AAA MICHIGAN ROAD IMPROVEMENT DEMONSTRATION PROGRAM EVALUATION

PHASE 2: EVALUATION RESULTS

DETROIT AND GRAND RAPIDS, MICHIGAN

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EXECUTIVE SUMMARY

Introduction

As part of a pro-active initiative to reduce the frequency and severity of motor vehicle collisions, the Automobile Club of Michigan (AAA Michigan) has developed the AAA Michigan Road Improvement Demonstration Program. Under this program, AAA Michigan has contributed to road improvement strategies in Detroit and Grand Rapids, Michigan since 1997. AAA Michigan now wishes to ascertain the effectiveness of its investment. This program evaluation study was therefore initiated by AAA Michigan to evaluate the benefits gained from investing in road improvement projects throughout the Cities of Detroit and Grand Rapids.

Methodology

This program evaluation study was divided into two Phases. The first Phase was completed in March 2002, and detailed the development of multivariate collision prediction models for both Detroit and Grand Rapids. A separate report documenting the findings of Phase 1 was released, under the title Program Evaluation Phase 1: Collision Prediction Modeling, Detroit and Grand Rapids (Hamilton Associates, 2002).

This report documents the findings for Phase 2. The second Phase involved evaluating the sites where improvements have been impDlemented in Detroit and Grand Rapids (referred to as the "treatment sites"). This post-improvement evaluation utilized the collision prediction models developed in Phase 1 to predict the number of collisions expected at a treatment site, had the improvement not been implemented. This predicted collision frequency was refined with an Empirical-Bayes (EB) approach, and compared to the actual post-improvement collision frequency to estimate the safety benefits of the improvement.

Detroit Results

Of the 35 Detroit treatment sites evaluated using the EB approach, 32 experienced fewer than predicted collisions, while the other three indicate an increase. The average treatment effects were -39 percent for total collisions, and -56 percent for injury collisions. The larger decrease in injury collisions indicates that the safety improvements have had a greater impact on severe collisions than on collisions involving property damage only. The estimated treatment effects for total collisions at the Detroit sites are illustrated in FIGURE ES.1.

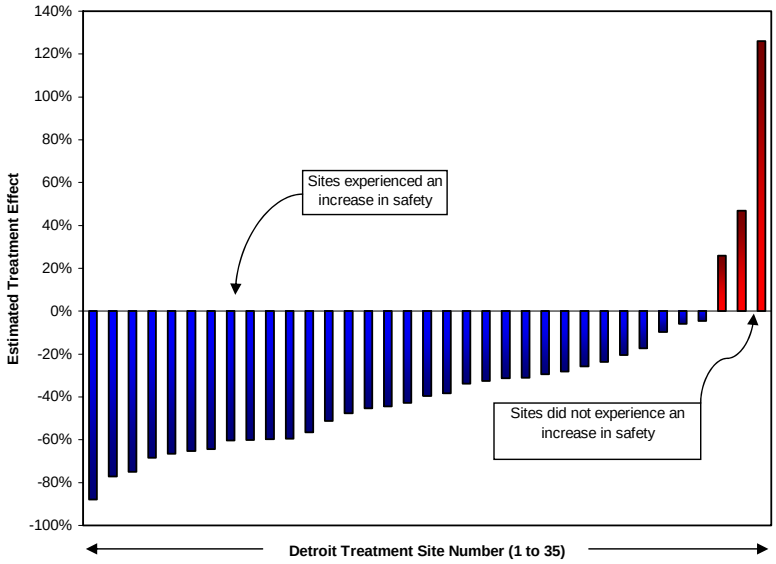

FIGURE ES.1 ESTIMATED TREATMENT EFFECTS USING EB APPROACH (TOTAL COLLISIONS) DETROIT

The results of the economic evaluation (in terms of societal costs) for the Detroit treatment sites are summarized below.

- Overall, the net present value of the Detroit improvements is $4,792,000 (two-year life cycle) or $33,720,000 (15-year life cycle).
- A total of 22 sites (or 65 percent) exceeded a B/C of 2:1 in two years.
- A total of 33 sites (or 97 percent) exceeded a B/C of 2:1 in 15 years.
- A total of 32 sites (or 94 percent) reported a positive NPV (benefits) over two years.

- The Woodward corridor (30 sites) was estimated to have a NPV of $3,530,000 and a B/C of 2.8 (two-year life cycle).
- In terms of the actual before-and-after comparison of societal costs, the average annual pre-improvement cost of collisions for the Detroit treatment group was $6,563,000. The actual average annual post-improvement cost of collisions was $3,640,000. This indicates an overall annual cost savings of $2,923,000.

Grand Rapids Results

There were 26 treatment sites evaluated in Grand Rapids. Of the evaluated sites, 17 indicate an overall reduction in collision frequency. In terms of total collisions, the treatment effects range from -83 percent to +72 percent, with an average treatment effect of -11 percent. The estimated treatment effects for total collisions at the Grand Rapids sites are illustrated in FIGURE ES.2.

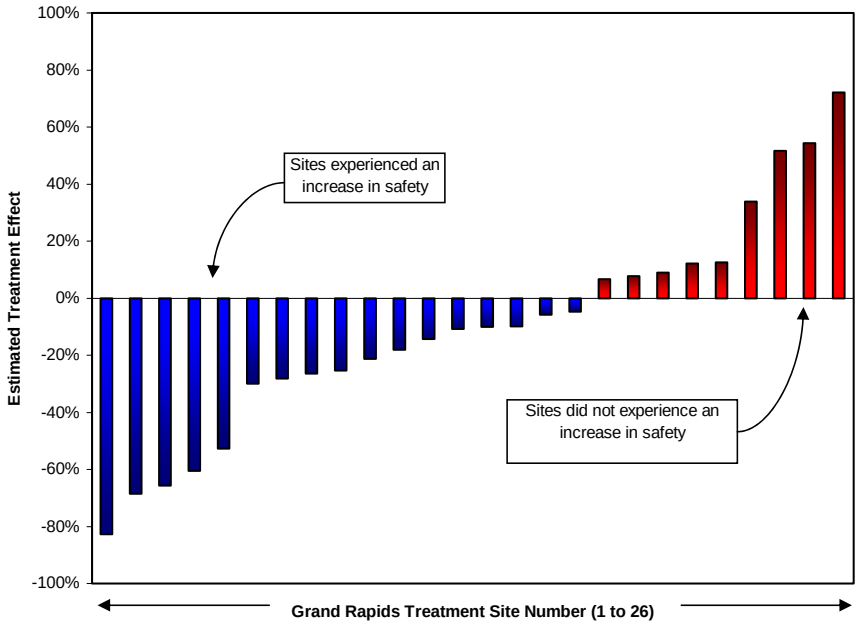

FIGURE ES.2 ESTIMATED TREATMENT EFFECTS USING EB APPROACH (TOTAL COLLISIONS) GRAND RAPIDS

The results of the economic evaluation for the Grand Rapids treatment sites (in terms of societal costs) are summarized below:

- Overall, the net present value of the Grand Rapids improvements is $2,635,000 (two-year life cycle) or $17,366,000 (15-year life cycle).
- A total of 16 sites (or 61 percent) exceeded a B/C of 2:1 in two years.
- A total of 20 sites (or 77 percent) exceeded a B/C of 2:1 in 15 years.
- A total of 18 sites (or 69 percent) reported a positive NPV (benefits) over two years.
- In terms of simple-before-and-after societal costs, the average annual pre-improvement cost of collisions for the Grand Rapids treatment group was $5,711,000 and the post-improvement cost of collisions was $3,305,000, indicating an overall annual cost savings of $2,406,000.

Overview

In terms of collision reduction, and using the EB refinement approach, the program has achieved overall treatment effects of -39 percent in Detroit and -11 percent in Grand Rapids, with a combined average treatment effect of -27 percent. In both cities, the program has been particularly effective in reducing the frequency of high severity collisions.

The Detroit improvements had a total implementation cost of $2,373,000, and a two-year benefit-cost ratio of 3.0 to 1. The Grand Rapids treatments had a total implementation cost of $1,014,000 and a two-year benefit-cost ratio of 3.6 to 1. In terms of societal costs, the net present value of the Detroit and Grand Rapids improvements combined was estimated to be $7,427,000, assuming a two-year life cycle.

This evaluation of the AAA Michigan Road Improvement Demonstration Program has demonstrated that the program as a whole has achieved a positive benefit-cost ratio over two, three, and 15-year life cycles. By combining the societal savings and improvement costs for both the two cities, the overall benefit-cost ratio of this program was determined to be 3.2:1 over two years, 4.6:1 (over three years) and 16.1:1 (over 15 years).

1.0 INTRODUCTION

1.1 Background

As part of a pro-active initiative to reduce the frequency and severity of motor vehicle collisions, the Automobile Club of Michigan (AAA Michigan) has developed the AAA Michigan Road Improvement Demonstration Program. Under this program, AAA Michigan has contributed to road improvement strategies in Detroit and Grand Rapids, Michigan since 1997. AAA Michigan now wishes to ascertain the effectiveness of its investment. This program evaluation study was therefore initiated by AAA Michigan to evaluate the benefits gained from investing in road improvement projects in the Cities of Detroit and Grand Rapids.

An evaluation study determines whether the expected safety benefits at each improved location and for the program as a whole have been achieved. Evaluating the impact of investments in traffic safety and road infrastructure is essential for AAA Michigan, in order to support continued investment in the Road Improvement Demonstration Program. An accurate evaluation ensures the effective use of future road improvement funding.

1.2 Study Objectives

The objectives of this study were to evaluate the pre- and post-improvement collision histories at a sample of the intersections improved under the AAA Michigan Road Improvement Demonstration Program, in order to quantify the safety benefits and claim cost savings to date.

1.3 Methodology

This program evaluation study was divided into two Phases. The first Phase was completed in March 2002, and detailed the development of multivariate collision prediction models for both Detroit and Grand Rapids. A separate report documenting the findings of Phase 1 was released, under the title Program Evaluation Phase 1: Collision Prediction Modeling, Detroit and Grand Rapids (Hamilton Associates, 2002).

This report documents the findings for Phase 2. The second Phase involved evaluating the sites where improvements have been implemented in Detroit and Grand Rapids (referred to as the "treatment sites"). This post-improvement evaluation utilized the collision prediction models developed in Phase 1 to predict the number of collisions expected at a treatment site, had the improvement not been implemented. This predicted collision frequency was refined with an Empirical-Bayes approach, and compared to the actual post-improvement collision frequency to estimate the safety benefits of the improvement.

A systematic approach was taken to conduct Phase 2 of the post-improvement evaluation. The methodology included the following components:

- The necessary data was collected and compiled by AAA Michigan. Care was taken to ensure that each treatment site had at least one year of post-improvement collision data available for analysis. Data included the monthly frequency of police-reported collisions at each treatment site, traffic volume and intersection information, the physical details of the improvements, the total cost and date of completion of the improvements, and the AAA Michigan share of the costs for each treatment site.

- The pre- and post-improvement collision data was examined, and a simple before-and-after evaluation was done. The change in frequency of total, injury, rear-end, side-swipe, angle and left-turn/head-on collision types was examined. The T-Test was applied to the results of the simple before-and-after analysis to determine a level of confidence in the results. The simple-before-and-after analysis is described further in Section 3.

- Using the models developed in Phase 1, the predicted collision frequency, Empirical-Bayes safety estimate, variance of the EB safety estimate, Odds Ratio and treatment effect were calculated. These calculations were repeated for each City and for four collision types: total, injury only, rear-end and side-swipe. The Empirical-Bayes approach is described further in Section 4.

- The average annual cost savings were estimated for the improved locations. The benefits were calculated based on the estimated reduction in collision frequency at each site, and on the average societal costs for PDO and injury collisions. The benefit-cost ratios for each location and for the program as a whole were estimated for two, three and 15-year post-improvement periods.

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2.0 SUMMARY OF IMPROVEMENTS

This section describes the intersection safety and road infrastructure improvements that were implemented in Detroit and Grand Rapids.

2.1 Detroit

The treatment sites selected for evaluation included those with at least one year of post-improvement collision data and up to three years of pre-improvement collision data available. In Detroit, there were 35 treatment intersections with at least one year of post-improvement collision data available for evaluation. The 35 sites included two intersections along Seven Mile Road, 30 intersections along the Woodward Avenue corridor, and three other intersections. During the post-improvement period, the average daily traffic (ADT) for the Detroit treatment sites ranged from 20,000 to 45,000 vehicles per day, with an average ADT of 27,000.

