
231 BENEFIT/COST RATIO ECONOMIC ANALYSIS

The purpose of the crash-based B/C ratio economic analysis is to provide an economic assessment of the extent to which a project or program may achieve its ultimate goal of reducing the number and/or severity of crashes. The B/C ratio analysis ultimately provides a means of selecting the most cost-effective countermeasure(s) for any given project.

The procedure involves the economic evaluation of improvement alternatives to develop effective improvement projects from the candidate alternatives. It is one of the most widely-used methods of screening programs and projects that are being considered for development.

The crash-based B/C ratio analysis should be made for those situations that are conducive to its use. The conclusion and recommendations for candidate projects should be based on the results of the B/C ratio analysis.

The crash-based B/C ratio method uses the ratio of expected benefits accrued (crash savings, reduced user costs, etc.) to the costs incurred for a countermeasure.

231.1 ANNUAL BENEFIT

The safety benefit is the anticipated reduction in the total annual number of crashes or crash frequency per countermeasure. The total annual crash cost saving (benefit) is obtained using FHWA's comprehensive motor vehicle crash costs (see page 231-6) and an appropriate crash reduction factor (ARF). The benefit should be evaluated for each countermeasure.

A comprehensive source for crash reduction factors is not available at this time. Available data and engineering judgment should be used to select appropriate crash reduction factors.

As a guideline to the magnitude of expected crash reduction factors for various types of improvements, reference may be made to the table on page 231-9, abstracted from *The 1996 Annual Report on Highway Safety Improvement Programs, Publication No. FHWA-SA-96-040*, and the listing on pages 231-10 through 231-20, *Crash Rate Reduction Levels Which May Be Attainable From Various Safety Improvements (Arizona Data) February 1991*.

231.2 ANNUAL COST

The cost of each alternative countermeasure is calculated as follows:

- (1) Determine the total construction cost (initial design, right-of-way, construction, and other costs associated with the projects).
- (2) Determine the service life of the countermeasure from the listing on page 231-7.

- (3) Obtain or assume an interest rate, which is appropriate for current economic conditions, in percent.
- (4) Compute the annual construction cost by multiplying the total construction cost by the appropriate capital recovery factor, based on the interest rate and service life of the countermeasure, from the table on page 231-8.
- (5) Determine the annual estimated operating and maintenance cost for the countermeasure, and subtract the existing annual operating and maintenance cost to obtain the annual maintenance cost difference.
- (6) Compute the total annual cost of the project (annual construction cost + annual maintenance cost difference).

231.3 BENEFIT/COST ANALYSIS

The B/C ratio is computed by dividing the annual benefit by the annual cost. The procedure is detailed on the worksheet on page 231-5.

When one alternative improvement involves several countermeasures, the following procedure should be used to calculate the overall crash reduction factor for that alternative improvement:

$$\text{Crash reduction factor} = 1 - (1 - \text{ARF}_1) (1 - \text{ARF}_2) (1 - \text{ARF}_3) \\ (1 - \text{ARF}_4) (1 - \text{ARF}_5) \dots\dots\dots$$

where ARF₁, ARF₂, ARF₃, etc. are crash reduction factors for countermeasures 1, 2, 3, etc., respectively.

231.4 INCREMENTAL BENEFIT/COST ANALYSIS ($\Delta B/\Delta C$)

The incremental B/C ratio method may be used to determine whether extra increments of cost (e.g., widening the curve plus roadside improvements vs. curve widening only) are justified for a particular location or for considering improvements at two or more locations. This method assumes that the relative merit of a project is measured by its change in benefits and costs, compared to the next lower-cost alternative.

The steps for using the incremental B/C ratio method are as follows:

- (1) Determine the benefits, costs, and the resulting B/C ratio for each countermeasure.
- (2) List countermeasures with a B/C ratio greater than 1.0 in order of increasing cost.

- (3) Calculate the incremental B/C ratio of the second lowest-cost countermeasure compared to the lowest-cost countermeasure. Pick the second lowest-cost countermeasure if this ratio is positive; else pick the lowest-cost countermeasure.
- (4) Continue in order of increasing costs to calculate the incremental B/C ratio for each countermeasure compared to the last-picked countermeasure.
- (5) Stop when the incremental B/C ratio (disregarding negative ratios) is less than 1.0.

To illustrate the use of this method, consider the costs and benefits in the following example. Notice that options must be ordered from lowest to highest cost. Each option may consist of a single countermeasure or a combination of countermeasures.

