NCHRP

REPORT 546

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Incorporating Safety into Long-Range Transportation Planning

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Step 1: Incorporating Safety into the Vision Statement

Questions to be asked…

- Is safety incorporated into the current vision statement of your jurisdiction's transportation plan? If not, why not?
- Is safety an important part of the mandates and enabling legislation of key agency participants in the planning process?
- Is safety an important concern to the general public and planning stakeholders? If not, should it be?
- How is safety defined by community stakeholders?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system?

Step 2: Incorporating Safety into the Set of Goals and Objectives

Goals and Objectives for the Houston-Galveston Area Council

Goal 1 - Reduce congestion and improve access to jobs, markets and services.

Goal 2 - Preserve and maintain the existing transportation infrastructure.

Goal 3 - Improve transportation safety and security.

Goal 4 - Be environmentally responsible.

Achieve the safety and security goal by….

- Increasing funding to reduce high accident levels in the region.
- Undertaking safety studies throughout the region.
- Mitigating 344 major accident hot spots at a cost of $172 million but with an annual benefit of $392 million.
- Supporting traffic safety education and traffic enforcement efforts.
- Building an information system that will identify crime incidents on transportation facilities to support strategic safety and security investments.

Step 3: Incorporating Safety into System Performance Measures

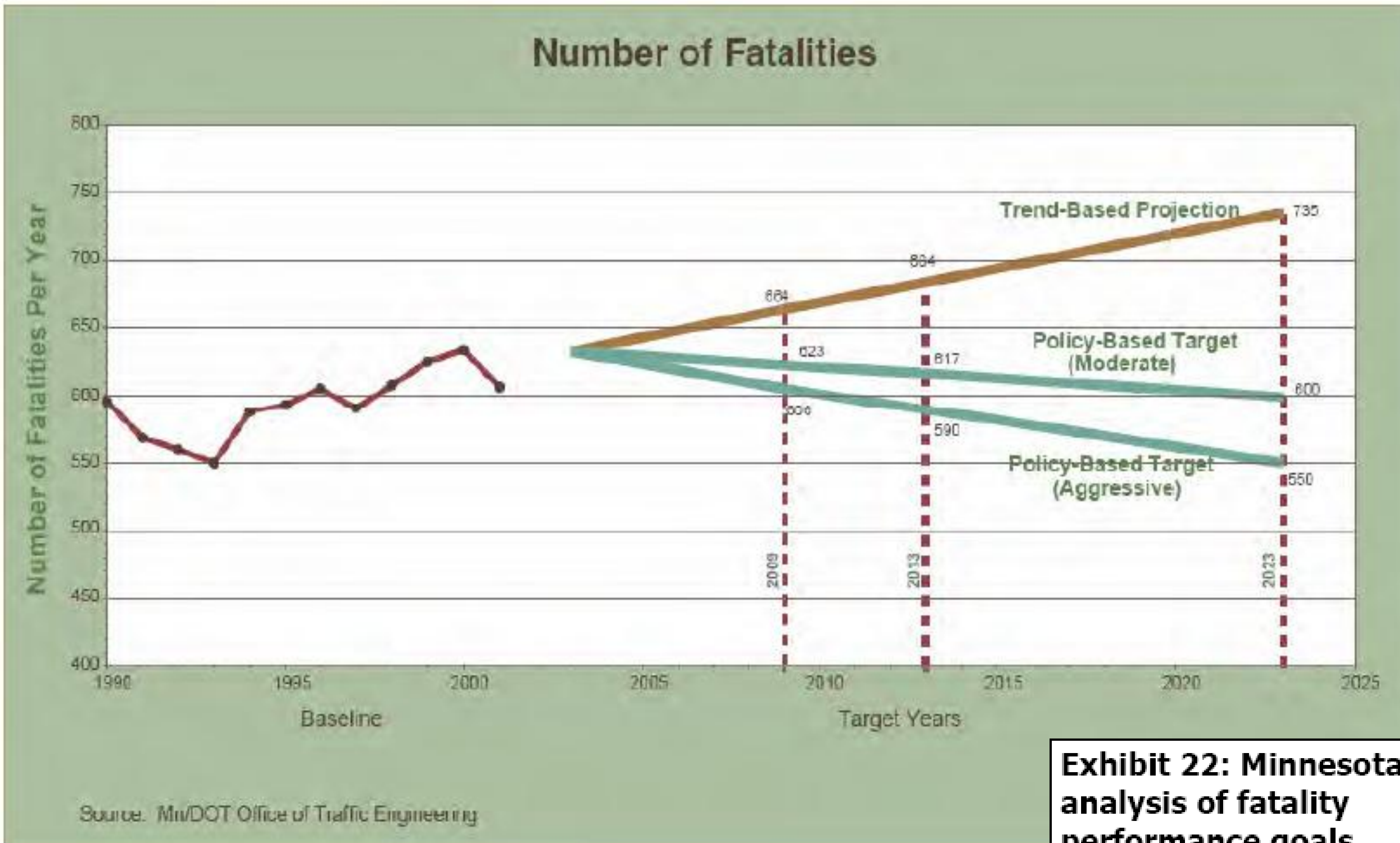


Exhibit 22: Minnesota DOT analysis of fatality performance goals

Step 4: Incorporate Safety into Technical Analysis

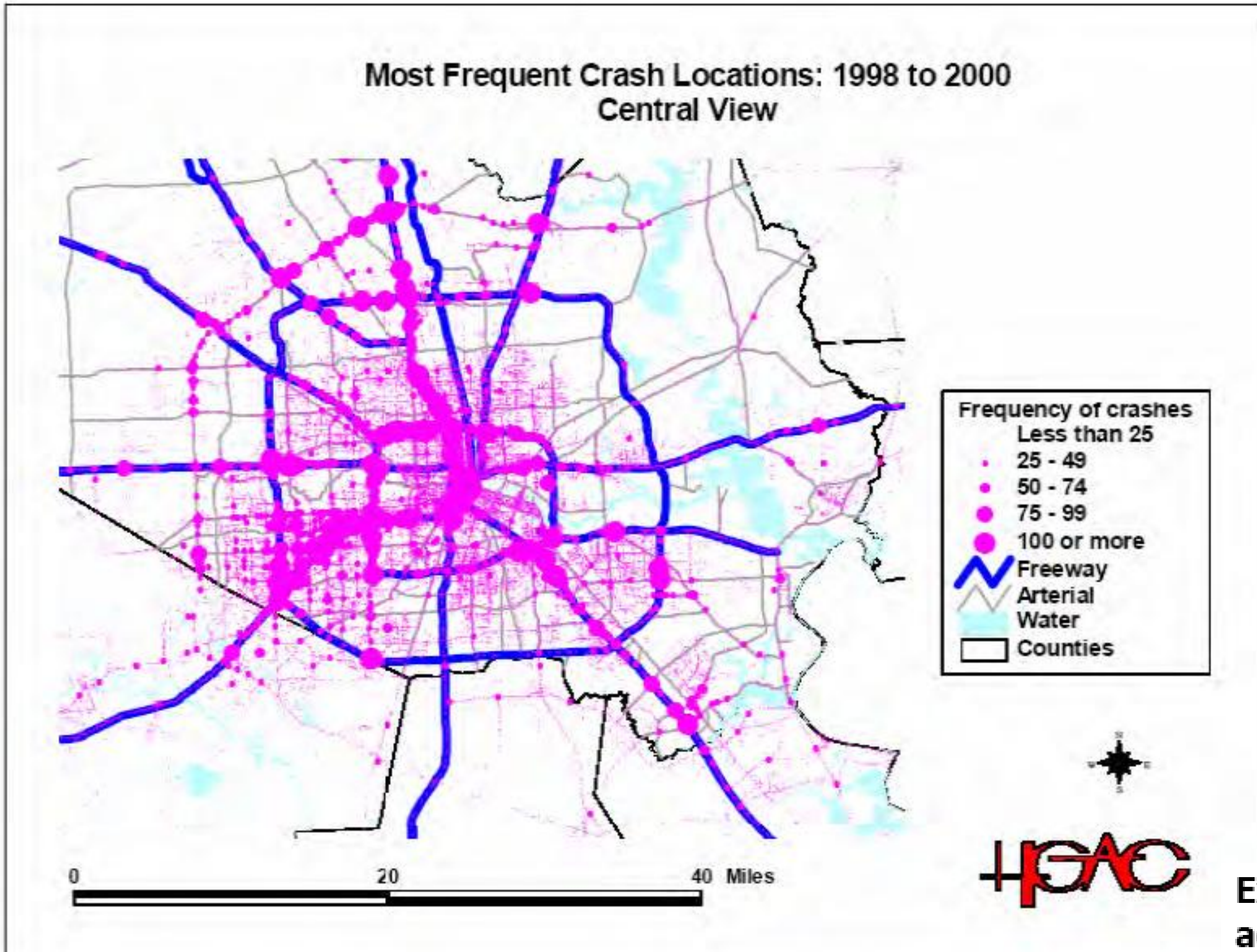


Exhibit 26: GIS map of accident frequencies on a transportation network

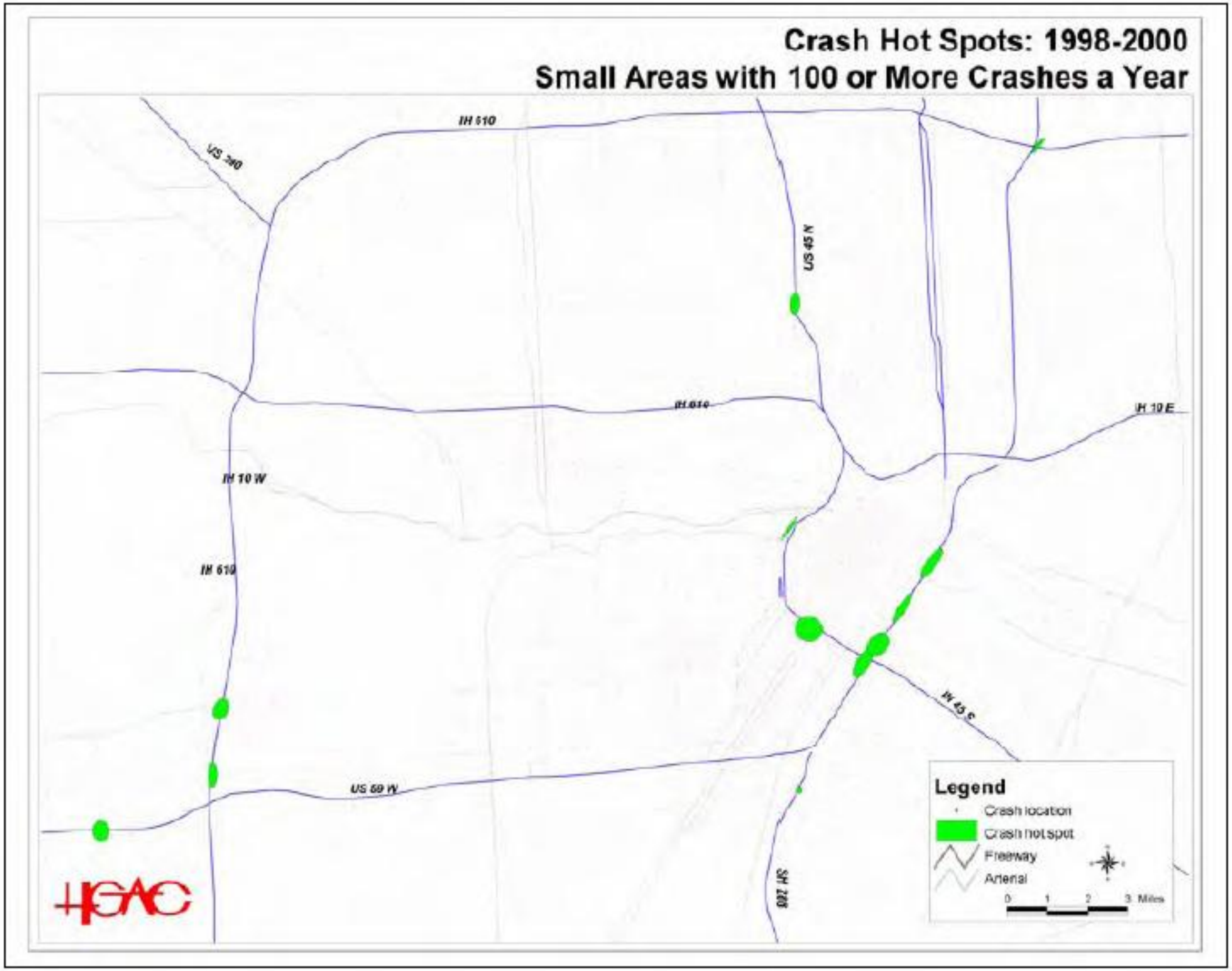