A summary of the safety improvements implemented at each site was provided by AAA Michigan, and is provided in APPENDIX A. The costs of the improvements are presented in APPENDIX B.

The types of safety treatments implemented at the Detroit intersections included a combination of:

- Upgrading traffic signals from 8" to 12" diameter lenses;
- Adding exclusive left-turn lanes;
- Adding permitted/protected left-turn phasing;
- Adding far-left low-level traffic signals;
- Adding an all red interval to the signal timing plan;
- Adding pedestrian signal displays;
- Adding additional overhead traffic signals;
- Improving the traffic signal placement; and
- Other site-specific improvements.

2.2 Grand Rapids

In Grand Rapids, there were 26 treatment intersections with up to three years of pre-improvement collision data and at least one year of post-improvement collision data available for evaluation. The 26 sites included nine intersections along the Division Avenue corridor, eight intersections along the Burton Street corridor, seven intersections along the Eastern Avenue corridor and two other intersections.

AAA Michigan provided traffic volumes counted between 1996 and 1999 for each Grand Rapids location. More recent traffic counts were unavailable, and therefore it was assumed that traffic volumes have remained relatively stable between the pre- and post-improvement periods. The average daily traffic (ADT) for the Grand Rapids treatment sites ranged from 15,000 to 59,000 vehicles per day, with an average ADT of 28,000.

A summary of the safety improvements implemented at each site was provided by AAA Michigan, and is presented in APPENDIX A. The implementation date for each treatment intersection is also shown in the same appendix. The costs of the improvements are presented in APPENDIX B.

The types of safety treatments implemented at the Grand Rapids intersections included a combination of:

- Upgrading traffic signals from 8" to 12" diameter lenses;
- Adding exclusive left-turn lanes;
- Adding permitted/protected left-turn phasing;
- Adding far-left low-level traffic signals;
- Adding an all red interval to the signal timing plan;
- Adding pedestrian signal displays; and
- Other site-specific improvements.

3.0 SIMPLE-BEFORE-AND-AFTER EVALUATION

3.1 Methodology

A simple-before-and-after study is a convenient method of identifying treatment sites that have experienced changes in collision frequency over time. This method is relatively easy to undertake and understand, however, it is acknowledged that this method does not account for three important confounding factors:

1) History of the treatment site (factors other than the treatment may have caused the change in safety).

2) The time trend effect (collision patterns change over time and these changes should be accounted for).

3) "Regression-to-the-mean," or RTM effects. The RTM effects refer to the phenomenon whereby extreme events are usually followed by less extreme events, even when no intervention has taken place. The failure to account for the RTM effect can lead to an overestimation of the safety benefits of an intervention.

The simple-before-and-after evaluation involved a comparison between the annual frequency of collisions recorded at an intersection before the improvement was implemented and the annual collision frequency after implementation. The simple-before-and-after method is summarized below in equation (1). A reduction in average annual collision frequency was defined as a negative value, while an increase in average annual collision frequency was defined as a positive value.

$$\% \text{ Change} = \frac{(\text{Average Annual Collisions Before} - \text{Average Annual Collisions After})}{(\text{Average Annual Collisions Before})} \quad (1)$$

Significance Testing

A significance test (T-test) was conducted to determine whether the treatment effects were significant based on the number of collisions occurring before and after the improvements. This derivation of the T-Test was based on research conducted at the University of British Columbia and documented in Update to the Economic Evaluation Methodologies for Road Improvement Programs (Sayed and Zein, 1997). The T value can be calculated by the following equation:

$$T = \frac{x - y}{\sqrt{x + y}} \qquad (2)$$

where:

x = the number of collisions per year observed before the treatment

y = the number of collisions per year observed after the treatment

The T value can be compared with the normal distribution Z-value of 1.960 at the 95 percent significance level. T values greater than or equal to 1.960 are considered statistically significant.

3.2 Simple Before-and-After Results for Detroit

The simple-before-and-after evaluation methodology was applied to total, injury, rear-end, sideswipe, angle and left-turn head-on collision types at the improved intersections in the City of Detroit. The 35 intersections were examined individually, however, the intersections included in the Woodward corridor were also examined as a group.

The simple-before-and-after evaluation indicated that overall collisions decreased by 34 percent at the Detroit treatment sites. Nine of the 35 sites recorded an overall increase in average annual collisions during the post-improvement period. Injury collisions decreased by 47 percent, suggesting that the safety improvements had a greater impact on severe collisions than collisions involving property damage only. The greatest reduction was in angle collisions (73 percent). The changes in collision frequency by location and collision type are summarized in TABLE 3.1.

TABLE 3.1 SUMMARY OF SIMPLE-BEFORE-AND-AFTER EVALUATION RESULTS, DETROIT

SITE #	TREATMENT LOCATION	PERCENT CHANGE BY COLLISION TYPE					
		TOTAL	INJURY	REAR-END	SIDE-SWIPE	ANGLE	LTHO
1	7 Mile and John R	-50%	-68%	22%	-34%	-63%	-84%
2	7 Mile and Ryan	-53%	-73%	-32%	-39%	-76%	-88%
3	Hubbell and Puritan	-64%	-72%	-50%	-56%	-86%	-82%
4	Schoolcraft and Evergreen	-34%	-47%	-40%	11%	-77%	-36%
5	Linwood and Davison*	115%	176%	189%	80%	129%	-77%
6	Woodward and Adelaide/Sibley	65%	n/a	-8%	-34%	n/a	-35%
7	Woodward and Charlotte	-50%	-38%	-100%	-39%	n/a	-8%
8	Woodward and Eliot/Stimson	-31%	n/a	-100%	-56%	n/a	n/a
9	Woodward and Mack	55%	62%	115%	11%	-50%	-31%
10	Woodward and Parsons	27%	269%	-38%	n/a	n/a	n/a
11	Woodward and Alexandrine	-27%	-45%	-69%	-54%	-38%	85%
12	Woodward and Canfield	-34%	-47%	-100%	n/a	-74%	-54%
13	Woodward and Forest	-28%	-16%	38%	119%	-87%	n/a
14	Woodward and Warren	-16%	-16%	23%	177%	-48%	-19%
15	Woodward and Putnam/Farnsworth	-11%	-26%	-8%	-21%	-65%	-100%
16	Woodward and Kirby	-57%	-79%	-65%	-8%	-100%	-100%
17	Woodward and Palmer	-25%	-26%	-21%	-20%	-54%	-54%
18	Woodward and Antoinette/Medbury	-74%	-54%	-100%	-33%	-69%	n/a
19	Woodward and Baltimore	-34%	-54%	13%	85%	-100%	-31%
20	Woodward and Milwaukee	-69%	-74%	131%	85%	-96%	-100%
21	Woodward and Bethune	21%	15%	-45%	23%	-100%	n/a
22	Woodward and Seward	-24%	-54%	223%	n/a	-54%	n/a
23	Woodward and Euclid	-44%	-69%	-23%	-8%	-54%	-69%
24	Woodward and Hazelwood/ Holbrook	-12%	11%	-31%	-54%	-8%	85%
25	Woodward and Clairmont/Owen	-57%	-85%	-69%	85%	-93%	177%
26	Woodward/Chicago	-62%	-100%	-59%	-8%	-77%	-8%
27	Woodward and Calvert/Towbridge	-42%	-100%	-8%	-42%	-100%	-100%
28	Woodward and Tux/Tennyson	-6%	-100%	125%	-8%	n/a	n/a
29	Woodward and Courtland	50%	n/a	n/a	-8%	-50%	n/a
30	Woodward and Glendale/Mclean	41%	29%	58%	-82%	88%	275%
31	Woodward and Buena Vista	50%	n/a	69%	-8%	-25%	n/a
32	Woodward and Gerald	125%	50%	125%	-25%	n/a	n/a
33	Woodward and Manchester	-53%	-57%	-13%	n/a	-79%	-21%
34	Woodward and Sears	-45%	-45%	-45%	-14%	-75%	-63%
35	Woodward and Feris	-11%	13%	-25%	-25%	-75%	-25%
INTERSECTIONS 1 TO 4		**-51%**	**-65%**	**-26%**	**-34%**	**-77%**	**-79%**
WOODWARD CORRIDOR		**-25%**	**-35%**	**-10%**	**-14%**	**-70%**	**-10%**
OVERALL		**-34%**	**-47%**	**-14%**	**-19%**	**-73%**	**-51%**

Notes:
n/a= no collisions recorded during pre-improvement period, therefore calculation not possible
LTHO = left-turn head-on collision type
* Treatment site removed from evaluation and not included in overall averages in TABLE 3.1

The T-test was applied to each treatment site to determine if the reduction in collision frequency may be considered statistically significant. To be considered significant, the T value (described previously in Section 3.1) must be greater than the normal distribution Z-value of 1.960, at the 95 percent confidence level. The T-test results indicated that nine treatment locations experienced statistically significant reductions in the frequency of various collision types. The Woodward Corridor (a group of 30 intersections) was also found to have statistically significant reductions in total, injury and angle collisions. The T-test results are summarized in TABLE 3.2.

TABLE 3.2 SUMMARY OF DETROIT LOCATIONS WITH STATISTICALLY SIGNIFICANT COLLISION REDUCTIONS

COLLISION TYPE	LOCATIONS WITH STATISTICALLY SIGNIFICANT REDUCTION IN COLLISION FREQUENCY	T-TEST VALUE*
TOTAL	7 Mile and John R	3.05
	7 Mile and Ryan	3.71
	Hubbell and Puritan	3.29
	Woodward and Milwaukee	2.97
	Woodward and Manchester	2.73
	Woodward Corridor (Group)	3.74
INJURY	7 Mile and John R	2.60
	7 Mile and Ryan	2.78
	Hubbell and Puritan	2.25
	Woodward and Chicago	2.12
	Woodward Corridor (Group)	2.77
ANGLE	7 Mile and John R	3.01
	7 Mile and Ryan	3.63
	Schoolcraft and Evergreen	2.07
	Woodward and Forest	3.05
	Woodward and Milwaukee	3.27
	Woodward and Clairmont/Owen	2.29
	Woodward and Manchester	2.75
	Woodward Corridor (Group)	6.07
LTHO	7 Mile and John R	3.41
	7 Mile and Ryan	3.90
REAR-END	None	
SIDESWIPE	None	

* Higher than 1.960 is significant at the 95 percent confidence level

It was noted that the frequency of collisions at the Linwood/Davison treatment site (site #5) increased by 115 percent during the post-improvement period. AAA Michigan noted that this large increase in collision frequency is likely related to a new commercial development that opened during the post-improvement period. This new development is situated near the treatment intersection, and the increase in collision frequency may be attributed to the increase in turning manoeuvres at nearby site access points. These changes in nearby traffic patterns were determined to be unique to this treatment site, and it was therefore removed from the analysis to avoid skewing the overall evaluation results.

3.3 Simple Before-and-After Results for Grand Rapids

There were 26 treatment intersections evaluated in the City of Grand Rapids. The simple-before-and-after evaluation methodology was applied to determine the decrease (or increase) in total, injury, rear-end, sideswipe, angle and left-turn head-on collision types.

The simple-before-and-after evaluation indicated that overall collisions decreased by 22 percent at the Grand Rapids treatment sites. Of the 26 treatment sites, 19 recorded an overall decrease in collisions during the post-improvement period, six recorded an increase, and one site experience no change in collision frequency. Injury collisions decreased by 47 percent, suggesting that the safety improvements had a greater impact on severe collisions than collisions involving property damage only. The most notable drop by collision type was angle collisions (decreased by 59 percent). Overall, there were no notable changes in rear-end or sideswipe collision types (both experienced a one percent increase in collision frequency). The changes in collision frequency by location and type are summarized in TABLE 3.3.

The T-test was applied to each Grand Rapids treatment site to determine if the reduction in collision frequency may be considered statistically significant. The T-test results indicated that nine treatment locations experienced statistically significant reductions in the frequency of various collision types. These locations are summarized in TABLE 3.4.