Illustration of Incremental B/C Analysis

Counter-measure	Annual Benefit	Annual Cost	B/C Ratio	Comparison of Counter-measures	Incremental Benefit	Cost	Incremental B/C Ratio ($\Delta B/\Delta C$)
B	\$15,200	\$1,510	10.1				
				B and C	\$-2,400	\$200	-12.0 (Pick B)
C	\$12,800	\$1,710	7.5				
				B and A	\$25,600	\$19,750	1.3 (Pick A)
A	\$40,800	\$21,260	1.9				
				A and D	\$12,000	\$3,240	3.7 (Pick D)
D	\$52,800	\$24,500	2.2				

From this example, countermeasure B (lowest-cost countermeasure) is first compared with countermeasure C, and countermeasure B is preferred to countermeasure C ($\Delta B/\Delta C = -12.0$). Countermeasure C is then excluded from further consideration. Countermeasure B is next compared with countermeasure A, and countermeasure A (the higher cost countermeasure) is preferred, since $\Delta B/\Delta C = 1.3$ (greater than 1.0). In this case, spending an additional \$19,750 on countermeasure A will yield \$25,600 of additional benefits. Countermeasure B is then eliminated from further consideration. Finally, countermeasures A and D are compared, and the additional \$3,240 in cost from countermeasure D is compared with the \$12,000 of additional benefits from countermeasure D. Thus, $\Delta B/\Delta C = 3.7$ between countermeasures D and A, and countermeasure D is the optimal solution based on incremental benefits and costs. Notice that countermeasure D was selected with a simple B/C ratio of 2.2, even though countermeasures B and C had B/C ratios of 10.1 and 7.5, respectively. This solution would be subject to funding availability, political considerations, environmental constraints, etc.

231.5 APPLICATION

The B/C ratio method requires that dollar values be placed on all estimated costs and the expected benefits related to the countermeasure. A countermeasure that has a B/C ratio

greater than 1.0 is considered economically justified. The countermeasure with the highest B/C ratio is normally the recommended alternative, unless the incremental B/C ratio method is used.

The B/C ratio method is recommended only when a set of costs for highway crashes (fatalities, injuries, property damages, etc.) has been established. ADOT has adopted FHWA's motor vehicle crash costs.

The method may be applicable to either an individual countermeasure or one consisting of several improvements. The B/C ratio should be evaluated for each alternative countermeasure. The selection of a countermeasure shall consider the highest B/C ratio, unless the incremental B/C ratio method is used.

231.6 STANDARD WORKSHEET AND TABLES

See the following pages.

ARIZONA DEPARTMENT OF TRANSPORTATION TRAFFIC ENGINEERING GROUP TRAFFIC DESIGN SECTION					
BENEFIT/COST ANALYSIS WORKSHEET					
Project Number		Date		Compiled by	
Route		from Milepost		to Milepost	
Alternative of		Type of Improvement			
BENEFITS					
Crash Types	Annual Average	Crash Reduction Factor	Total Reduction	Unit Cost	Annual Benefit
Fatal				5,800,000.00	
Incap. Injury				400,000.00	
Non-incap. Inj				80,000.00	
Possible Inj.				42,000.00	
PDO				4000.00	
<u>Unknown</u>				<u>4000.00</u>	
			Total Annual Benefit		
COSTS					
Total Construction Cost					
Project Life (Years)					
Interest Rate (%)					
Capital Recovery Factor (CRF)					
Annual Const. Cost = CRF x Total Const. Cost (A)					
Annual Maintenance Cost Difference (if applicable) (B)					
Total Annual Cost: (A + B)					
BENEFIT/COST					
Annual Benefit		Annual Cost		Benefit/Cost Ratio	

TRAFFIC CRASH COSTS

(FHWA's comprehensive costs in 1994 dollars converted to 2002 dollars)

<u>Crash Types</u>	<u>Cost</u>
Fatal	\$5,800,000
Incapacitating	\$ 400,000
Evident	\$ 80,000
Possible	\$ 42,000
Property Damage Only	\$ 4,000
Unknown	\$ 4,000

