV/0!	6%	0%	100%	0%	0%	#DIV/0!	25%	0%	100%	6%	0.0	100%
Trucks	0.0	0.0	#DIV/0!	0.16	0.14	13%	0.0	0.5	#DIV/0!	0.1	0.0	100%	0.2	0.0	100%

### ROUNDAABOUTS RATES

Rate/MVE	MD 17 @ "B" Street			MD 140 @ Antrim Blvd.			MD 94 @ MD 144A			MD 213 @ Leeds Road			MD 2 @ MD 408/MD 422		
	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.
Fatal	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.15	0.00	100%	0.08	0.00	100%
Injury	0.50	0.33	33%	1.34	0.18	87%	3.06	0.26	91%	2.15	0.09	96%	2.13	0.43	80%
PDO	0.00	0.33	#DIV/0!	1.34	0.36	73%	3.71	0.93	75%	0.77	1.29	-68%	0.98	1.20	-22%
Total	0.50	0.67	-33%	2.68	0.54	80%	6.77	1.19	82%	3.08	1.38	55%	3.20	1.63	49%
VMT (mill)	2.0	3.0	-50%	11.2	16.8	-50%	6.2	15.1	-144%	6.5	11.6	-78%	12.2	20.9	-71%
Angle	0.50	0.33	33%	1.70	0.06	96%	6.29	0.26	96%	2.46	0.26	89%	1.80	0.05	97%
Rear End	0.00	0.00	#DIV/0!	0.45	0.12	73%	0.32	0.07	79%	0.15	0.09	44%	0.25	0.81	-231%
Fixed Obj.	0.00	0.00	#DIV/0!	0.18	0.36	-100%	0.00	0.79	-100%	0.00	0.78	-100%	0.08	0.57	-600%
Opp. Dir.	0.00	0.00	#DIV/0!	0.09	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Sideswipe	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.16	0.00	100%	0.00	0.09	#DIV/0!	0.00	0.00	#DIV/0!
Left turn	0.00	0.00	#DIV/0!	0.27	0.00	100%	0.00	0.07	#DIV/0!	0.46	0.00	100%	0.98	0.00	100%
Pedestrian	0.00	0.33	-100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Parked veh	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Other	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.17	-100%	0.08	0.19	-133%
Nighttime	0%	50%	#DIV/0!	27%	33%	-22%	7%	50%	-614%	20%	50%	-150%	18%	29%	-61%
Wet Surfac	0%	0%	#DIV/0!	17%	44%	-159%	12%	50%	-317%	20%	13%	35%	23%	29%	-26%
Alcohol use	0%	0%	#DIV/0!	3%	33%	-1000%	2%	28%	-1300%	15%	25%	-67%	5%	9%	-80%
Trucks	0.0	0.0	#DIV/0!	0.1	0.0	100%	0.5	0.07	86%	0.0	0.04	#DIV/0!	0.12	0.0	100%

**ROUNDBABOUTS RATES**

Rate/MVE	MD 637 @ Oxen Run Road			MD 637 @ Good Hope Road			MD 63 @ MD 58			MD 372 @ Hilltop Road			MD 307@MD 313/MD 318		
	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.	Before	After	% Reduc.
Fatal	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.17	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Injury	0.18	0.00	100%	0.18	0.24	-34%	1.38	0.10	93%	0.61	0.10	83%	1.85	0.13	93%
PDO	0.27	0.24	11%	0.09	0.12	-34%	1.72	0.41	76%	1.06	0.41	61%	0.62	0.26	57%
Total	0.45	0.24	46%	0.27	0.37	-34%	3.28	0.52	84%	1.67	0.52	69%	2.46	0.39	84%
VMT (mill)	11.0	8.2	25%	11.0	8.2	25%	5.8	9.7	-67%	6.6	9.7	-47%	6.5	7.6	-17%
Angle	0.09	0.00	100%	0.18	0.00	100%	2.07	0.31	85%	1.06	0.00	100%	1.69	0.00	100%
Rear End	0.09	0.00	100%	0.00	0.24	-100%	0.34	0.00	100%	0.61	0.21	66%	0.31	0.13	57%
Fixed Obj.	0.00	0.00	#DIV/0!	0.00	0.12	-100%	0.52	0.21	60%	0.00	0.31	-100%	0.15	0.26	-71%
Opp. Dir.	0.18	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.31	0.00	100%
Sideswipe	0.09	0.24	-168%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Left turn	0.00	0.00	#DIV/0!	0.09	0.00	100%	0.17	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Pedestrian	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Parked veh	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Other	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!	0.17	0.00	100%	0.00	0.00	#DIV/0!	0.00	0.00	#DIV/0!
Nighttime	40%	50%	-25%	33%	67%	-103%	11%	20%	-82%	9%	80%	-789%	19%	33%	-74%
Wet Surfac	40%	0%	100%	67%	0%	100%	37%	20%	46%	55%	80%	-45%	31%	33%	-6%
Alcohol use	0%	0%	#DIV/0!	0%	0%	#DIV/0!	5%	0%	100%	0%	40%	-100%	0%	33%	#DIV/0!
Trucks	0.05	0.0	100%	0.0	0.0	#DIV/0!	0.1	0.0	100%	0.0	0.0	#DIV/0!	0.08	0.0	100%