TABLE 3.3 SUMMARY OF SIMPLE-BEFORE-AND-AFTER EVALUATION RESULTS, GRAND RAPIDS

SITE #	TREATMENT LOCATION	PERCENT CHANGE BY COLLISION TYPE					
		TOTAL	INJURY	REAR-END	SIDE-SWIPE	ANGLE	LTHO
1	Leonard and College	-74%	-69%	-47%	-93%	-56%	-91%
2	Ottawa and Michigan	40%	22%	117%	47%	127%	77%
3	Division and Oakes	-52%	-100%	9%	-45%	-100%	n/a
4	Division and Cherry	55%	100%	52%	138%	-27%	-100%
5	Division and Weston	47%	60%	-4%	60%	-71%	n/a
6	Division and Wealthy	-36%	-56%	71%	17%	-77%	-65%
7	Division and Delaware	-59%	-100%	-65%	-42%	-45%	n/a
8	Division and Franklin	-6%	-27%	17%	29%	-84%	43%
9	Division and Cottage Grove	0%	-77%	31%	-100%	129%	n/a
10	Division and Hall	-36%	-67%	-39%	11%	-38%	-74%
11	Division and Burton	-23%	-52%	19%	4%	-61%	-71%
12	Burton and Raybrook	-42%	-17%	-38%	-84%	-100%	20%
13	Burton and Breton	-33%	-50%	-14%	29%	-100%	-72%
14	Burton and Plymouth	-20%	-54%	-40%	71%	-51%	-62%
15	Burton and Sylvan	-2%	-22%	88%	-100%	-70%	140%
16	Burton and Kalamazoo	-16%	-66%	19%	125%	-60%	-85%
17	Burton and Madison	-37%	-77%	-28%	71%	-41%	-70%
18	Burton and Jefferson	74%	60%	112%	-43%	14%	243%
19	Burton and Buchanan	-10%	-10%	8%	-22%	-89%	-25%
20	Eastern and Lake	-64%	-56%	9%	-100%	-75%	-40%
21	Eastern and Cherry	-83%	-100%	-73%	-100%	-80%	-100%
22	Eastern and Wealthy	43%	-100%	173%	87%	-64%	45%
23	Eastern and Sherman	-27%	64%	-33%	-69%	45%	191%
24	Eastern and Hall	-23%	-31%	-8%	-80%	-9%	-66%
25	Eastern and Oakdale	20%	17%	27%	145%	255%	-40%
26	Eastern and Franklin	-42%	-69%	-31%	-45%	-42%	-64%
OVERALL		**-22%**	**-47%**	**1%**	**1%**	**-59%**	**-50%**

Notes:
n/a= no collisions recorded during pre-improvement period, therefore calculation not possible
LTHO = left-turn head-on collision type

TABLE 3.4 SUMMARY OF GRAND RAPIDS LOCATIONS WITH STATISTICALLY SIGNIFICANT COLLISION REDUCTIONS

COLLISION TYPE	LOCATIONS WITH STATISTICALLY SIGNIFICANT REDUCTION IN COLLISION FREQUENCY	T-TEST VALUE*
TOTAL	Leonard and College	3.49
	Burton and Breton	2.08
	Eastern and Lake	2.11
	Eastern and Cherry	2.78
INJURY	Division and Hall	2.24
	Burton and Madison	2.43
ANGLE	Division and Wealthy	2.40
	Division and Franklin	2.51
	Eastern and Lake	1.98
LTHO	Leonard and College	2.21
	Division and Hall	2.52
	Division and Burton	2.64
	Burton and Breton	1.96
REAR-END	None	
SIDESWIPE	None	

* Higher than 1.960 is significant at the 95 percent confidence level

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4.0 EMPIRICAL-BAYES APPROACH

The Empirical-Bayes approach comprised two steps. First, the EB safety estimate (a prediction of the collision frequency at the treatment site, had the treatment not been implemented) was calculated for each site and for each collision type. Secondly, the treatment effect in terms of a percent decrease (or increase) in collision frequency, was calculated.

4.1 Background

The Empirical-Bayes (EB) approach to before-and after evaluations is considered statistically more robust than the simple-before-and-after approach. The EB process uses a reference group to help account for the RTM effect described in Section 3.1. Previous research documented in Update to the Economic Evaluation Methodologies for Road Improvement Programs (Hamilton Associates, 1997) compared the EB approach to classical statistical techniques (such as simple-before-and-after). The comparison indicated a potentially significant difference in the estimated treatment effectiveness measurement. The difference was lower for sites with high exposure and higher for low exposure sites.

According to Hauer[1], there are two kinds of clues to the safety of a location: (1) characteristics of the location such as geometry and traffic conditions, and (2) the collision history of the location. In an EB analysis, the collision prediction for a site is based on the two clues: the historical collision experience for similar intersections (a reference group) as well as the collision experience at the treatment site.

[1] Hauer, E. (1997). "Observational Before-After Studies in Road Safety," Department of Civil Engineering, University of Toronto.

The EB approach makes use of the multivariate collision prediction models that were previously developed in Phase 1 of the evaluation study. These models were developed based on the characteristics of reference groups. The expected number of collisions at each treatment site (had no improvement taken place) was predicted by using the collision prediction models. The EB refinement process involved combining the predicted collision frequency (as determined by model output) with the historical collision data at each site to predict the expected number of collisions that would have occurred at an intersection, had the treatment not been implemented.

A more detailed description of the collision prediction model development may be found in the Phase 1 report. A summary of the models used for this evaluation is provided in APPENDIX D.

4.2 Calculating the EB Safety Estimate

The process of determining the EB safety estimate is described in detail in Hauer (1997), and is summarized below in equation (3).

$$EB\ Safety\ Estimate = \alpha \times (Predicted) + (1-\alpha) \times (Counted) \qquad (3)$$

Where:

$$\alpha = \frac{1}{1+\frac{Var(Predicted)}{Predicted}} \qquad (4)$$

And: Predicted = number of collisions predicted from a model
Counted = number of collisions counted at the treatment site
Var (Predicted) = variance of the model's estimate

According to Hauer (1997), the variance of the EB Safety Estimate never exceeds the EB Safety Estimate and is almost always smaller. The variance of the EB Safety Estimate can be calculated using equation (5):

$$Var(EB\ Safety\ Estimate) = (1-\forall) \times EB\ Safety\ Estimate \quad (5)$$

In the case of the negative binomial distribution, the variance of the predicted collision frequency is defined by equation (6):

$$Var(Predicted) = \frac{(Predicted)^2}{\blacktriangleright} \quad (6)$$

Where ► is a parameter of the negative binomial distribution, provided by the GLIM model.

Therefore, when using collision prediction models based on the negative binomial assumption, equations (3) and (5) can be rearranged to yield equations (7) and (8):

$$EB\ Safety\ Estimate = \frac{(Predicted) \times (\blacktriangleright + Counted)}{(\blacktriangleright + Predicted)} \quad (7)$$

$$Var(EB\ Safety\ Estimate) = \frac{(Predicted)^2 \times (\blacktriangleright + Counted)}{(\blacktriangleright + Predicted)} \quad (8)$$

4.3 Determining the Treatment Effect

The treatment effect of a safety improvement is ideally expressed as an estimated percent reduction (or increase) in collision frequency. In the context of the EB approach, the treatment effect may be defined as the difference between *the estimated collision frequency at the treatment site, had the treatment not been implemented* and *the actual post-improvement collision frequency at the treatment site*.

The EB refinement process accounts for the RTM effect. In order to account for the other two confounding factors (history and the time trend effect), a

comparison group was defined. The comparison group comprised a small group of non-treatment sites (approximately 10) considered to be similar to the treatment sites. The comparison group accounts for unrelated changes in collision frequency over time. By combining the simple before-and-after change in collision frequency within the comparison group, the change of collision frequency at the treatment site and the EB safety estimate, an Odds Ratio (O.R.) was calculated as shown in equation (9).

$$O.R. = \frac{(A/C)}{(B/D)} \qquad (9)$$

Where A = Pre-improvement collision frequency of comparison group
B = EB safety estimate
C = Post-improvement collision frequency of comparison group
D = Post-improvement collision frequency at treatment site

Finally, the treatment effect was calculated as shown in equation (10). The treatment effect was converted to a percentage to indicate either a percent decrease in collision frequency (a negative value) or an increase (a positive value).

$$Treatment\ Effect = O.R. - 1 \qquad (10)$$

FIGURE 4.1 graphically illustrates how, in theory, the treatment effect is calculated for a typical intersection. In reality, depending on the actual characteristics of the treatment and comparison group data being analyzed, the points on the graph fluctuate.

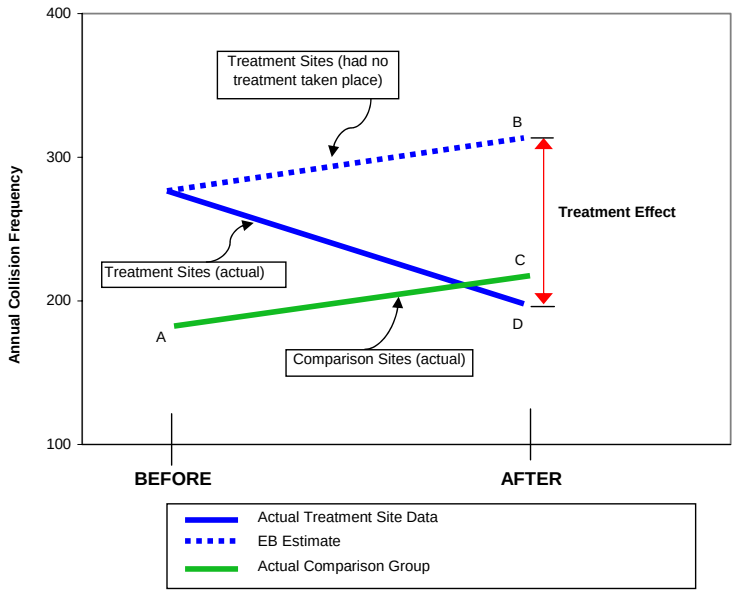

FIGURE 4.1 DETERMINATION OF THE TREATMENT EFFECT

4.4 Detroit Results

Of the 35 Detroit treatment sites evaluated, 32 indicate an overall reduction in collisions, while the other three indicate an increase. The average treatment effects were -39 percent for total collisions, and -56 percent for injury collisions. The larger decrease in injury collisions indicates that the safety improvements have had a greater impact on severe collisions than on collisions involving property damage only. The average treatment effects for rear-end and sideswipe collisions were -42 and -48 percent, respectively. The relatively low pre- and post-improvement frequencies of rear-end and side-swipe collisions make a site-by-site comparison between the simple-before-and-after results and EB analysis results difficult.

Changes in left-turn/head-on and angle collisions were not examined as part of the EB evaluation. Collision prediction models for left-turn/head-on and angle collision types developed in Phase 1 were not found to be statistically meaningful (see the Phase 1 report).

The Woodward corridor sites were also examined as a group to determine the corridor-wide treatment effect. The average Woodward corridor treatment effects were noted to be greater than or equal to the overall Detroit average treatment effects for each collision type evaluated. A 39 percent reduction in total collision frequency along this corridor was estimated, with an even greater (57 percent) reduction in injury collisions. The estimated treatment effects for total collisions at the Detroit sites are illustrated in FIGURE 4.2. The treatment effects are summarized by location and collision type in TABLE 4.1.