**SAFETY IMPROVEMENT PROJECT CODES, DESCRIPTIONS, AND
 SERVICE LIVES USED IN EFFECTIVENESS EVALUATIONS**

<u>Code</u>	<u>Description</u>	<u>Service Life (Years)</u>	
INTERSECTION PROJECTS			
10	Channelization, left-turn bay	10	
11	Traffic Signals	10	
12	Combination of 10 and 11	10	
13	Sight distance improvement	10	
19	Other intersection improvements, except structures	10	
1A	Combination of 10 and 19	10	
1B	Combination of 11, 13, 19, and 65	10	
CROSS SECTION PROJECTS			
20	Pavement widening, no lanes added	20	
21	Lanes added without new median	20	
22	Highway divided, new median added	20	
23	Shoulder widening or improvement		20
24	Combination of 20 - 23	20	
25	Skid treatment - grooving	10	
26	Skid treatment - overlay	10	
27	Flattening, clearing side slopes	20	
29	Other cross section or combinations of 20 - 27		20
2A	Combination of 20 and 26	15	
STRUCTURES			
30	Widening bridge or major structure		20
31	Replace bridge or major structure	30	
32	New bridge or major structure (except 34 and 51)	30	
33	Minor structure	20	
34	Pedestrian over- or under-crossing		30
39	Other structure	20	
ALIGNMENT PROJECTS			
40	Horizontal alignment changes (except 52)	20	
41	Vertical alignment changes	20	
42	Combination of 40 and 41	20	
49	Other alignments	20	
RAILROAD GRADE CROSSING PROJECTS			
50	Flashing lights replacing signs	10	
51	Elimination by new or reconstructed grade separation	30	
52	Elimination by relocation of highway or railroad		30
53	Illumination	10	
54	Flashing lights replacing active devices	10	
55	Automatic gates replacing signs	10	
56	Automatic gates replacing active devices	10	
57	Signing, marking	10	
58	Crossing surface improvement	10	
59	Other railroad grade crossing improvement	10	
5A	Any combination of 50, 54, 55, 56, 57, and 58	10	
ROADSIDE APPURTENANCES			
60	Traffic Signs	6	
61	Breakaway sign or luminaire supports	10	
62	Road edge guardrail	10	
63	Median barrier	15	
64	Markings, delineators	2	
65	Lighting	15	
66	Improved drainage structures	20	
67	Fencing	10	
68	Impact attenuators	10	
69	Other roadside improvements	10	
6A	Combination of 60 - 64	10	
6B	Combination of 64 and 68	10	
6C	Combination of 60 and 62	8	
6D	Combination of 60 and 64	4	
6E	Combination of 62 and 69	10	
6F	Combination of 62, 66, and 69	10	
6G	Combination of 60 and 63	10	
OTHER SAFETY IMPROVEMENTS			
90	Safety provisions for roadside features and appurtenances		20
99	All projects not otherwise classifiable	20	
9A	Combination of 11, 26, and 69	10	
9B	Combination of 26 and 66	15	
9C	Combination of 27, 30, 62, and 99	20	
9D	Combination of 11 and 60	8	
9E	Combination of 11 and 64	6	
9F	Combination of 23, 26, and 62	15	
9G	Combination of 27, 61, 62, and 64	10	
9H	Combination of 22, 39, and 65	20	
9I	Combination of 23, 61, 62, 64, 65, and 66	15	

**INTEREST FACTORS FOR ANNUAL COMPOUNDING INTEREST
(EQUAL PAYMENT SERIES)**

CAPITAL RECOVERY FACTOR

Year	8%	10%	12%	14%	16%
2	0.5608	0.5762	0.5917	0.6073	0.6230
4	0.3019	0.3155	0.3292	0.3432	0.3574
6	0.2163	0.2296	0.2432	0.2572	0.2714
8	0.1740	0.1874	0.2013	0.2156	0.2302
10	0.1490	0.1627	0.1770	0.1917	0.2069
15	0.1168	0.1315	0.1468	0.1628	0.1794
20	0.1019	0.1175	0.1339	0.1510	0.1687
25	0.0937	0.1102	0.1275	0.1455	0.1640
30	0.0888	0.1061	0.1241	0.1428	0.1619

**EVALUATION OF SAFETY IMPROVEMENTS BY CONSTRUCTION CLASSIFICATION
 1974 -1994**

Construction Classification	Percent Reduction in Crash Rates After Improvements		
	Fatal	Nonfatal Injury	Combined Fatal+Nonfatal Injury
INTERSECTIONS AND TRAFFIC CONTROL			
Turning lanes & Traffic Channelization	48	26	26
Sight Distance Improvements	*56	*43	*43
Traffic Signs	32	15	15
Pavement Markings & Delineators	15	5	6
Illumination	38	14	14
Upgraded Traffic Signals	40	22	22
New Traffic Signals	*53	22	23
STRUCTURES			
Widen or Modify Bridge	49	30	31
New Bridge	86	69	70
Replace or Improve Minor Structure	36	20	21
Upgrade Bridge Rail	75	29	33
ROADWAY			
Construct Median for Traffic Separation	71	28	30
Widen or Improve Shoulder	21	12	12
Realign Roadway	63	41	42
Overlay for Skid Treatment	18	18	18
Groove Pavement for Skid Treatment	33	15	15
ROADSIDE			
Relocated/Breakaway Utility Poles	32	45	44
Upgrade Guardrail	36	8	9
Upgrade Median Barrier	*65	20	22
New Median Barrier	64	12	15
Impact Attenuators	*38	34	34
Flatten Side Slopes	*26	27	27
Remove Obstacles	60	23	25
RAILROAD-HIGHWAY CROSSINGS			
Upgrade Flashing Lights	85	35	44
New Flashing Lights	87	79	81
New Flashing Lights & Gates	92	85	86
New Gates	92	74	78

Note: * indicates no significant change at the 95 percent confidence level.