**Appendix C**  
**ROUNDBOUTS AVERAGE ACCIDENTS PER YEAR**

Average Accidents	MD 94 @ Old Frederick		MD 24 @ MD 165		MD 193 @ Oak Grove		MD 18A @ MD 18H		MD 17 @ MD 180	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Injury	3.5	0.0	4.0	0.4	0.0	1.0	0.7	0.0	3.0	0.0
PDO	1.5	1.0	2.0	0.0	0.3	0.0	0.7	0.3	2.7	0.0
Total	5.0	1.0	6.4	0.4	0.3	1.0	1.3	0.3	5.7	0.0
Days	1461	1461	1826	852	1095	730	1095	1096	1095	730
VMT (mill)										
Years	4.0	4.0	5.0	2.3	3.0	2.0	3.0	3.0	3.0	2.0
Angle	4.2	0.2	2.8	0.0	0.0	0.0	0.7	0.3	4.7	0.0
Rear End	0.2	0.0	1.6	0.4	0.0	0.5	0.0	0.0	0.7	0.0
Fixed Obj.	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Opp. Dir.	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sideswipe	0.0	0.0	0.2	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Left turn	0.5	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.3	0.0
Pedestrian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parked veh.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nighttime	0.5	0.2	1.4	0.0	0.0	0.0	0.0	0.0	1.3	0.0
Wet Surface	0.2	0.2	0.6	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Alcohol use	0.0	0.2	0.4	0.0	0.0	0.0	0.3	0.0	0.3	0.0
Trucks	0.0	0.0	0.4	0.4	0.0	0.5	0.3	0.0	0.7	0.0

**ROUNDBOUTS AVERAGE ACCIDENTS PER YEAR**

Average Accidents	MD 17 @ "B" Street		MD 140 @ Antrim Blvd.		MD 94 @ MD 144A		MD 213 @ Leeds Road		MD 2 @ MD 408/MD 422	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
Injury	0.3	0.2	3.0	0.5	3.8	0.4	2.8	0.1	5.2	1.3
PDO	0.0	0.2	3.0	0.9	4.6	1.4	1.0	2.0	2.4	3.5
Total	0.3	0.5	6.0	1.4	8.4	1.9	4.0	2.2	7.8	4.7
Days	1096	1461	1827	2326	1827	3550	1826	2708	1826	2624
VMT (mill)										
Years	3.0	4.0	5.0	6.4	5.0	9.7	5.0	7.4	5.0	7.2
Angle	0.3	0.2	3.8	0.2	7.8	0.4	3.2	0.4	4.4	0.1
Rear End	0.0	0.0	1.0	0.3	0.4	0.1	0.2	0.1	0.6	2.4
Fixed Obj.	0.0	0.0	0.4	0.9	0.0	1.2	0.0	1.2	0.2	1.7
Opp. Dir.	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sideswipe	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0
Left turn	0.0	0.0	0.6	0.0	0.0	0.1	0.6	0.0	2.4	0.0
Pedestrian	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parked veh.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.6
Nighttime	0.0	0.2	1.6	0.5	0.6	0.9	0.8	1.1	1.4	1.4
Wet Surface	0.0	0.0	1.0	0.6	1.0	0.9	0.8	0.3	1.8	1.4
Alcohol use	0.0	0.0	0.2	0.5	0.2	0.5	0.6	0.5	0.4	0.4
Trucks	0.0	0.0	0.4	0.0	1.2	0.2	0.0	0.1	0.6	0.3