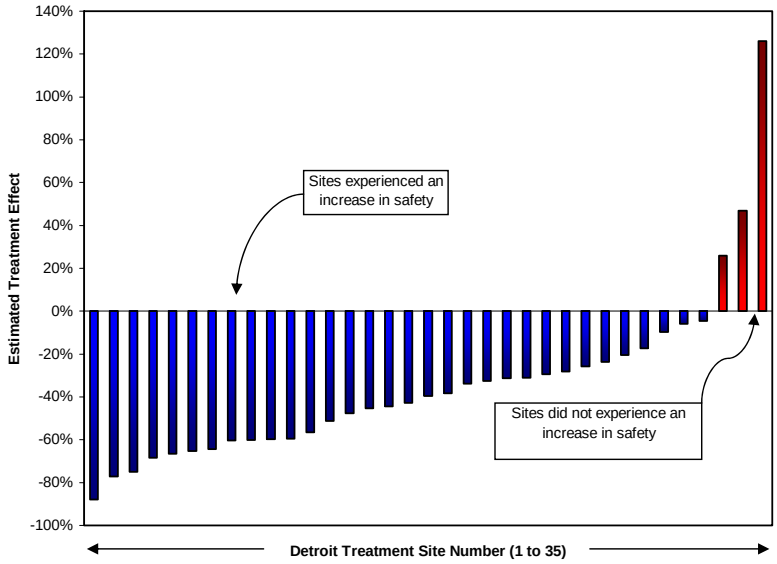

FIGURE 4.2 ESTIMATED TREATMENT EFFECTS USING EB APPROACH (TOTAL COLLISIONS) DETROIT

It should be emphasized that the average treatment effects determined by the EB approach (shown in the bottom row of TABLE 4.1) are calculated simply by summing the treatment effects and dividing by the total number of treatment sites. A comparison between the overall average EB treatment effect and the overall results of the simple-before-and-after analysis (shown in the bottom row of TABLE 3.1) should be done, as they have different meanings. The EB averages shown in the bottom row of TABLE 4.1 are not weighted, whereas the simple-before-and-after reductions are calculated based on an overall change in magnitude of collisions in the treatment group.

TABLE 4.1 ESTIMATED TREATMENT EFFECTS USING EB APPROACH BY LOCATION AND COLLISION TYPE, DETROIT

SITE #	LOCATION	TREATMENT EFFECT BY COLLISION TYPE			
		TOTAL	INJURY	REAR-END	SIDE-SWIPE
1	7 Mile and John R	-38%	-47%	62%	-14%
2	7 Mile and Ryan	-43%	-58%	24%	-13%
3	Hubbell and Puritan	-57%	-57%	-48%	-53%
4	Schoolcraft and Evergreen	-29%	-28%	-39%	-41%
5	Linwood and Davison	126%	125%	140%	27%
6	Woodward and Adelaide/Sibley	-60%	-65%	-86%	-77%
7	Woodward and Charlotte	-65%	-68%	-100%	-81%
8	Woodward and Eliot/Stimson	-77%	-82%	-100%	-100%
9	Woodward and Mack	47%	5%	13%	49%
10	Woodward and Parsons	-34%	-39%	-75%	-39%
11	Woodward and Alexandrine	-28%	-65%	-67%	-26%
12	Woodward and Canfield	-40%	-61%	-100%	-18%
13	Woodward and Forest	-24%	-27%	5%	-6%
14	Woodward and Warren	-6%	-8%	8%	-29%
15	Woodward and Putnam/Farnsworth	-5%	-43%	-16%	3%
16	Woodward and Kirby	-60%	-80%	-67%	-29%
17	Woodward and Palmer	-31%	-57%	-35%	-37%
18	Woodward and Antoinette/Medbury	-88%	-85%	-100%	-100%
19	Woodward and Baltimore	-44%	-64%	-7%	-62%
20	Woodward and Milwaukee	-68%	-74%	-52%	-68%
21	Woodward and Bethune	-20%	-38%	-71%	-41%
22	Woodward and Seward	-33%	-55%	-24%	-69%
23	Woodward and Euclid	-51%	-74%	-56%	-52%
24	Woodward and Hazelwood/ Holbrook	-31%	-46%	-53%	-78%
25	Woodward and Clairmont/Owen	-60%	-86%	-83%	-69%
26	Woodward/Chicago	-67%	-100%	-64%	-88%
27	Woodward and Calvert/Towbridge	-60%	-100%	-53%	-72%
28	Woodward and Tuxedo/Tennyson	-64%	-100%	-65%	-83%
29	Woodward and Courtland	-75%	-100%	-88%	-100%
30	Woodward and Glendale/Mclean	26%	-6%	30%	-39%
31	Woodward and Buena Vista	-17%	-29%	-9%	-84%
32	Woodward and Gerald	-10%	-65%	-19%	-63%
33	Woodward and Manchester	-48%	-41%	-18%	-49%
34	Woodward and Sears	-45%	-41%	-31%	-7%
35	Woodward and Feris	-26%	-30%	-23%	-44%
INTERSECTIONS 1 TO 4*		**-42%**	**-47%**	**-0.4%**	**-30%**
WOODWARD CORRIDOR AVERAGE*		**-39%**	**-57%**	**-47%**	**-52%**
AVERAGE TREATMENT EFFECT*		**-39%**	**56%**	**-42%**	**-48%**

* Averages are calculated based on the sum of treatment effects divided by the number of treatment sites
** Treatment site removed from evaluation and not included in overall averages shown in TABLE 4.1

TABLE 4.2 provides an overview of the evaluation results.

TABLE 4.2 SUMMARY OF TREATMENT EFFECTS USING EB APPROACH, DETROIT

COLLISION TYPE	TOTAL TREATMENT SITES	NUMBER OF SITES WITH ESTIMATED COLLISION REDUCTION	PERCENT OF SITES WITH ESTIMATED COLLISION REDUCTION	AVERAGE TREATMENT EFFECT
TOTAL	35	32	91%	-39%
INJURY	35	33	94%	-56%
REAR-END	35	28	80%	-42%
SIDE-SWIPE	35	31	89%	-48%

The total collision treatment effects for the Detroit intersections range from -88 percent (Woodward and Antoinette/Medbury) to +126 percent (Linwood/Davison). As indicated earlier in the simple-before-and-after analysis, the notably high increase in collision frequency at Linwood/Davison was attributed to a new commercial development located adjacent to the intersection. The treatment effect at this intersection has been obscured by the unrelated changes in traffic patterns. Therefore, as was done for the simple-before-and-after analysis, this treatment site was removed from the analysis to avoid skewing the overall evaluation results.

The EB safety estimates and their variances are provided in APPENDIX F. The variance of each EB safety estimate was found to be in the expected range, according to the definition provided by Hauer (1997).

In Phase 1 of the evaluation study, two additional models were developed to predict the frequency of total collisions at an intersection: (1) a model incorporating the presence of large diameter signal displays and the total number of left-turn lanes, and (2) a model incorporating the sum of all-red intervals. The inclusion of intersection layout variables in a collision prediction model helps correlate collision frequency to existing intersection features such as geometry and traffic signal characteristics. These two models are included in APPENDIX D. A more detailed discussion of the models incorporating layout variables, including an examination of the coefficients for these models, is provided in the Phase 1 report.

The EB evaluation was repeated for total collisions using the two models that incorporate layout variables. The results of this additional evaluation are very similar to the results of the previously discussed evaluation, and are presented in APPENDIX G.

4.5 Grand Rapids Results

There were 26 treatment sites evaluated in Grand Rapids. Of the evaluated sites, 17 indicate an overall reduction in collision frequency. In terms of total collisions, the treatment effects range from -83 percent to +72 percent, with an average treatment effect of -11 percent.

In Phase 1 of the evaluation study, it was determined that a statistically significant injury collision prediction model could only be developed for intersections with a total average daily traffic (ADT) of 28,000 or greater. Of the 26 treatment sites, 11 have an ADT greater than 28,000. Therefore, the EB evaluation for injury collisions only examined 11 treatment sites in Grand Rapids. Of these sites, nine indicate a reduction in injury collision frequency, with an average treatment effect of -36 percent.

Of the 26 treatment sites, seven indicate a reduction in rear-end collisions, and 13 indicate a reduction in side-swipe collisions. However, the average treatment effects for rear-end and sideswipe collisions were +35 and +8 percent, respectively, indicating an overall increase in the risk of these collision types. It should be noted that the relatively low pre- and post-improvement frequencies of rear-end and side-swipe collisions make a comparison between the simple-before-and-after results and EB analysis results difficult.

The treatment effects are summarized by location and collision type in TABLE 4.3. Changes in left-turn/head-on and angle collisions were not examined as part of the EB evaluation. Collision prediction models involving left-turn/head-on and angle collision types were developed in Phase 1 of the evaluation study, but were not found to be statistically meaningful.

The EB safety estimates and their variances are provided in APPENDIX F. The variance of each EB safety estimate was found to be in the expected range, according to the definition provided by Hauer (1997).

TABLE 4.3 ESTIMATED TREATMENT EFFECTS USING EB APPROACH BY LOCATION AND COLLISION TYPE, GRAND RAPIDS

SITE #	LOCATION	TREATMENT EFFECT BY COLLISION TYPE			
		TOTAL	INJURY	REAR-END	SIDE-SWIPE
1	Leonard and College	-68%	n/a	-47%	-100%
2	Ottawa and Michigan	72%	4%	101%	165%
3	Division and Oakes	-53%	n/a	10%	-42%
4	Division and Cherry	54%	n/a	81%	172%
5	Division and Weston	9%	n/a	-17%	45%
6	Division and Wealthy	-18%	-47%	90%	53%
7	Division and Delaware	-66%	n/a	-73%	-47%
8	Division and Franklin	12%	-8%	97%	39%
9	Division and Cottage Grove	7%	n/a	92%	-100%
10	Division and Hall	-10%	-50%	20%	46%
11	Burton and Division	12%	-35%	131%	72%
12	Burton and Raybrook	-21%	7%	68%	-79%
13	Burton and Breton	-14%	-53%	40%	59%
14	Burton and Plymouth	-30%	-56%	-10%	37%
15	Burton and Sylvan	-11%	n/a	26%	-100%
16	Burton and Kalamazoo	-5%	-61%	75%	134%
17	Burton and Madison	-25%	-66%	-5%	69%
18	Burton and Jefferson	52%	n/a	88%	-65%
19	Burton and Buchanan	8%	n/a	60%	-6%
20	Eastern and Lake	-61%	n/a	-21%	-100%
21	Eastern and Cherry	-83%	n/a	-63%	-100%
22	Eastern and Wealthy	-6%	n/a	32%	81%
23	Eastern and Sherman	-10%	n/a	28%	-58%
24	Eastern and Hall	-28%	-32%	6%	-78%
25	Eastern and Oakdale	34%	n/a	66%	129%
26	Eastern and Franklin	-26%	n/a	23%	-18%
AVERAGE TREATMENT EFFECT*		**-11%**	**-36%**	**35%**	**8%**

* Averages are calculated based on the sum of treatment effects divided by the number of treatment sites
n/a = not applicable: EB analysis for injury collisions only conducted for intersections with ADT>28,000

The estimated treatment effects for total collisions at the Grand Rapids sites are illustrated in FIGURE 4.3. TABLE 4.4 summarizes the evaluation results by collision type.

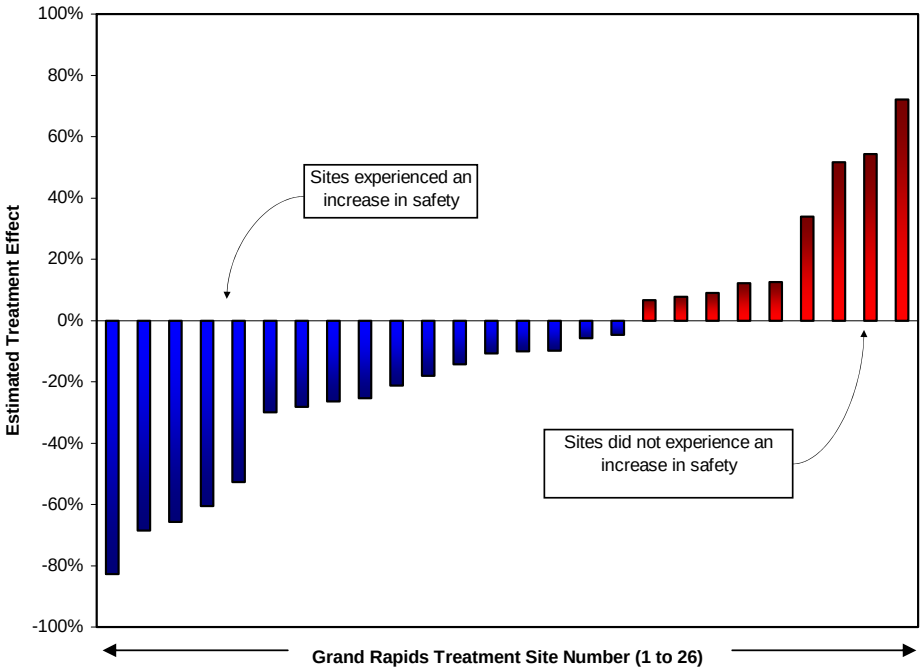

FIGURE 4.3 ESTIMATED TREATMENT EFFECTS USING EB APPROACH (TOTAL COLLISIONS) GRAND RAPIDS

TABLE 4.4 SUMMARY OF TREATMENT EFFECTS USING EB APPROACH, GRAND RAPIDS

COLLISION TYPE	TOTAL TREATMENT SITES	NUMBER OF SITES WITH ESTIMATED COLLISION REDUCTION	PERCENT OF SITES WITH ESTIMATED COLLISION REDUCTION	AVERAGE TREATMENT EFFECT
TOTAL	26	17	65%	-11%
INJURY	11	9	82%	-36%
REAR-END	26	7	27%	35%
SIDE-SWIPE	26	13	50%	8%

In Phase 1 of the evaluation study, one additional model was developed to predict the frequency of total collisions at an intersection. This model (shown in APPENDIX D) was developed based on a Grand Rapids reference group, and incorporates the total number of existing signal heads at a treatment intersection. A more detailed discussion of the model incorporating layout variables, including an examination of the coefficients for this model, is provided in the Phase 1 report. The results from this model are included in APPENDIX G, and are very similar to the results of the EB evaluation using the total collision prediction model.