(Adapted from The 1996 Annual Report on Highway Safety Improvement Programs, Publication No. FHWA-SA-96-040)

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

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CRASH REDUCTION FACTOR CATEGORIES

1 - ROADWAY IMPROVEMENTS

- 1-1 Lane Addition
- 1-2 Lane Widening
- 1-3 Shoulder Widening
- 1-4 Two-Way Continuous Left – Turn Lane
- 1-5 Realignment
- 1-6 Shoulder Grooving
- 1-7 Skid – Resistant Overlay
- 1-8 Truck Escape Ramp
- 1-9 Brake Check Area

2 - ROADSIDE IMPROVEMENT

- 2-1 New Guardrail
- 2-2 Upgraded and / or Extended Guardrail
- 2-3 Drainage Structure Extensions
- 2-4 Slope Flattening
- 2-5 Vegetation / Obstacle Removal
- 2-6 New/Upgraded Median Barrier
- 2-7 Impact Attenuators
- 2-8 Object Markers
- 2-9 Delineation
- 2-10 Animal Fencing
- 2-11 Animal Reflectors
- 2-12 Snow Fencing
- 2-13 Rockfall Containment
- 2-14 Illumination

3 - INTERSECTIONS AND INTERCHANGES

- 3-1 New Signals
- 3-2 New Signals and Geometric Revamp
- 3-3 Revamped Signals
- 3-4 Revamped Signals and Geometric Revamp
- 3-5 Left–Turn Phasing
- 3-6 Turn Lanes
- 3-7 Geometric Ramp
- 3-8 Illumination
- 3-9 Sight Distance Improvement
- 3-10 Channelization Pavement Markings
- 3-11 Channelization Signing
- 3-12 Cross Road/Side Road Signing
- 3-13 Stop Signs
- 3-14 Yield Signs
- 3-15 Signal Removal

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

Sheet 2 of 15

4 - TRAFFIC CONTROL DEVICES

- 4-1 Edgeline Markings
- 4-2 RPMs
- 4-3 Rumble Strips
- 4-4 New Curve Signing
- 4-5 Upgraded Curve Signing
- 4-6 Icy Pavement Signing
- 4-7 Slippery When Wet Signing
- 4-8 Narrow Bridge Signing
- 4-9 Watch For Rocks Signing
- 4-10 Animal Warning Signs
- 4-11 Interstate Signing

5 - PEDESTRIANS

- 5-1 Sidewalks
- 5-2 Pedestrian Overpass
- 5-3 Pedestrian Signing

6 - STRUCTURES

- 6-1 Bridge Widening
- 6-2 Bridge Replacement
- 6-3 New Bridge
- 6-4 Bridge Barrier Upgrade

7 - RAILROAD – HIGHWAY CROSSINGS

- 7-1 New Flashing Lights
- 7-2 Upgraded Flashing Lights
- 7-3 New Gates and Flashing Lights to Replace X- Bucks
- 7-4 New Gates to Supplement Flashing Lights
- 7-5 Surface Improvement
- 7-6 Signing
- 7-7 Pavement Markings

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 3 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
1 – ROADWAY IMPROVEMENTS							
1-1 LANE ADDITION	30						
All Crashes		2719	<u>25</u>	<u>39</u>	<u>23</u>	<u>23</u>	<u>27</u>
Rear-End		931	<u>32</u>	67	<u>28</u>	<u>28</u>	<u>35</u>
Run- Off – Road		542	<u>44</u>	<u>55</u>	<u>44</u>	<u>45</u>	<u>44</u>
SS / Same		248	<u>30</u>	100	<u>36</u>	<u>37</u>	<u>28</u>
SS Opp & Head- on		80	<u>53</u>	<u>100</u>	<u>39</u>	<u>70</u>	<u>59</u>
1- 2 LANE WIDENING	6						
All Crashes		491	<u>56</u>	<u>58</u>	<u>57</u>	<u>57</u>	<u>54</u>
Run- Off – Road		59	<u>49</u>	100	35	<u>41</u>	<u>54</u>
SS / Same		31	<u>52</u>	0	43	43	<u>54</u>
SS Opp & Head- on		10	<u>70</u>	0	<u>100</u>	<u>100</u>	25
1-3 SHOULDER WIDING	16						
All Crashes		600	<u>57</u>	<u>48</u>	<u>59</u>	<u>58</u>	<u>57</u>
Run- Off – Road		242	<u>60</u>	25	<u>57</u>	<u>54</u>	<u>65</u>
SS / Same		34	<u>41</u>	100	<u>75</u>	<u>78</u>	28
SS / Opp. & Head on		24	<u>75</u>	33	<u>80</u>	<u>72</u>	<u>83</u>
Pedestrian		14	<u>71</u>	<u>86</u>	<u>57</u>	<u>71</u>	0
1- 4 TWO- WAY LEFT- TURN LANE	19						
All Crashes		1254	30	40	20	20	35
Rear- End		407	<u>36</u>	0	<u>38</u>	<u>38</u>	<u>34</u>
Left- Turn		147	<u>33</u>	100	0	2	<u>48</u>
Run- Off- Road		134	<u>37</u>	100	(3)	0	<u>49</u>
Pedestrian		53	19	0	19	18	50
SS / Opp. & Head- On		25	<u>36</u>	0	<u>50</u>	<u>50</u>	27