**ROUNDABOUTS AVERAGE ACCIDENTS PER YEAR**

Average Accidents	MD 637 @ Oxen Run Road		MD 637 @ Good Hope Road		MD 63 @ MD 58		MD 372 @ Hilltop Road		MD 307 @ MD 313/MD 318	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fatal	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Injury	0.7	0.0	0.7	1.0	4.0	0.1	1.3	0.2	3.1	0.2
PDO	1.0	1.0	0.3	0.5	5.0	0.6	2.3	1.0	1.0	0.5
Total	1.7	1.0	1.0	1.5	3.8	0.7	3.7	1.2	4.2	0.7
Days	1095	730	1095	730	1826	2573	1096	1461	1400	1461
VMT (mill)										
Years	3.0	2.0	3.0	2.0	5.0	7.0	3.0	4.0	3.8	4.0
Angle	0.3	0.0	0.7	0.0	2.4	0.4	2.3	0.0	2.9	0.0
Rear End	0.3	0.0	0.0	1.0	0.4	0.0	1.3	0.5	0.5	0.2
Fixed Obj.	0.0	0.0	0.0	0.5	0.6	0.3	0.0	0.7	0.3	0.5
Opp. Dir.	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Sideswipe	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Left turn	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Pedestrian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parked veh.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Nighttime	1.0	0.5	0.3	1.0	0.4	0.1	0.3	1.0	0.8	0.2
Wet Surface	0.7	0.0	0.7	0.0	1.4	0.1	2.0	1.0	1.3	0.2
Alcohol use	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.2
Trucks	0.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0

Total Accidents	Total		% Reduc.
	Before	After	
Fatal	1.3	0.0	100
Injury	36.1	5.6	85
PDO	27.9	13.0	53
Total	59.5	18.6	69
Days/study	21486	24493	
VMT (mill)	0.0	0.0	#REF!
Years	#DIV/0!	#DIV/0!	
Angle	40.5	2.4	94
Rear End	7.3	5.6	23
Fixed Obj.	1.5	8.1	-454
Opp. Dir.	3.0	0.0	100
Sideswipe	1.4	1.1	19
Left turn	5.5	0.1	98
Pedestrian	0.0	0.2	#DIV/0!
Parked veh.	0.0	0.0	#DIV/0!
Other	0.4	1.1	-169
Nighttime	10.5	7.3	31
Wet Surface	12.5	4.9	61
Alcohol use	2.7	2.9	-10
Trucks	4.7	1.5	67

## Appendix D *Roundabouts*

	Before				After			
	Days	Years	Avg. ADT	VMT	Days	Years	Avg. ADT	VMT
MD 94@ Old Frederick	1461	4.0	3106	4.5	1461	4.0	3424	5.0
MD 24@ MD165	1826	5.0	3300	6.0	852	2.3	4279	3.7
MD193@Oak Grove	1095	3.0	5968	6.5	730	2.0	6429	4.7
MD18A@ MD18H	1095	3.0	6794	7.4	1096	3.0	7428	8.1
MD 17@MD180	1095	3.0	6728	7.4	730	2.0	7468	5.5
MD17@"B"St	1096	3.0	1869	2.0	1461	4.0	2074	3.0
MD140@Antrim	1827	5.0	6094	11.2	2326	6.4	7173	16.8
MD94@MD144A	1827	5.0	3430	6.2	3550	9.7	4227	15.1
MD213@Leeds	1826	5.0	3561	6.5	2708	7.4	4256	11.6
MD2@MD408/MD422	1826	5.0	6595	12.2	2624	7.2	7884	20.9
MD637@Oxen Run	1095	3.0	10088	11.0	730	2.0	11187	8.2
MD637@Good Hope	1095	3.0	10088	11.0	730	2.0	11187	8.2
MD63@MD58	1826	5.0	3112	5.8	2573	7.0	3719	9.7
MD372@Hilltop	1096	3.0	6002	6.6	1461	4.0	6658	9.7
MD307@MD313/MD318	1400	3.8	4621	6.5	1461	4.0	5201	7.6
Total Days	21486				24493			
Average Years	3.92				4.47			
Average ADT			5424				6173	
Total VMT				110.8				137.8