5.0 ECONOMIC EVALUATION

5.1 Calculating the Benefit-Cost Ratio

A benefit-cost ratio (B/C) was calculated for each treatment site and was used as an indicator to assess the cost effectiveness of the safety improvements, in terms of societal savings. Several steps were involved in calculating the benefit-cost ratios. First, the cost savings related to the reduction in collisions were determined. The difference between the EB expected annual collision frequency (the number of collisions that would have occurred had the treatment not been implemented) and the actual post-improvement collision frequency was calculated for both total and injury collisions. These values indicated the collisions reduced by the treatment effect.

Average collision costs were then applied to convert the reduced collisions to an estimated cost savings. The National Safety Council has developed average societal costs relating to motor vehicle collisions. These estimates include the calculable costs of collisions (wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage and employer costs), as well as an estimated value of the reduced quality of life resulting from the collision. These costs are summarized in TABLE 5.1.

TABLE 5.1 AVERAGE SOCIETAL COLLISION COSTS

COLLISION TYPE	AVERAGE COLLISION COST
Property Damage Only	$1,800
Injury	High Severity Injury: $153,500 Medium Severity Injury: $39,500 Low Severity Injury: $18,800
	Average Injury (Weighted): $34,000

Source: National Safety Council

A graphical illustration of the estimated cost savings at a typical intersection is shown in FIGURE 5.1.

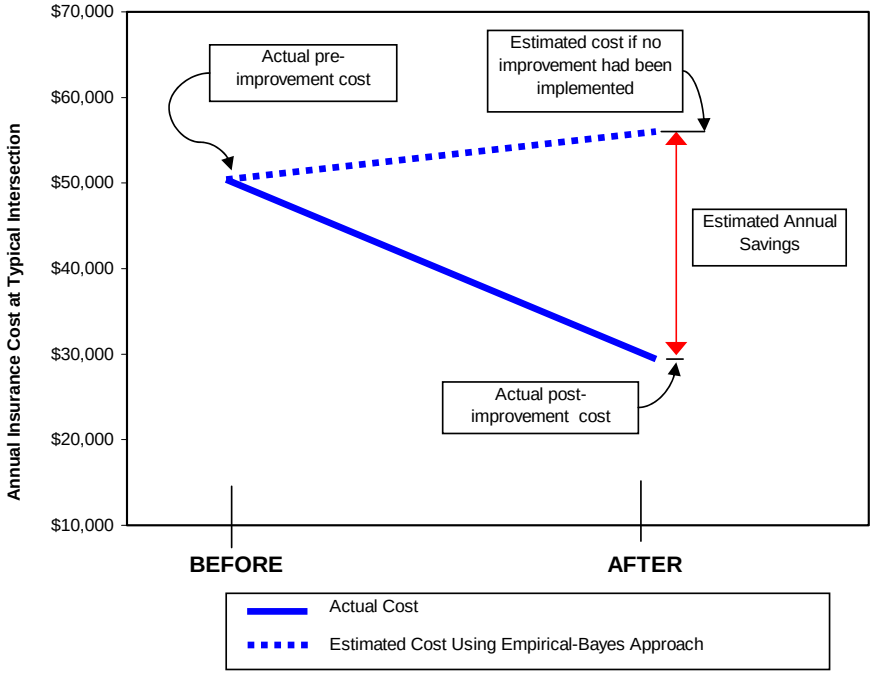

FIGURE 5.1 ILLUSTRATION OF TYPICAL COST SAVINGS

The annual cost savings at each intersection were converted to 2, 3, and 15-year cost savings by assuming an annual discount rate of 7 percent. The benefit-cost ratio for these improvement life cycles was then calculated for each intersection by dividing the discounted cost savings by the total cost of improvement implementation.

The expected net present value (NPV) of each improvement was also determined. The NPV is determined by subtracting the implementation cost from the discounted savings over the payback period (2, 3 or 15 years).

5.2 Economic Evaluation Results, Detroit

An overall benefit-cost ratio of 3.0:1 (over two years) was calculated for the improved Detroit locations. With the 15-year life cycle assumption, the benefit-cost ratio was estimated to be approximately 15.2:1. The results of the economic evaluation for the Detroit treatment sites are presented in TABLE 5.2.

TABLE 5.2 SUMMARY OF THE ECONOMIC EVALUATION, DETROIT

SITE #	LOCATION	BENEFIT-COST RATIO			NET PRESENT VALUE		
		2-YEAR	3-YEAR	15-YEAR	2-YEAR	3-YEAR	15-YEAR
1	7 Mile and John R	12.1	17.5	60.7	$390,000	$581,000	$2,103,000
2	7 Mile and Ryan	15.1	21.9	76.0	$509,000	$755,000	$2,709,000
3	Hubbell and Puritan	12.5	18.1	63.0	$349,000	$520,000	$1,878,000
4	Schoolcraft and Evergreen	1.1	1.5	5.3	$16,000	$146,000	$1,178,000
6	Woodward and Adelaide/Sibley	1.8	2.7	9.3	$57,000	$113,000	$555,000
7	Woodward and Charlotte	2.2	3.2	11.1	$81,000	$147,000	$673,000
8	Woodward and Eliot/Stimson	2.3	3.3	11.4	$84,000	$152,000	$691,000
9	Woodward and Mack	-0.3	-0.4	-1.4	($86,000)	($94,000)	($161,000)
10	Woodward and Parsons	1.4	2.0	6.9	$25,000	$66,000	$392,000
11	Woodward and Alexandrine	2.7	4.0	13.8	$116,000	$199,000	$853,000
12	Woodward and Canfield	3.2	4.6	16.0	$145,000	$241,000	$999,000
13	Woodward and Forest	2.3	3.3	11.6	$87,000	$156,000	$706,000
14	Woodward and Warren	1.6	2.4	8.3	$43,000	$93,000	$486,000
15	Woodward and Putnam/Farnsworth	1.5	2.2	7.5	$33,000	$77,000	$431,000
16	Woodward and Kirby	3.9	5.6	19.6	$193,000	$310,000	$1,238,000
17	Woodward and Palmer	2.7	3.9	13.4	$112,000	$192,000	$829,000
18	Woodward and Antoinette/Medbury	2.9	4.2	14.7	$128,000	$216,000	$913,000
19	Woodward and Baltimore	3.6	5.2	18.2	$175,000	$283,000	$1,146,000
20	Woodward and Milwaukee	5.8	8.4	29.3	$322,000	$497,000	$1,888,000
21	Woodward and Bethune	1.6	2.3	8.1	$41,000	$90,000	$474,000
22	Woodward and Seward	1.9	2.7	9.3	$58,000	$113,000	$557,000
23	Woodward and Euclid	4.3	6.3	21.7	$221,000	$351,000	$1,383,000
24	Woodward and Hazelwood/ Holbrook	2.6	3.8	13.3	$110,000	$190,000	$824,000
25	Woodward and Clairmont/Owen	5.9	8.6	29.9	$330,000	$509,000	$1,929,000
26	Woodward/Chicago	5.0	7.2	25.0	$265,000	$414,000	$1,600,000
27	Woodward and Calvert/Towbridge	3.9	5.7	19.7	$195,000	$313,000	$1,249,000
28	Woodward and Tuxedo/Tennyson	3.2	4.7	16.3	$149,000	$247,000	$1,020,000
29	Woodward and Courtland	2.9	4.2	14.5	$126,000	$212,000	$900,000
30	Woodward and Glendale/Mclean	0.6	0.8	2.9	($28,000)	($11,000)	$129,000
31	Woodward and Buena Vista	1.2	1.8	6.2	$15,000	$52,000	$345,000
32	Woodward and Gerald	1.9	2.7	9.4	$58,000	$115,000	$561,000
33	Woodward and Manchester	5.2	7.6	26.4	$283,000	$440,000	$1,692,000
34	Woodward and Sears	3.5	5.0	17.5	$165,000	$269,000	$1,098,000
35	Woodward and Feris	1.6	2.3	8.0	$40,000	$87,000	$466,000
INTERSECTIONS 1 TO 4		**4.4**	**6.4**	**22.1**	**$1,262,000**	**$2,001,000**	**$7,866,000**
WOODWARD CORRIDOR		**2.8**	**4.0**	**13.9**	**$3,530,000**	**$6,026,000**	**$25,855,000**
OVERALL (ROUNDED)		**3.0**	**4.4**	**15.2**	**$4,792,000**	**$8,027,000**	**$33,720,000**

The results of the economic evaluation for the Detroit treatment sites are further summarized below.

- Overall, the net present value of the Detroit improvements is $4,792,000 (two-year life cycle) or $33,720,000 (15-year life cycle).
- A total of 22 sites (or 65 percent) exceeded a B/C of 2:1 in two years.
- A total of 33 sites (or 97 percent) exceeded a B/C of 2:1 in 15 years.
- A total of 32 sites (or 94 percent) reported a positive NPV (benefits) over two years.
- The Woodward corridor (30 sites) was estimated to have a NPV of $3,530,000 and a B/C of 2.8 (two-year life cycle).
- In terms of simple-before-and-after societal costs, the average annual pre-improvement cost of collisions for the Detroit treatment group was $6,563,000. The actual average annual post-improvement cost of collisions was $3,640,000. This indicates an overall annual cost savings of $2,923,000.

5.3 Economic Evaluation Results, Grand Rapids

The societal savings related to the treatment effect were estimated for the Grand Rapids treatment sites. An overall benefit-cost ratio of 3.6:1 (over two years) was calculated for the improved Grand Rapids locations. With the 15-year life cycle assumption, the benefit-cost ratio was estimated to be approximately 18.1:1. The results of the economic evaluation for the Grand Rapids treatment sites are presented in TABLE 5.3, and are summarized below:

- Overall, the net present value of the Grand Rapids improvements is $2,635,000 (two-year life cycle) or $17,366,000 (15-year life cycle).
- A total of 16 sites (or 61 percent) exceeded a B/C of 2:1 in two years.
- A total of 20 sites (or 77 percent) exceeded a B/C of 2:1 in 15 years.
- A total of 18 sites (or 69 percent) reported a positive NPV (benefits) over two years.

- In terms of simple-before-and-after societal costs, the average annual pre-improvement cost of collisions for the Grand Rapids treatment group was $5,711,000. The actual average annual post-improvement cost of collisions was $3,305,000. This indicates an overall annual cost savings of $2,406,000.