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

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TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
1- 5 REALIGNMENT	26						
All Crashes		459	<u>48</u>	33	<u>56</u>	<u>55</u>	<u>42</u>
Run- Off- Road		190	<u>66</u>	33	<u>71</u>	<u>69</u>	<u>62</u>
Rear-End		71	<u>37</u>	0	<u>42</u>	<u>42</u>	<u>34</u>
SS / Opp. & Head- On		27	<u>85</u>	67	<u>89</u>	<u>83</u>	<u>87</u>
SS/ Same		26	<u>54</u>	0	<u>57</u>	<u>57</u>	<u>53</u>
1- 6 SHOULDER GROVING	18						
All Crashes		1210	<u>18</u>	15	<u>18</u>	<u>18</u>	<u>17</u>
Run - Off - Road		711	<u>27</u>	12	<u>27</u>	<u>26</u>	<u>26</u>
1-7 OVERLAY	177						
All Crashes		11278	9	2	4	4	<u>13</u>
Rear – End		3047	<u>19</u>	25	<u>18</u>	<u>18</u>	<u>20</u>
Run – Off- Road		2500	<u>13</u>	(16)	11	10	<u>15</u>
Wet Pavement		1191	<u>39</u>	<u>61</u>	<u>25</u>	<u>27</u>	<u>43</u>
1-8 TRUCK ESCAPE RAMP	3						
All Crashes		111	<u>18</u>	(75)	<u>28</u>	20	16
Def. Brakes		7	(14)	(100)	0	(100)	20
Rear – End		9	33	0	<u>71</u>	<u>71</u>	(100)
1-9 BRAKE CHECK AREA	2						
All Crashes		42	<u>45</u>	<u>100</u>	<u>55</u>	<u>58</u>	<u>50</u>
Def. Brakes		1	100	0	100	100	0
<u>2– ROADSIDE IMPROVEMENTS</u>							

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

Sheet 5 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
2-1 NEW GUARDRAIL	43						
All Crashes		409	<u>19</u>	<u>47</u>	12	<u>15</u>	<u>21</u>
Run – Off - Road		191	<u>30</u>	<u>56</u>	<u>23</u>	<u>26</u>	<u>34</u>
2-2 UP GRADED EXTENDED GUARDRIL	152						
All Crashes		3257	<u>15</u>	9	<u>13</u>	<u>13</u>	<u>16</u>
Run – Off –Road		1600	<u>26</u>	<u>10</u>	<u>27</u>	<u>25</u>	<u>26</u>
2-3 DRAINAGE STRUCTURE EXTENDED DUARDRAIL	26						
All Crashes		1634	<u>36</u>	18	<u>34</u>	<u>33</u>	<u>38</u>
Run- Off – Road		1027	<u>44</u>	<u>27</u>	<u>36</u>	<u>36</u>	<u>50</u>
2-4 SLOPE FLATTENING	11						
All Crashes		647	(4)	30	(15)	(12)	2
Run – Off – Road		252	10	30	<u>18</u>	<u>19</u>	(2)
2-5 VEGETATION/ OBSTACLE REMOVAL	16						
All Crashes		92	<u>61</u>	0	<u>59</u>	<u>58</u>	<u>64</u>
Run- Off - Road		64	<u>77</u>	100	<u>76</u>	<u>77</u>	<u>76</u>
2-6 NEW/ UPGRADED MEDIAN BARRIER	2						
All Crashes		541	<u>36</u>	60	<u>26</u>	<u>28</u>	<u>39</u>
Run- Off – Road		116	<u>35</u>	50	11	13	<u>46</u>
SS/Op Head – on		1	0	0	0	0	0

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

Sheet 6 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
2-7 IMPACT ATTENUATORS	15						
All Crashes		61	<u>41</u>	(100)	<u>55</u>	<u>50</u>	<u>36</u>
Run- Off- Road		22	<u>45</u>	0	30	30	<u>58</u>
2-8 OBJECT MARKERS	368						
All Crash		416	<u>16</u>	<u>41</u>	<u>17</u>	<u>19</u>	<u>14</u>
Run- Off – Road		171	<u>29</u>	<u>60</u>	<u>24</u>	<u>29</u>	<u>29</u>
2-9 DELINEATION	106						
All Crashes		663	11	8	<u>19</u>	<u>18</u>	4
Run- Off – Road		133	<u>34</u>	14	<u>43</u>	<u>40</u>	<u>24</u>
Nighttime		112	<u>25</u>	14	<u>41</u>	<u>38</u>	10
SS/ Op Head-On		15	<u>67</u>	<u>100</u>	25	<u>63</u>	<u>71</u>
2-10 ANIMAL FENCING	16						
All Crashes		295	(12)	0	(17)	(15)	(9)
Animal		68	<u>66</u>	0	<u>91</u>	<u>91</u>	<u>61</u>
2-11 ANIMAL REFLECTORS	2						
All Crashes		61	10	0	6	6	11
Nighttime Animal		4	25	0	<u>0</u>	0	25
2-12 SNOW FENCING	1						
All Crashes		17	<u>71</u>	0	<u>83</u>	<u>83</u>	<u>64</u>
Snowy Pavement		12	<u>58</u>	0	67	67	<u>56</u>