## Appendix E Cost of Roundabouts

<u>Single Lane Roundabouts</u>	<u>County</u>	<u>Cost</u>	
MD 94 @ Old Frederick Rd	Howard	\$232,284	
MD 24 @ MD 165	Harford	\$520,613	
MD 193 @ Grove Road	Prince George	\$300,000	*
MD 18A @ MD 18H	Queen Annes	\$300,000	*
MD 17 @ MD 180	Frederick	\$679,569	
MD 17 @ B Street	Frederick	\$687,434	
MD 140 @ Antrim	Carroll	\$464,540	
MD 94 @ MD 144A	Howard	\$200,000	*
MD 213 @ Leeds	Cecil	\$472,014	
MD 2 @ MD 408/MD 422	Anne Arundel	\$493,881	
MD 637 @ Oxon Run Road	Prince George	\$300,000	*
MD 637 @ Good Hope Road	Prince George	\$300,000	*
MD 58 @ MD 63	Washington	\$386,145	
MD 372 @ Hilltop Road	Baltimore	\$500,678	
MD 307 @ MD 313/MD 318	Caroline	<u>\$382,347</u>	
Total		\$6,219,505	
Average Cost		<b>\$414,634</b>	

*\*ESTIMATED (part of larger project)*

## Appendix F

### TWO-LANE ROUNDABOUTS ACCIDENTS, YEARLY AVERAGES AND RATES

Total Accidents	US 1 @ 34th St/Perry St.		MD450 @ MD435/MD387		MD 139 @ Bellona Avenue		MD 45 Towson Roundabout	
	Before	After	Before	After	Before	After	Before	After
Fatal	0	0	0	0	0	0	0	0
Injury	0	1	5	1	2	0	21	14
PDO	1	8	7	8	3	0	13	63
Total	1	9	12	9	5	0	34	77
1/2 ADT(Avg.)	10300	10931	10822	12364	12504	13870	22455	26029
VMT (mill)	11.3	4.0	7.9	13.6	13.7	20.3	41.0	47.5
Rate/mve	0.09	2.25	1.52	0.66	0.36	0.00	0.83	1.62
Angle	0	2	1	0	1	0	5	13
Rear End	0	1	4	0	4	0	14	28
Fixed Obj.	0	2	0	2	0	0	1	2
Opp. Dir.	0	0	0	0	0	0	0	0
Sideswipe	1	3	4	6	0	0	1	30
Left turn	0	0	1	0	0	0	9	0
Pedestrian	0	0	1	0	0	0	2	3
Parked veh.	0	0	0	0	0	0	0	0
Other	0	1	1	1	0	0	2	1
Nighttime	0	3	1	2	1	0	10	18
Wet Surface	0	2	3	2	2	0	8	14
Alcohol use	0	0	1	1	0	0	3	1
Trucks	0	0	0	0	0	0	2	4

Total Accidents	Total Accidents		Rate		% Reduction
	Before	After	Before	After	
Fatal	0	0	0.00	0.00	#DIV/0!
Injury	28	16	0.38	0.19	51
PDO	24	79	0.32	0.93	-185
Total	52	95	0.70	1.11	-58
VMT (mill)	73.9	85.4	73.9	85.4	
Rate/mve	0.70	1.11			
Angle	7	15	0.09	0.18	-85
Rear End	22	29	0.30	0.34	-14
Fixed Obj.	1	6	0.01	0.07	-419
Opp. Dir.	0	0	0.00	0.00	#DIV/0!
Sideswipe	6	39	0.08	0.46	-462
Left turn	10	0	0.14	0.00	100
Pedestrian	3	3	0.04	0.04	13
Parked veh.	0	0	0.00	0.00	#DIV/0!
Other	3	3	0.04	0.04	13
Nighttime	12	23	0.16	0.27	-66
Wet Surface	13	18	0.18	0.21	-20
Alcohol use	4	2	0.05	0.02	57
Trucks	2	4	0.03	0.05	-73