TABLE 5.3 SUMMARY OF THE ECONOMIC EVALUATION, GRAND RAPIDS

SITE #	LOCATION	BENEFIT-COST RATIO			NET PRESENT VALUE		
		2-YEAR	3-YEAR	15-YEAR	2-YEAR	3-YEAR	15-YEAR
1	Leonard and College	4.6	6.6	23.0	$233,000	$367,000	$1,433,000
2	Ottawa and Michigan	n/a	n/a	n/a	n/a	n/a	n/a
3	Division and Oakes	8.9	13.0	45.0	$172,000	$259,000	$950,000
4	Division and Cherry	-5.2	-7.5	-26.0	($133,000)	($184,000)	($583,000)
5	Division and Weston	-1.6	-2.4	-8.2	($57,000)	($73,000)	($200,000)
6	Division and Wealthy	14.0	20.3	70.5	$281,000	$417,000	$1,500,000
7	Division and Delaware	6.2	8.9	31.0	$112,000	$172,000	$649,000
8	Division and Franklin	1.1	1.6	5.6	$7,000	$36,000	$266,000
9	Division and Cottage Grove	5.2	7.6	26.3	$91,000	$142,000	$546,000
10	Division and Hall	4.2	6.0	21.0	$254,000	$404,000	$1,599,000
11	Burton and Division	3.7	5.4	18.7	$177,000	$287,000	$1,154,000
12	Burton and Raybrook	0.5	0.8	2.6	($15,000)	($8,000)	$50,000
13	Burton and Breton	5.6	8.2	28.4	$330,000	$510,000	$1,945,000
14	Burton and Plymouth	4.9	7.1	24.6	$169,000	$265,000	$1,024,000
15	Burton and Sylvan	1.6	2.3	8.1	$17,000	$36,000	$193,000
16	Burton and Kalamazoo	4.0	5.9	20.4	$234,000	$373,000	$1,484,000
17	Burton and Madison	5.7	8.3	28.8	$312,000	$482,000	$1,834,000
18	Burton and Jefferson	-3.4	-5.0	-17.3	($133,000)	($180,000)	($550,000)
19	Burton and Buchanan	0.5	0.8	2.7	($32,000)	($16,000)	$114,000
20	Eastern and Lake	4.4	6.5	22.4	$88,000	$139,000	$542,000
21	Eastern and Cherry	6.1	8.8	30.5	$129,000	$198,000	$748,000
22	Eastern and Wealthy	10.6	15.4	53.5	$244,000	$365,000	$1,330,000
23	Eastern and Sherman	-2.7	-3.9	-13.5	($94,000)	($124,000)	($368,000)
24	Eastern and Hall	3.2	4.6	16.0	$90,000	$149,000	$617,000
25	Eastern and Oakdale	-0.8	-1.2	-4.2	($68,000)	($82,000)	($192,000)
26	Eastern and Franklin	12.0	17.5	60.7	$280,000	$418,000	$1,511,000
OVERALL (ROUNDED)		**3.6**	**5.2**	**18.1**	**$2,635,000**	**$4,283,000**	**$17,366,000**

Note:
n/a = improvement cost not available

6.0 OVERVIEW

In terms of collision reduction, and using the EB refinement approach, the program has achieved overall treatment effects of -39 percent in Detroit and -11 percent in Grand Rapids, with a combined average treatment effect of -27 percent. In both cities, the program has been particularly effective in reducing the frequency of higher severity collisions.

The Detroit improvements had a total implementation cost of $2,373,000, and a two-year benefit-cost ratio of 3.0 to 1. The Grand Rapids treatments had a total implementation cost of $1,014,000 and a two-year benefit-cost ratio of 3.6 to 1. In terms of societal costs, the net present value of the Detroit and Grand Rapids improvements combined was estimated to be $7,427,000, assuming a two-year life cycle.

This evaluation of the AAA Michigan Road Improvement Demonstration Program has demonstrated that the program as a whole has achieved a positive benefit-cost ratio over two, three, and 15-year life cycles. By combining the societal savings and improvement costs for both the two cities, the overall benefit-cost ratio of this program was determined to be 3.2:1 over two years, 4.6:1 (over three years) and 16.1:1 (over 15 years).

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APPENDIX A

SUMMARY OF SAFETY IMPROVEMENTS IMPLEMENTED

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Appendix A Summary of Safety Improvements and Implementation Dates (Provided by AAA Michigan)

TABLE A.1 WOODWARD AVENUE CORRIDOR IMPROVEMENTS, DETROIT

SITE #	INTERSECTION	YEAR COMPLETED	12"	LTL	LTP	LL	AR	P	AO	ISP
1.	Woodward at Alexandrine	1999	X				X	X	X	X
2.	Woodward at Antoinette/Medbury	1999	X				X	X	X	X
3.	Woodward at Baltimore	1999	X				X	X	X	X
4.	Woodward at Bethune	1999	X				X	X	X	X
5.	Woodward at Buena Vista	1999	X			X	X	X	X	X
6.	Woodward at Calvert/Trowbridge	1999	X				X	X	X	X
7.	Woodward at Canfield	1999	X				X	X		X
8.	Woodward at Charlotte	1999	X				X	X		X
9.	Woodward at Chicago/Arden Park	1999	X				X	X	X	X
10.	Woodward at Clairmont/Owen	1999	X				X	X		X
11.	Woodward at Cortland	1999	X				X	X		X
12.	Woodward at Euclid	1999	X				X	X	X	X
13.	Woodward at Farnsworth/Putnam	1999	X				X	X		X
14.	Woodward at Forest	1999	X				X	X		X
15.	Woodward at Gerald	1999	X				X			X
16.	Woodward at Glendale/McLean	1999	X				X		X	X
17.	Woodward at Hazelwood/Holbrook	1999	X				X	X	X	X
18.	Woodward at Kirby	1999	X				X			X
19.	Woodward at Mack/MLK	1999	X				X			X
20.	Woodward at Manchester	1999	X				X			X
21.	Woodward at Milwaukee	1999	X				X	X	X	X
22.	Woodward at Palmer	1999	X			X	X	X	X	X
23.	Woodward at Parsons	1999	X				X			X
24.	Woodward at Pilgrim/Ferris	1999	X				X	X		X
25.	Woodward at Sears/Ford	1999	X				X	X		X
26.	Woodward at Seward/Marston	1999	X				X	X	X	X
27.	Woodward at Sibley/Adelaide	1999	X						X	X
28.	Woodward at Stimson/Eliot	1999	Signal Removed							
29.	Woodward at Tuxedo/Tennyson	1999	X				X	X	X	X
30.	Woodward at Warren	1999	X				X			X

LEGEND
12" - Upgraded traffic signals from 8" to 12" diameter lenses
LTL - Added exclusive left-turn lanes
LTP - Added permitted/protected left-turn phasing
LL - Added low level traffic signals
AR - Added an all red interval to the signal timing
P - Added pedestrian signals
AO - Added additional overhead traffic signals
ISP - Improved the traffic signal placement

TABLE A.2 OTHER DETROIT INTERSECTION IMPROVEMENTS

SITE #	INTERSECTION	YEAR COMPLETED	12"	LTL	LTP	LL	AR	P	AO	ISP
1.	Seven Mile at Ryan	1997	X	X	X	X	X			
2.	Seven Mile at John R	1997	X	X	X	X	X			
3.	Hubbell at Puritan	1997	X	X		X	X			
4.	Schoolcraft at Evergreen	1998	X	X		X	X			
5.	Linwood at Davison	1999	X	X	X	X	X			X

TABLE A.3 GRAND RAPIDS INTERSECTION IMPROVEMENTS

SITE #	INTERSECTION	YEAR COMPLETED	12"	LTL	LTP	LL	AR
1.	Leonard at College	1998	X	X			X
2.	Michigan at Ottawa	1998		X			X
3.	Division at Franklin	1998	X		X		X
4.	Division at Hall	1998	X	X	X	X	X
5.	Division at Burton	1999	X	X	X		X
6.	Division at Cottage Grove	1999	X	X			X
7.	Division at Weston	1999	X				X
8.	Division at Oakes	1999	X				X
9.	Division at Wealthy	1999	X		X		X
10.	Eastern at Hall	2000	X	X		X	X
11.	Eastern at Oakdale	2000	X	X		X	X
12.	Burton at Buchanan	2000	X		X	X	X
13.	Burton at Jefferson	2000	X			X	X
14.	Burton at Madison	2000	X	X	X	X	X
15.	Burton at Plymouth	2000	X	X	X	X	X
16.	Burton at Breton	2000	X			X	X
17.	Burton at Kalamazoo	2000	X		X	X	X
18.	Burton at Raybrook	2000	X			X	X
19.	Burton at Sylvan	2000	X			X	X
20.	Division at Cherry	2000	X				X
21.	Division at Delaware	2000	X	X			X
22.	Eastern at Cherry	2001	X	X		X	X
23.	Eastern at Franklin	2001	X	X	X	X	X
24.	Eastern at Lake	2001	X	X	X	X	X
25.	Eastern at Sherman	2001	X	X		X	X
26.	Eastern at Wealthy	2001	X	X	X	X	X

LEGEND
12" - Upgraded traffic signals from 8" to 12" diameter lenses
LTL - Added exclusive left-turn lanes
LTP - Added permitted/protected left-turn phasing
LL - Added low level traffic signals
AR - Added an all red interval to the signal timing
P - Added pedestrian signals
AO - Added additional overhead traffic signals
ISP - Improved the traffic signal placement

APPENDIX B

SUMMARY OF IMPROVEMENT COSTS

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Appendix B Summary of Improvement Costs (Provided by AAA Michigan)

TABLE B.1 DETROIT IMPROVEMENT COSTS

TREATMENT LOCATION	TOTAL COST OF IMPLEMENTATION
Seven Mile-John R	$35,200
Seven Mile-Ryan	$36,100
Hubbell-Puritan	$30,300
Schoolcraft-Evergreen	$272,000
Linwood-Davison	$157,000
Woodward Corridor (30 intersections)	$2,000,000
ROUNDED TOTAL	$2,531,000

TABLE B.2 GRAND RAPIDS IMPROVEMENT COSTS

SITE #	TREATMENT LOCATION	TOTAL COST OF IMPLEMENTATION*
1	Leonard and College	$65,000
2	Ottawa and Michigan	not available
3	Division and Oakes	$21,589
4	Division and Cherry	$21,589
5	Division and Weston	$21,589
6	Division and Wealthy	$21,589
7	Division and Delaware	$21,589
8	Division and Franklin	$58,000
9	Division and Cottage Grove	$21,589
10	Division and Hall	$80,000
11	Division and Burton	$65,000
12	Burton and Raybrook	$30,061
13	Burton and Breton	$70,986
14	Burton and Plymouth	$43,340
15	Burton and Sylvan	$27,227
16	Burton and Kalamazoo	$76,596
17	Burton and Madison	$65,872
18	Burton and Jefferson	$29,925
19	Burton and Buchanan	$67,239
20	Eastern and Lake	$25,314
21	Eastern and Cherry	$25,314
22	Eastern and Wealthy	$25,314
23	Eastern and Sherman	$25,314
24	Eastern and Hall	$41,050
25	Eastern and Oakdale	$37,175
26	Eastern and Franklin	$25,314
ROUNDED TOTAL		$1,014,000

*Note: Intersection cost estimates for Burton/Eastern Corridor improvements based on overall implementation cost of approximately $670,000 (not all improvements are currently being evaluated). Intersection cost estimates for Division Corridor improvements based on overall implementation cost of approximately $380,000 (not all improvements are currently being evaluated).