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 7 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
2-13 ROCKFALL CONTAINMENT	1						
All Crashes		7	14	0	0	0	25
Strike Rocks		1	100	0	0	0	100
2-14 ILLUMINATION	2						
All Crashes		154	<u>19</u>	0	8	8	<u>23</u>
Nighttime		50	<u>30</u>	100	35	<u>42</u>	23
3-INTERSECTIONS INTERCHANGES							
3-1 NEW SIGNAL	73						
All Crashes		1024	(17)	(14)	(20)	(20)	(15)
Angle		443	<u>42</u>	60	<u>39</u>	<u>40</u>	<u>45</u>
3-2 NEW SIGNAL GEOMETRIC REVAMP	23						
All Crashes		419	<u>21</u>	<u>57</u>	<u>28</u>	<u>30</u>	<u>13</u>
Angle		247	<u>68</u>	<u>56</u>	<u>73</u>	<u>72</u>	<u>63</u>
SS/Same		15	<u>53</u>	0	<u>100</u>	<u>100</u>	42
Pedestrian		6	33	100	0	33	0
3-3 REVAMPED SIGNAL	20						
All Crashes		645	9	0	3	3	<u>13</u>
Angle		210	<u>32</u>	100	<u>37</u>	<u>37</u>	<u>27</u>
Left- Turn		115	3	0	(44)	(44)	<u>26</u>
Pedestrian		7	<u>57</u>	0	50	50	100

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

Sheet 8 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES					
			ALL	FATAL	INJURY	FATAL & INJURY	PDO	
3-4 REVAMPED SIGNAL & GEMETRIC REVAMP	19							
All Crashes		841	<u>40</u>	50	<u>33</u>	<u>34</u>	<u>43</u>	
Rear – End		338	<u>48</u>	100	<u>45</u>	<u>45</u>	<u>50</u>	
Left- Turn		152	<u>18</u>	50	<u>24</u>	<u>25</u>	11	
Angle		129	<u>19</u>	0	21	20	<u>19</u>	
Improper Turn		83	<u>80</u>	0	<u>83</u>	<u>83</u>	<u>79</u>	
SS/Same		50	<u>48</u>	0	17	17	<u>52</u>	
Pedestrian		7	(14)	100	(60)	(33)	100	
3-5 LEFT- TURN PHASING	13							
All Crashes		623	<u>15</u>	33	6	6	<u>21</u>	
Left-turn		133	<u>35</u>	50	4	6	<u>52</u>	
3-6 TURN LANES	24							
All Crashes		180	6	<u>100</u>	(1)	3	9	
Rear-End		53	(8)	100	(40)	(31)	3	
Angle		40	13	100	14	17	6	
Left- Turn		33	24	100	33	38	12	
SS/Same		17	<u>59</u>	0	<u>75</u>	<u>75</u>	<u>54</u>	
Improper Turn		13	<u>54</u>	0	25	25	<u>67</u>	
3-7 GEOMETRIC REVAMP	25							
All Crashes		75	<u>43</u>	0	<u>71</u>	<u>71</u>	20	
Angle		23	17	0	<u>58</u>	<u>58</u>	(27)	
Run- Off- Road		18	<u>67</u>	0	<u>80</u>	<u>80</u>	50	
Rear- End		15	<u>60</u>	0	<u>100</u>	<u>100</u>	33	
Improper Turn		12	<u>100</u>	0	<u>100</u>	<u>100</u>	<u>100</u>	
Left – Turn		3	67	0	50	50	100	
SS/Same		3	67	0	100	100	50	