## Appendix G

### TWO-LANE ROUNDABOUTS ACCIDENTS, YEARLY AVERAGES AND RATES

<i>Total Rates</i>	<i>US 1 @ 34th St/Perry St.</i>		<i>MD450 @ MD435/MD387</i>		<i>MD 139 @ Bellona Avenue</i>		<i>MD 45 Towson Roundabout</i>	
	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>
<b>Fatal</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Injury</b>	0.00	0.25	0.63	0.07	0.15	0.00	0.51	0.29
<b>PDO</b>	0.09	2.00	0.89	0.59	0.22	0.00	0.32	1.33
<b>Total</b>	0.09	2.25	1.52	0.66	0.36	0.00	0.83	1.62
<b>VMT (mill)</b>	11.3	4.0	7.9	13.6	13.7	20.3	41.0	47.5
<b>Angle</b>	0.00	0.50	0.13	0.00	0.07	0.00	0.12	0.27
<b>Rear End</b>	0.00	0.25	0.51	0.00	0.29	0.00	0.34	0.59
<b>Fixed Obj.</b>	0.00	0.50	0.00	0.15	0.00	0.00	0.02	0.04
<b>Opp. Dir.</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Sideswipe</b>	0.09	0.75	0.51	0.44	0.00	0.00	0.02	0.63
<b>Left turn</b>	0.00	0.00	0.13	0.00	0.00	0.00	0.22	0.00
<b>Pedestrian</b>	0.00	0.00	0.13	0.00	0.00	0.00	0.05	0.06
<b>Parked veh.</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Other</b>	0.00	0.25	0.13	0.07	0.00	0.00	0.05	0.02
<b>Nighttime</b>	0.00	0.75	0.13	0.15	0.07	0.00	0.24	0.38
<b>Wet Surface</b>	0.00	0.50	0.38	0.15	0.15	0.00	0.20	0.29
<b>Alcohol use</b>	0.00	0.00	0.13	0.07	0.00	0.00	0.07	0.02
<b>Trucks</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.08

## Appendix H

### TWO-LANE ROUNDABOUTS ACCIDENTS, YEARLY AVERAGES AND RATES

Averages	US 1 @ 34th St/Perry St.		MD450 @ MD435/MD387		MD 139 @ Bellona Avenue		MD 45 Towson Roundabout	
	Before	After	Before	After	Before	After	Before	After
Fatal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Injury	0.00	1.00	2.50	0.30	0.70	0.00	4.20	2.80
PDO	0.30	8.00	3.50	2.70	1.00	0.00	2.60	12.60
Total	0.30	9.00	6.00	3.00	1.70	0.00	6.80	15.40
VMT (mill)	11.3	4.0	7.9	13.6	13.7	20.3	41.0	47.5
Angle	0.00	2.00	0.50	0.00	0.30	0.00	1.00	2.60
Rear End	0.00	1.00	2.00	0.00	1.30	0.00	2.80	5.60
Fixed Obj.	0.00	2.00	0.00	0.70	0.00	0.00	0.20	0.40
Opp. Dir.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideswipe	0.30	3.00	2.00	2.00	0.00	0.00	0.20	6.00
Left turn	0.00	0.00	0.50	0.00	0.00	0.00	1.80	0.00
Pedestrian	0.00	0.00	0.50	0.00	0.00	0.00	0.40	0.60
Parked veh.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	1.00	0.50	0.30	0.00	0.00	0.40	0.20
Nighttime	0.00	4.00	0.50	0.70	0.30	0.00	2.00	3.60
Wet Surface	0.00	2.00	1.50	0.70	0.70	0.00	1.60	2.80
Alcohol use	0.00	0.00	0.50	0.30	0.00	0.00	0.60	0.20
Trucks	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.80

### *Acronyms and Terms:*

EUAC –	Equivalent Uniform Annual Cost
AB –	Annual Benefit
CRF –	Capital Recovery Factor
SSF –	Sinking Fund Factor
FYB -	First Year Benefit

Capital Recovery Factor – A factor to measure the amount of invested capital that can be recuperated from a project.

Confidence Interval – Interval estimation. Two numbers, computed from sample data, forming an interval estimate for some parameter.

Benefit/Cost Analysis – A form of economic evaluation in which input is measured in terms of dollar cost and output is measured in terms of economic benefit of a project as compared to the incurred cost of the project.

Cost/Effectiveness Analysis – A form of economic evaluation in which input is measured in terms of project effectiveness and output is measured in terms of the cost achieving one unit of the desired measure of effectiveness.

Poisson Distribution – A distribution which often appears in observed events which are very improbable compared to all possible events, but which occur occasionally since so many trials occur. The mean and variance of the Poisson Distribution are equal.

### *References:*

1. The Costs of Highway Crashes, U.S. Department of Transportation – Publication No. FHWA – RD-91-055, October 1991.
2. Maryland State Highway Administration, Office of Traffic and Safety's Accident Database.
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4. Evaluation of Highway Safety Project – Procedural Guide, Federal Highway Administration.