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APPENDIX C

SUMMARY OF COLLISION DATA USED FOR SIMPLE BEFORE-AND-AFTER ANALYSIS

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TABLE C.1 SUMMARY OF DETROIT COLLISION DATA USED FOR SIMPLE BEFORE-AND-AFTER ANALYSIS

SITE #	LOCATION	PRE-IMPROVEMENT		POST-IMPROVEMENT	
		YEARS	COLLISIONS	YEARS	COLLISIONS
1	7 Mile and John R	2.0	111	4.3	120
2	7 Mile and Ryan	2.0	142	4.6	152
3	Hubbell and Puritan	3.0	108	4.2	54
4	Schoolcraft and Evergreen	2.0	69	3.3	76
5	Linwood and Davison	2.0	66	1.8	124
6	Woodward and Adelaide/Sibley	2.0	2	2.2	5
7	Woodward and Charlotte	2.0	11	2.2	6
8	Woodward and Eliot/Stimson	2.0	4	2.2	3
9	Woodward and Mack	2.0	38	2.2	64
10	Woodward and Parsons	2.0	8	2.2	11
11	Woodward and Alexandrine	2.0	29	2.2	23
12	Woodward and Canfield	2.0	28	2.2	20
13	Woodward and Forest	2.0	58	2.2	45
14	Woodward and Warren	2.0	102	2.2	93
15	Woodward and Putnam/Farnsworth	2.0	27	2.2	26
16	Woodward and Kirby	2.0	26	2.2	12
17	Woodward and Palmer	2.0	27	2.2	22
18	Woodward and Antoinette/Medbury	2.0	7	2.2	2
19	Woodward and Baltimore	2.0	25	2.2	18
20	Woodward and Milwaukee	2.0	48	2.2	16
21	Woodward and Bethune	2.0	13	2.2	17
22	Woodward and Seward	2.0	17	2.2	14
23	Woodward and Euclid	2.0	28	2.2	17
24	Woodward and Hazelwood/ Holbrook	2.0	21	2.2	20
25	Woodward and Clairmont/Owen	2.0	32	2.2	15
26	Woodward/Chicago	2.0	24	2.2	10
27	Woodward and Calvert/Towbridge	2.0	16	2.2	10
28	Woodward and Tuxedo/Tennyson	1.5	4	2.0	5
29	Woodward and Courtland	1.0	1	2.0	3
30	Woodward and Glendale/Mclean	1.5	24	2.0	45
31	Woodward and Buena Vista	1.5	8	2.0	16
32	Woodward and Gerald	1.5	4	2.0	12
33	Woodward and Manchester	1.6	61	2.0	36
34	Woodward and Sears	1.5	33	2.0	24
35	Woodward and Feris	1.5	16	2.0	19

TABLE C.2 SUMMARY OF GRAND RAPIDS COLLISION DATA USED FOR SIMPLE BEFORE-AND-AFTER ANALYSIS

SITE #	LOCATION	PRE-IMPROVEMENT		POST-IMPROVEMENT	
		YEARS	COLLISIONS	YEARS	COLLISIONS
1	Leonard and College	3	83	3.3	23
2	Ottawa and Michigan	3	96	3.1	138
3	Division and Oakes	2	18	0.9	4
4	Division and Cherry	3	28	0.9	13
5	Division and Weston	2	12	1.3	11
6	Division and Wealthy	2	87	1.1	30
7	Division and Delaware	3.2	25	0.9	3
8	Division and Franklin	3	101	2.3	74
9	Division and Cottage Grove	2	24	1.8	21
10	Division and Hall	3	126	2.1	56
11	Burton and Division	2	126	2.0	97
12	Burton and Raybrook	3	68	1.7	22
13	Burton and Breton	3	199	1.7	74
14	Burton and Plymouth	3	49	1.8	23
15	Burton and Sylvan	2	18	1.7	15
16	Burton and Kalamazoo	3.5	108	1.7	44
17	Burton and Madison	3	81	1.8	30
18	Burton and Jefferson	2	19	1.8	29
19	Burton and Buchanan	3	80	1.8	42
20	Eastern and Lake	2	30	0.9	5
21	Eastern and Cherry	2	26	0.9	2
22	Eastern and Wealthy	3	32	0.9	14
23	Eastern and Sherman	2	27	0.9	9
24	Eastern and Hall	4	68	1.8	24
25	Eastern and Oakdale	3	30	1.8	22
26	Eastern and Franklin	2	56	0.9	15

APPENDIX D

SUMMARY OF COLLISION PREDICTION MODELS DEVELOPED FOR DETROIT AND GRAND RAPIDS

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TABLE D.1 SUMMARY OF DETROIT COLLISION PREDICTION MODELS

COLLISION TYPE		MODEL*	k-value
TOTAL COLLISIONS	Total Collisions (All Traffic Volumes)	Predicted = $0.0313 \times V_1^{0.3849} \times V_2^{0.3304}$	7.9
	Total Collisions (Low Volume Reference Group – ADT<30,000)	Predicted = $0.0013 \times V_1^{0.7047} \times V_2^{0.3425}$	8.7
INJURY COLLISIONS	Injury Collisions (All Traffic Volumes)	Predicted = $0.0221 \times V_1^{0.3147} \times V_2^{0.3039}$	10
REAR-END COLLISIONS	Rear-end Collisions (All Traffic Volumes)	Predicted = $0.000004 \times (V_1+V_2)^{1.404}$	12.8
	Rear-end Collisions (High Volume Reference Group - ADT>30,000)	Predicted = $0.0000004 \times (V_1+V_2)^{1.625}$	10.9
	Rear-end Collisions (Low Volume Reference Group – ADT<35,000)	Predicted = $0.0001 \times (V_1+V_2)^{1.078}$	22.1
SIDESWIPE COLLISIONS	Sideswipe Collisions (All Traffic Volumes)	Predicted = $0.0008 \times (V_1+V_2)^{0.8130}$	n/a
	Sideswipe Collisions (High Volume Reference Group - ADT>30,000)	Predicted = $0.00008 \times (V_1+V_2)^{1.024}$	n/a
TOTAL COLLISIONS WITH LAYOUT VARIABLES	Total Collisions (Incorporating signal lens size and number of left-turn phases)	Predicted = $0.0719 \times V_1^{0.2841} \times V_2^{0.3658} \times e^{\Gamma b_i x_i}$ *Where:* $\Gamma b_i x_i$ *= (-0.1185 x "large lenses")+(0.0894 x number of left-turn phases)* *And:* *"large lenses" = 1 if 12-inch lenses present at intersection, or 2 if not present*	10.2
	Total Collisions (Incorporating the length of all-red intervals)	Predicted = $0.0226 \times V_1^{0.2953} \times V_2^{0.4508} \times e^{\Gamma b_i x_i}$ *Where:* $\Gamma b_i x_i$ *= 0.0772 x sum of all-red intervals*	8.8

Notes: Predicted annual collisions = $a_0 \times V_1^{a1} \times V_2^{a2} \times e^{\Gamma b_i x_i}$
V_1 and V_2 denote major and minor street ADT,
a_0, a_1, a_2 and b_i are model parameters
n/a denotes poisson model (k is a GLIM parameter relating to negative binomial distribution only)

TABLE D.2 SUMMARY OF GRAND RAPIDS COLLISION PREDICTION MODELS

COLLISION TYPE		MODEL*	k-value
TOTAL COLLISIONS	Total Collisions (All Traffic Volumes)	Predicted = $0.0058 \times V_1^{0.4582} \times V_2^{0.4037}$	14.8
	Total Collisions (High Volume Reference Group - ADT>28,000)	Predicted = $0.0047 \times V_1^{0.5397} \times V_2^{0.3374}$	25.5
INJURY COLLISIONS	Injury Collisions (High Volume Reference Group - ADT>28,000)	Predicted = $0.00008 \times V_1^{0.6319} \times V_2^{0.5293}$	n/a
REAR-END COLLISIONS	Rear-end Collisions (All Traffic Volumes)	Predicted = $0.000009 \times (V_1+V_2)^{1.304}$	16.7
	Rear-end Collisions (High Volume Reference Group - ADT>28,000)	Predicted = $0.00001 \times (V_1+V_2)^{1.262}$	20.6
SIDESWIPE COLLISIONS	Sideswipe Collisions (All Traffic Volumes)	Predicted = $0.0015 \times (V_1+V_2)^{0.7367}$	n/a
	Sideswipe Collisions (High Volume Reference Group - ADT>28,000)	Predicted = $0.00007 \times (V_1+V_2)^{1.020}$	n/a
TOTAL COLLISIONS WITH LAYOUT VARIABLES	Layout Variables (All Traffic Volumes)	Predicted = $0.0346 \times V_1^{0.4088} \times V_2^{0.3215} \times e^{\Gamma b_i x_i}$	44.7
		Where: $\Gamma b_i x_i$ = -0.0698 x total number of signal heads	

Notes: Predicted annual collisions = $a_0 \times V_1^{a1} \times V_2^{a2} \times e^{\Gamma b_i x_i}$
V_1 and V_2 denote major and minor street ADT,
a_0, a_1, a_2 and b_i are model parameters
n/a denotes poisson model (k is a GLIM parameter relating to negative binomial distribution only)

Notes

As illustrated in the Phase 1 report, some of the prediction models may underestimate collisions at high frequency locations, and overestimate collisions at low frequency locations. This pattern appears to be typical of models developed using generalized linear interactive modeling, and has been documented in previous studies.

For comparison purposes, graphical results from three previous collision prediction modeling studies are provided in APPENDIX E, along with graphical results of a model prepared for the Phase 1 report. Hamilton Associates did not research the reasons for this apparent trend. However, we ensured that all the models used for this study met the rigid significance criteria, as documented in the Phase 1 report.

Several of the collision prediction models were determined to have k-values (parameters of the Negative Binomial distribution) larger than typical for models based on data that follows this distribution. This trait may be attributed to several factors, including the use of a relatively small reference group, and that the dispersion of the data cannot be described completely by one error structure. For example, the Poisson distribution for these models was examined, and found to be a satisfactory assumption based on the magnitude of the coefficients estimated for these models.

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APPENDIX E

GRAPHICAL ILLUSTRATION OF PREVIOUS COLLISION PREDICTION MODELS

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APPENDIX E GRAPHICAL ILLUSTRATION OF COLLISION PREDICTION MODELS

The graphs presented in this Appendix (FIGURES E.1 to E.4) provide a simple comparison of collision prediction models developed in Program Evaluation Phase 1: Collision Prediction Modeling, Detroit and Grand Rapids (Hamilton Associates, 2002) to models developed in previous studies. Each of the four graphs illustrates a relationship between observed collisions and predicted collisions within a reference group. A well-fitted model should have the plotted points clustered near the 45 degree line. All four graphs were developed using generalized linear modeling techniques, and have the common trait of "over-predicting" collisions at low frequency locations and "under-predicting" collisions at high frequency locations. The impact of this model trait is mitigated by the use of the Empirical-Bayes refinement process, which combines collision prediction modeling results with historical collision data to refine the predicted values.

FIGURE E.1 PLOT OF PREDICTED COLLISIONS VS. OBSERVED COLLISIONS FOR DETROIT TOTAL COLLISION PREDICTION MODEL

SOURCE: PROGRAM EVALUATION PHASE 1: COLLISION PREDICTION MODELING, DETROIT AND GRAND RAPIDS (HAMILTON ASSOCIATES, 2002)

FIGURE E.2 PLOT OF PREDICTED COLLISIONS VS. OBSERVED COLLISIONS FOR TOTAL COLLISION PREDICTION MODEL

SOURCE: ADVANCE WARNING FLASHERS-DO THEY IMPROVEMENT SAFETY? (SAYED AND SAWALHA, 1999)

FIGURE E.3 PLOT OF PREDICTED COLLISIONS VS. OBSERVED COLLISIONS FOR TOTAL COLLISION PREDICTION MODEL

SOURCE: MICROSCOPIC COLLISION PREDICTION MODELS FOR SIGNALIZED INTERSECTIONS (M. QUINTERO, 1999)

FIGURE E.4 PLOT OF PREDICTED COLLISIONS VS. OBSERVED COLLISIONS FOR TOTAL COLLISION PREDICTION MODEL

SOURCE: PREDICTING THE SAFETY OF URBAN SIGNALIZED INTERSECTIONS IN BRITISH COLUMBIA (SAYED, RODRIGUEZ AND FENG, 1998)