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 9 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES					
			ALL	FATAL	INJURY	FATAL & INJURY	PDO	
3-8 ILLUMINATION	18							
All Crashes		143	(48)	0	(14)	(14)	(73)	
Nighttime		45	18	0	29	29	8	
3-9 SIGHT DISTANCE IMPROVEMENT	58							
All Crashes		586	7	0	6	5	8	
Angle		165	<u>21</u>	<u>75</u>	3	7	<u>31</u>	
Rear- End		145	10	0	17	17	4	
Left- Turn		115	<u>13</u>	0	21	21	3	
Improper Turn		54	<u>30</u>	0	30	30	<u>29</u>	
					-			
3-10 CHANNELIZATION PAVEMENT MARKINGS	17							
All Crashes		127	0	100	(4)	(2)	1	
Left- Turn		32	19	0	9	9	24	
Angle		27	(33)	100	(50)	(36)	(31)	
Improper Turn		12	17	0	60	60	(14)	
Pedestrian		5	<u>80</u>	0	<u>100</u>	<u>100</u>	(100)	
SS/Same		4	25	0	0	0	33	
3-11 CHANNELIZATION SIGNING	15							
ALL Crashes		110	<u>14</u>	(100)	(2)	(7)	<u>27</u>	
Left- Turn		22	36	(100)	36	27	45	
Angle		14	14	0	(50)	(50)	<u>63</u>	
SS/Same		6	<u>67</u>	0	<u>100</u>	<u>100</u>	33	
Improper Turn		4	<u>100</u>	0	100	100	<u>100</u>	

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 10 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
3-12 CROSS ROAD/SIDE SIGNING	63						
All Crashes		82	<u>33</u>	100	<u>56</u>	<u>59</u>	15
Rear- End		26	27	0	38	38	(75)
Angle		21	29	100	25	50	20
Improper Turn		14	<u>64</u>	0	<u>86</u>	<u>86</u>	43
Left Turn		7	<u>86</u>	0	<u>75</u>	<u>75</u>	<u>100</u>
3-13 STOP SIGNS	40						
All Crashes		85	<u>19</u>	0	20	20	18
Angle		26	8	0	0	0	17
Rear- End		25	<u>48</u>	0	<u>67</u>	<u>67</u>	38
Left-Turn		18	22	0	14	14	27
3-14 YIELD SIGNS	6						
All Crashes		35	(37)	0	25	25	(89)
Angle		7	43	0	33	33	50
3-15 SIGNAL REMOVAL	2						
All Crashes		5	<u>100</u>	0	<u>100</u>	<u>100</u>	100
Rear-End		4	<u>100</u>	0	<u>100</u>	<u>100</u>	100
4 - TRAFFIC CONTROL DEVICES							
4-1 EDGELINE MARKING	4						
All Crashes		79	<u>30</u>	(100)	<u>63</u>	<u>52</u>	15
Run- Off – Road		37	<u>30</u>	0	<u>60</u>	<u>56</u>	10

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 11 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
4-2 RAISED PAVEMENT MARKINGS	43						
All Crashes		4275	11	16	11	12	11
Nighttime		1309	<u>16</u>	<u>35</u>	10	12	<u>18</u>
Run-Off – Road		800	<u>33</u>	23	<u>37</u>	<u>37</u>	<u>31</u>
SS/Same		431	<u>13</u>	100	6	7	<u>14</u>
SS/Op&Head-on		41	12	40	(15)	(4)	38
4-3 RUMBLE STRIPS	5						
All Crashes		43	<u>53</u>	<u>83</u>	<u>65</u>	<u>73</u>	29
Run- Off – Road		28	<u>54</u>	<u>75</u>	<u>56</u>	<u>60</u>	38
SS/Op&Head –On		5	<u>80</u>	100	100	100	67
4-4 NEW CURVE SIGNING	188						
All Crashes		558	<u>14</u>	<u>55</u>	<u>20</u>	<u>24</u>	3
Run-Off - Road		328	<u>17</u>	<u>57</u>	<u>24</u>	<u>27</u>	1
SS/Op&Head- On		73	<u>29</u>	<u>57</u>	<u>47</u>	<u>49</u>	3
SS/Same		20	<u>75</u>	100	100	<u>100</u>	<u>71</u>
4-5 UPGRADED CURVE SIGNING	138						
All Crashes		439	<u>21</u>	6	<u>23</u>	<u>22</u>	<u>21</u>
Run- Off – Road		286	<u>21</u>	0	<u>25</u>	<u>23</u>	<u>18</u>
SS/Op&Head- On		53	<u>26</u>	50	11	14	<u>34</u>
Rear- End		25	<u>48</u>	0	38	38	<u>76</u>
SS/Same		5	<u>100</u>	100	100	100	<u>100</u>
4-6 ICY PAVEMENT SIGNING	20						
All Crashes		247	(15)	<u>67</u>	(24)	(13)	(17)
Icy Pavement		76	(22)	<u>100</u>	(52)	(42)	(16)

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS (ARIZONA DATA)