APPENDIX F

EB SAFETY ESTIMATES AND VARIANCES

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TABLE F.1 EB SAFETY ESTIMATES AND VARIANCES, DETROIT

SITE #	LOCATION	COLLISION TYPE							
		TOTAL		INJURY		REAR-END		SIDESWIPE	
		EB ESTIMATE	VAR	EB ESTIMATE	VAR	EB ESTIMATE	VAR	EB ESTIMATE	VAR
1	7 Mile and John R	48.2	46.1	12.1	5.1	5.7	1.1	6.7	3.3
2	7 Mile and Ryan	62.2	61.3	12.8	5.7	8.0	1.8	9.4	4.7
3	Hubbell and Puritan	32.1	27.7	9.0	3.6	4.5	0.8	4.4	2.2
4	Schoolcraft and Evergreen	34.7	28.1	13.0	6.4	10.1	5.0	7.1	3.6
5	Linwood and Davison	33.7	26.8	7.9	3.9	11.0	6.3	10.7	5.3
6	Woodward and Adelaide/Sibley	6.2	1.8	2.8	0.8	3.7	0.6	2.1	1.1
7	Woodward and Charlotte	8.5	3.5	3.1	0.8	4.1	0.7	2.6	1.3
8	Woodward and Eliot/Stimson	6.5	2.0	2.8	0.8	3.8	0.6	2.1	1.1
9	Woodward and Mack	21.6	14.4	6.6	3.1	6.2	2.7	6.3	3.2
10	Woodward and Parsons	8.2	3.0	3.2	1.0	3.9	0.6	2.4	1.2
11	Woodward and Alexandrine	15.9	9.7	4.2	1.4	4.6	0.8	4.0	2.0
12	Woodward and Canfield	16.4	9.7	5.1	1.9	4.3	0.8	4.2	2.1
13	Woodward and Forest	29.3	22.4	6.8	3.0	5.7	1.2	6.8	3.4
14	Woodward and Warren	49.0	43.7	10.8	5.5	11.0	6.1	13.2	6.6
15	Woodward and Putnam/Farnsworth	13.5	8.2	3.5	1.0	4.1	0.7	2.9	1.4
16	Woodward and Kirby	14.8	8.6	4.9	1.6	4.5	0.8	2.8	1.4
17	Woodward and Palmer	15.8	9.2	4.6	1.7	4.6	0.8	3.2	1.6
18	Woodward and Antoinette/Medbury	8.2	2.9	3.4	1.0	4.9	1.0	2.8	1.4
19	Woodward and Baltimore	16.1	8.9	5.5	2.2	5.9	1.3	3.9	1.9
20	Woodward and Milwaukee	25.1	18.4	7.5	3.3	5.1	2.2	6.1	3.1
21	Woodward and Bethune	10.6	4.6	4.0	1.3	5.1	1.0	3.4	1.7
22	Woodward and Seward	10.3	5.1	3.3	0.8	4.6	0.9	3.2	1.6
23	Woodward and Euclid	17.3	10.0	5.8	2.3	5.6	1.2	5.2	2.6
24	Woodward and Hazelwood/ Holbrook	14.4	7.7	5.5	2.4	6.4	2.7	4.6	2.3
25	Woodward and Clairmont/Owen	18.8	11.8	7.1	3.1	6.0	2.6	4.8	2.4
26	Woodward/Chicago	14.9	8.2	5.1	1.8	5.6	1.2	4.2	2.1
27	Woodward and Calvert/Towbridge	12.2	5.7	4.1	1.5	5.2	1.1	3.5	1.7
28	Woodward and Tuxedo/Tennyson	7.5	2.4	3.4	1.0	4.6	0.9	3.1	1.6
29	Woodward and Courtland	6.4	1.8	3.0	0.9	4.5	0.9	2.8	1.4
30	Woodward and Glendale/Mclean	19.2	12.0	6.9	3.2	7.9	3.6	7.1	3.5
31	Woodward and Buena Vista	10.4	4.2	3.8	1.4	5.3	1.1	3.4	1.7
32	Woodward and Gerald	7.1	2.3	3.1	0.9	4.0	0.7	2.9	1.5
33	Woodward and Manchester	36.9	31.5	10.9	5.0	7.2	3.0	8.4	4.2
34	Woodward and Sears	23.5	16.4	7.3	3.1	6.2	1.3	4.6	2.3
35	Woodward and Feris	13.8	7.3	4.6	1.7	4.9	0.9	3.8	1.9

TABLE F.2 EB SAFETY ESTIMATES AND VARIANCES, GRAND RAPIDS

SITE #	LOCATION	COLLISION TYPE							
		TOTAL		INJURY		REAR-END		SIDESWIPE	
		EB ESTIMATE	VAR	EB ESTIMATE	VAR	EB ESTIMATE	VAR	EB ESTIMATE	VAR
1	Leonard and College	22.0	7.9	n/a	n/a	5.0	1.2	3.7	1.8
2	Ottawa and Michigan	24.0	9.4	5.0	2.5	5.0	1.0	9.0	4.5
3	Division and Oakes	11.4	2.2	n/a	n/a	3.2	0.5	2.0	1.0
4	Division and Cherry	10.2	1.9	n/a	n/a	3.3	0.5	2.2	1.1
5	Division and Weston	10.7	1.9	n/a	n/a	3.1	0.5	1.8	0.9
6	Division and Wealthy	33.9	16.4	9.3	4.7	6.8	1.7	4.5	2.3
7	Division and Delaware	12.3	2.4	n/a	n/a	4.3	0.9	2.2	1.1
8	Division and Franklin	28.5	11.9	8.5	4.2	7.3	1.7	3.3	1.7
9	Division and Cottage Grove	10.6	2.1	n/a	n/a	5.1	1.1	2.5	1.3
10	Division and Hall	29.2	13.6	10.2	5.1	6.0	1.1	3.5	1.8
11	Burton and Division	41.2	24.8	10.8	5.4	8.8	2.1	7.5	3.8
12	Burton and Raybrook	18.7	5.9	3.6	1.8	6.5	1.1	3.1	1.6
13	Burton and Breton	42.3	26.3	11.0	5.5	14.3	4.8	6.1	3.0
14	Burton and Plymouth	21.0	6.2	5.5	2.8	5.5	1.1	2.2	1.1
15	Burton and Sylvan	12.4	2.5	n/a	n/a	4.0	0.8	1.7	0.9
16	Burton and Kalamazoo	28.3	11.4	8.1	4.0	6.9	1.6	3.2	1.6
17	Burton and Madison	23.7	8.6	8.9	4.5	5.1	1.0	2.5	1.3
18	Burton and Jefferson	15.1	3.4	n/a	n/a	4.3	0.9	1.7	0.9
19	Burton and Buchanan	22.3	7.9	n/a	n/a	6.5	1.6	3.3	1.6
20	Eastern and Lake	15.1	3.8	n/a	n/a	2.9	0.5	1.8	0.9
21	Eastern and Cherry	14.3	3.4	n/a	n/a	3.1	0.5	2.5	1.2
22	Eastern and Wealthy	19.3	5.0	4.5	2.2	4.4	0.9	2.6	1.3
23	Eastern and Sherman	12.2	2.7	n/a	n/a	3.7	0.6	2.8	1.4
24	Eastern and Hall	20.4	6.0	5.2	2.6	4.4	0.8	2.6	1.3
25	Eastern and Oakdale	10.6	2.0	n/a	n/a	2.5	0.3	1.5	0.8
26	Eastern and Franklin	21.5	7.7	n/a	n/a	5.7	1.3	4.3	2.1

Note:
n/a = no EB safety estimate possible for low volume intersections (ADT<28,000) due to collision prediction model traits.

APPENDIX G

ADDITIONAL EMPIRICAL-BAYES ANALYSIS

(USING COLLISION PREDICTION MODELS THAT INCORPORATE INTERSECTION LAYOUT VARIABLES

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APPENDIX G

ADDITIONAL EMPIRICAL-BAYES ANALYSIS (USING COLLISION PREDICTION MODELS THAT INCORPORATE INTERSECTION LAYOUT VARIABLES

The additional collision prediction models developed in Phase 1 were used to repeat the EB analysis. These models incorporated the intersection characteristics present at each treatment site prior to the improvement implementation. The EB safety estimates calculated with these additional models were found to be very similar to the EB safety estimates using the total collision models, and are presented in TABLES G.1 and G.2.

The EB safety estimate is a prediction of what would have happened at the treatment site, had the safety improvements not been done. Each treatment site had multiple improvements done, causing a combined treatment effect. The effects of each individual safety improvement are not possible to separate. Therefore, due to the combined treatment effect at each site, it was not possible to determine a "cause and effect" relationship between the individual improvements by using a layout variable model.

The collision prediction models incorporating layout variables models have several applications outside of evaluation studies, including the following.

- The identification of collision-prone locations. Collision-prone locations are sites that exhibit a significant number of collisions compared to the norm. The layout variable models can be used to identify collision-prone locations in cases where intersection layout information is known.

- Collision prediction models may be used in safety planning to identify the geometric variables that have the most impact (positive or negative) on the safety performance of signalized intersections.

TABLE G.1 SUMMARY OF ADDITIONAL EMPIRICAL-BAYES EVALUATION FOR DETROIT TREATMENT SITES

SITE #	LOCATION	TREATMENT EFFECT		
		Collision Prediction Model Used to Determine EB Safety Estimate		
		Total	Layout Variable	All-red
1	7 Mile and John R	-38%	-35%	-36%
2	7 Mile and Ryan	-43%	-40%	-41%
3	Hubbell and Puritan	-57%	-56%	-56%
4	Schoolcraft and Evergreen	-29%	-28%	-28%
5	Linwood and Davison	126%	132%	133%
6	Woodward and Adelaide/Sibley	-60%	-60%	-52%
7	Woodward and Charlotte	-65%	-63%	-57%
8	Woodward and Eliot/Stimson	-77%	-76%	-72%
9	Woodward and Mack	47%	45%	47%
10	Woodward and Parsons	-34%	-32%	-23%
11	Woodward and Alexandrine	-28%	-24%	-19%
12	Woodward and Canfield	-40%	-37%	-34%
13	Woodward and Forest	-24%	-21%	-20%
14	Woodward and Warren	-6%	-4%	-5%
15	Woodward and Putnam/Farnsworth	-5%	5%	16%
16	Woodward and Kirby	-60%	-57%	-54%
17	Woodward and Palmer	-31%	-28%	-24%
18	Woodward and Antoinette/Medbury	-88%	-87%	-85%
19	Woodward and Baltimore	-44%	-41%	-38%
20	Woodward and Milwaukee	-68%	-68%	-67%
21	Woodward and Bethune	-20%	-15%	-6%
22	Woodward and Seward	-33%	-22%	-9%
23	Woodward and Euclid	-51%	-48%	-46%
24	Woodward and Hazelwood/ Holbrook	-31%	-33%	-30%
25	Woodward and Clairmont/Owen	-60%	-60%	-59%
26	Woodward/Chicago	-67%	-64%	-61%
27	Woodward and Calvert/Towbridge	-60%	-57%	-54%
28	Woodward and Tuxedo/Tennyson	-64%	-62%	-56%
29	Woodward and Courtland	-75%	-74%	-69%
30	Woodward and Glendale/Mclean	26%	24%	28%
31	Woodward and Buena Vista	-17%	-14%	-7%
32	Woodward and Gerald	-10%	-7%	9%
33	Woodward and Manchester	-48%	-46%	-46%
34	Woodward and Sears	-45%	-43%	-42%
35	Woodward and Feris	-26%	-23%	-18%
Woodward Corridor Average*		-39%	-32.0%	-28.1%
AVERAGE TREATMENT EFFECT*		**-39%**	**-37%**	**-33%**

Notes:

Total = Collision prediction model that predicts total collisions (previously discussed in main body of report)

Layout Variable = Collision prediction model that predicts total collisions, incorporating intersection layout variables (refer to APPENDIX D for description)

All-red = Collision prediction model that predicts total collisions, incorporating intersection layout variables (refer to APPENDIX D for description)

TABLE G.2 SUMMARY OF ADDITIONAL EMPIRICAL-BAYES EVALUATION FOR GRAND RAPIDS TREATMENT SITES

SITE #	LOCATION	TREATMENT EFFECT	
		Collision Prediction Model Used to Determine EB Safety Estimate	
		Total	Layout Variable
1	Leonard and College	-68%	-65%
2	Ottawa and Michigan	72%	100%
3	Division and Oakes	-53%	-59%
4	Division and Cherry	54%	52%
5	Division and Weston	9%	-12%
6	Division and Wealthy	-18%	-12%
7	Division and Delaware	-66%	-71%
8	Division and Franklin	12%	20%
9	Division and Cottage Grove	7%	22%
10	Division and Hall	-10%	-1%
11	Burton and Division	12%	27%
12	Burton and Raybrook	-21%	-24%
13	Burton and Breton	-14%	13%
14	Burton and Plymouth	-30%	-33%
15	Burton and Sylvan	-11%	-23%
16	Burton and Kalamazoo	-5%	-2%
17	Burton and Madison	-25%	-22%
18	Burton and Jefferson	52%	18%
19	Burton and Buchanan	8%	16%
20	Eastern and Lake	-61%	-61%
21	Eastern and Cherry	-83%	-84%
22	Eastern and Wealthy	-6%	-15%
23	Eastern and Sherman	-10%	-13%
24	Eastern and Hall	-28%	-31%
25	Eastern and Oakdale	34%	21%
26	Eastern and Franklin	-26%	-18%
AVERAGE TREATMENT EFFECT*		-11%	-10%

Notes:

Total = Collision prediction model that predicts total collisions (previously discussed in main body of report)

Layout Variable = Collision prediction model that predicts total collisions, incorporating intersection layout variables (refer to APPENDIX D for description)

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