Sheet 12 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
4 -7 SLIPPERY WHEN WET SIGNING	185						
All Crashes		1819	7	(81)	10	6	8
Wet Pavement		323	<u>31</u>	0	<u>29</u>	<u>28</u>	<u>33</u>
4-8 NARROW BRIDGE SIGNING	9						
All Crashes		15	<u>47</u>	0	<u>86</u>	<u>86</u>	13
Run-Off – Road		6	50	0	<u>100</u>	<u>100</u>	0
SS/Opp. & Head – On		5	20	0	100	100	(33)
4 – 9 WATCH FOR ROCKS SIGNING	32						
All Crashes		342	<u>13</u>	0	<u>13</u>	12	<u>14</u>
Strike Rocks		33	<u>64</u>	0	<u>88</u>	<u>88</u>	<u>56</u>
4 –10 ANIMAL WARNING SIGNING	195						
All Crashes		2039	10	(15)	8	6	<u>13</u>
Strike Animals		400	<u>18</u>	<u>83</u>	2	12	<u>19</u>
4 –11 INTERSTATE SIGNING	20						
All Crashes		3961	7	8	10	10	<u>25</u>
5 - PEDESTRIANS							
-							
5– 1 SIDWALKS	4						
All Crashes		128	(15)	100	(70)	(58)	7
Hit Pedestrian		9	<u>89</u>	100	<u>88</u>	<u>89</u>	0

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 13 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
5- 2 PEDESTRIAN OVERPASS	6						
All Crashes		15	(33)	0	0	0	(62)
Hit Pedestrian		3	67	0	50	67	0
5 - 3 PEDESTRIAN SIGNING	96						
All Crashes		1870	4	4	8	8	1
Hit Pedestrian		66	15	22	17	17	(33)
6- STRUCTURES							
6-1 BRIDGE	23						
WIDENING		76	<u>36</u>	50	<u>38</u>	<u>38</u>	<u>32</u>
All Crashes		54	<u>44</u>	50	27	29	<u>62</u>
Run - Off - Road		7	<u>57</u>	0	<u>100</u>	<u>100</u>	0
SS/Same							
6 -2 BRIDGE	17						
REPLACEMENT		52	<u>62</u>	100	36	40	<u>70</u>
All Crashes		23	<u>52</u>	100	0	17	<u>65</u>
Run- Off - Road		6	<u>100</u>	0	100	100	<u>100</u>
Rear - End		1	100	0	0	0	100
SS/Op&Head-On		1	100	0	100	100	0
SS/Same							
6 - 3 NEW BRIDGE	13						
All Crashes		27	11	0	38	36	(15)
Wet Pavement		4	50	0	50	50	50

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases

**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 14 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES					
			ALL	FATAL	INJURY	FATAL & INJURY	PDO	
6-4 BRIDGE BARRIER UPGRADE	45							
All Crashes		51	<u>25</u>	(100)	<u>50</u>	<u>41</u>	14	
Run- Off - Road		33	<u>42</u>	0	<u>46</u>	<u>46</u>	<u>40</u>	
7 - RAILROAD - HIGHWAY CROSSINGS								
7-1 NEW FLASHING LIGHTS	3							
All Crashes		7	43	0	0	0	60	
Hit Train		0	0	0	0	0	0	
7-2 UPGRADED FLASHING LIGHTS	7							
All Crashes		28	<u>43</u>	0	29	29	<u>57</u>	
Hit Train		8	38	0	0	0	60	
7-3 NEW GATES TO REPLACE X-BUCKS	105							
All Crashes		107	<u>59</u>	<u>90</u>	<u>73</u>	<u>76</u>	<u>44</u>	
Hit Train		48	<u>96</u>	<u>100</u>	<u>95</u>	<u>96</u>	<u>95</u>	
7-4 NEW GATES TO SUPPLEMENT FLASHING LIGHTS	22							
All Crashes		34	<u>62</u>	100	<u>71</u>	<u>73</u>	<u>53</u>	
Hit Train		10	<u>80</u>	100	<u>100</u>	<u>100</u>	60	

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**CRASH RATE REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS
 SAFETY IMPROVEMENTS (ARIZONA DATA)**

Sheet 15 of 15

TYPE OF IMPROVEMENTS	NO OF PROJECTS	NO OF BEFORE ACCT'S	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
7 -5 SURFACE IMPROVEMENT	16						
All Crashes		29	7	(100)	0	(22)	20
Hit Train		5	20	(100)	50	(50)	67
Run- Off -Road		8	25	0	33	33	20
7 -6 SIGNING	13						
All Crashes		4	<u>100</u>	0	<u>100</u>	<u>100</u>	100
Hit Train		2	100	0	100	100	0
Run- Off- Road		2	100	0	100	100	100
7 - 7 PAVEMENT MARKINGS	141						
All Crashes		169	<u>48</u>	(100)	<u>43</u>	<u>42</u>	<u>51</u>
Hit Train		43	<u>56</u>	(100)	<u>50</u>	<u>43</u>	<u>62</u>
Rear- End		71	<u>58</u>	0	<u>52</u>	<u>52</u>	<u>62</u>
Run- Off - Road		32	22	0	8	8	30

NOTE: Underlined numbers represent statistically significant rate reductions. Numbers in parentheses represent rate increases