Exhibit 27: GIS map of crashes on a small road network

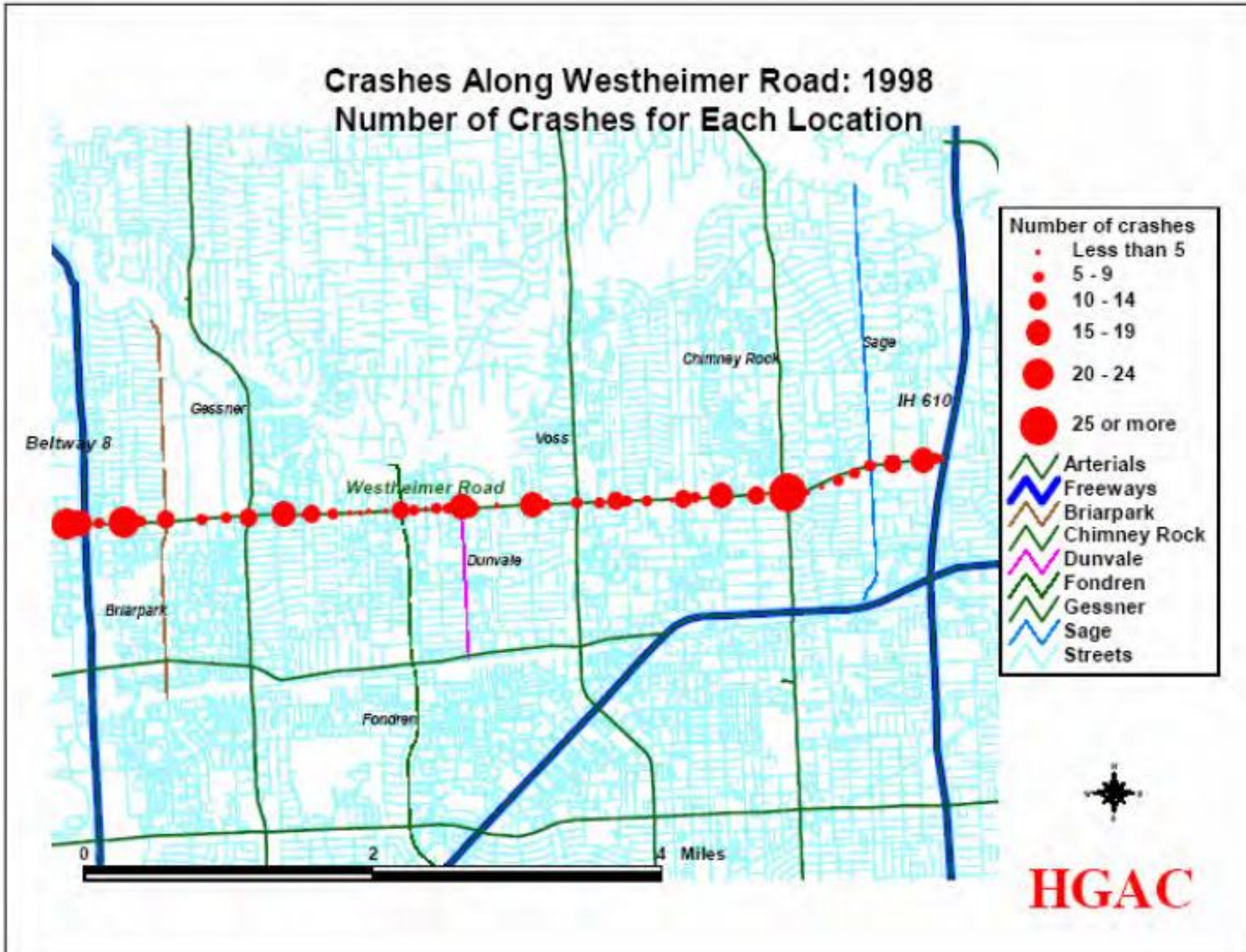


Exhibit 28: GIS map of crashes along a corridor

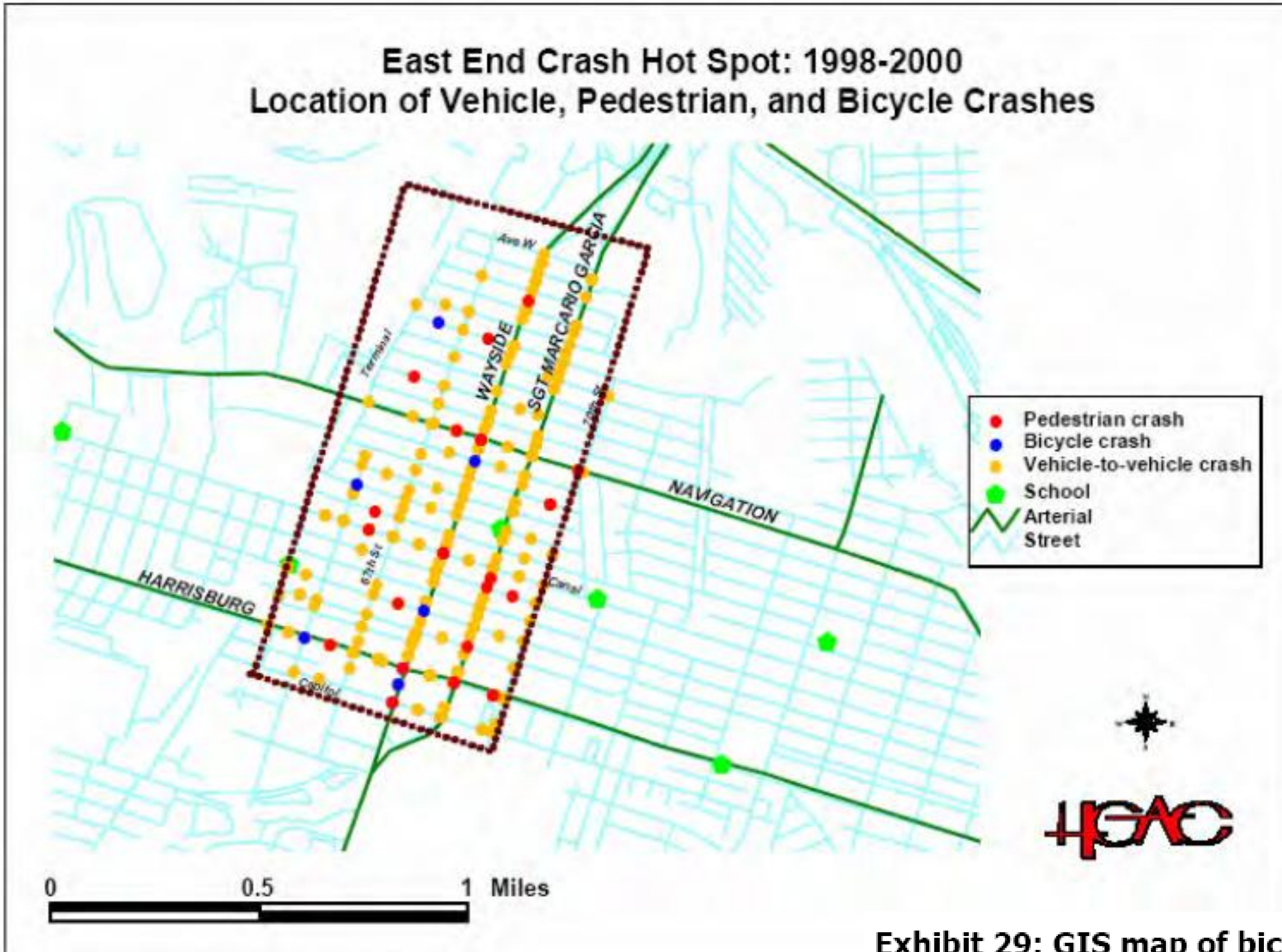


Exhibit 29: GIS map of bicycle and pedestrian crashes at the neighborhood scale

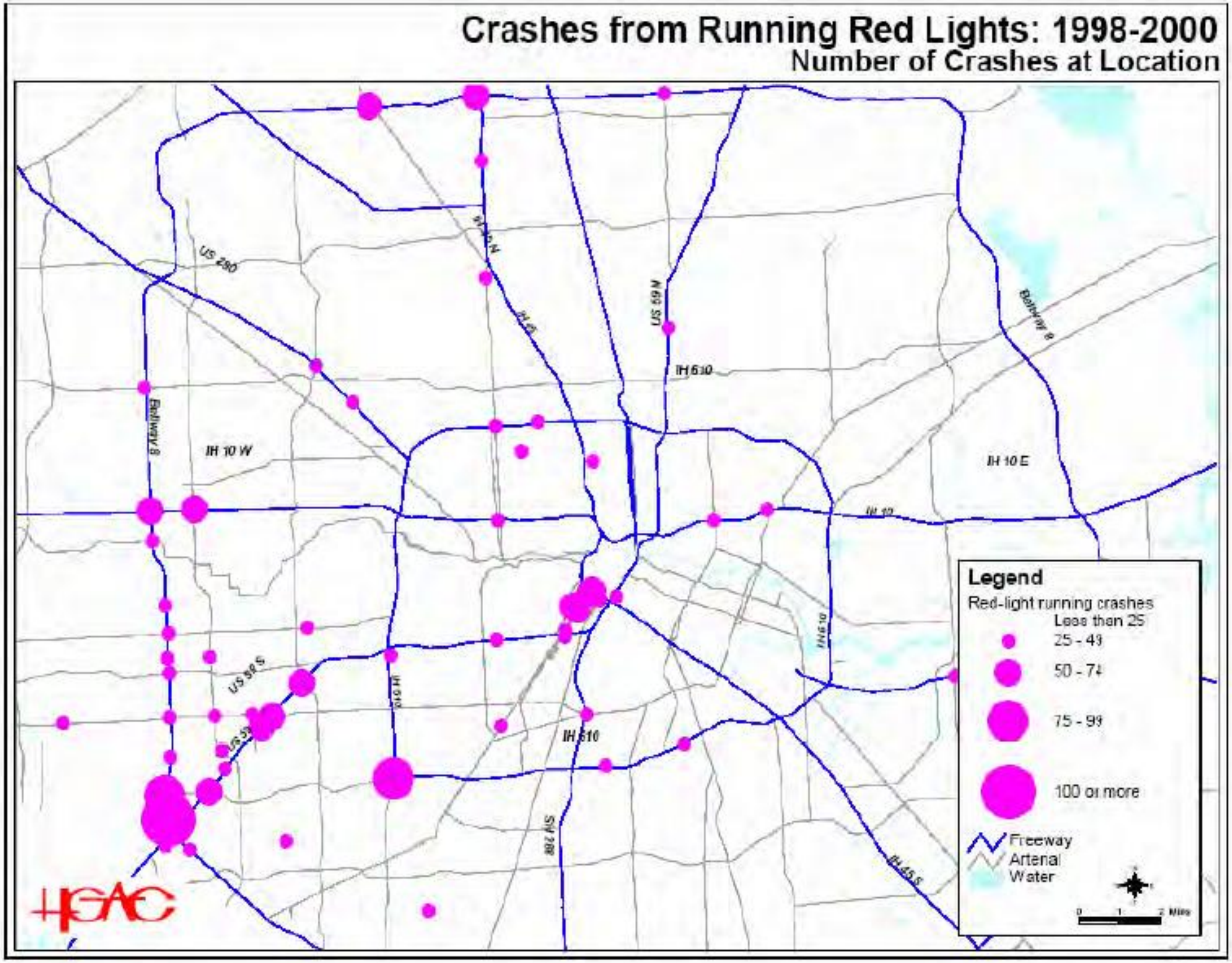


Exhibit 30: GIS map of red-light-running-related crashes on a transportation network

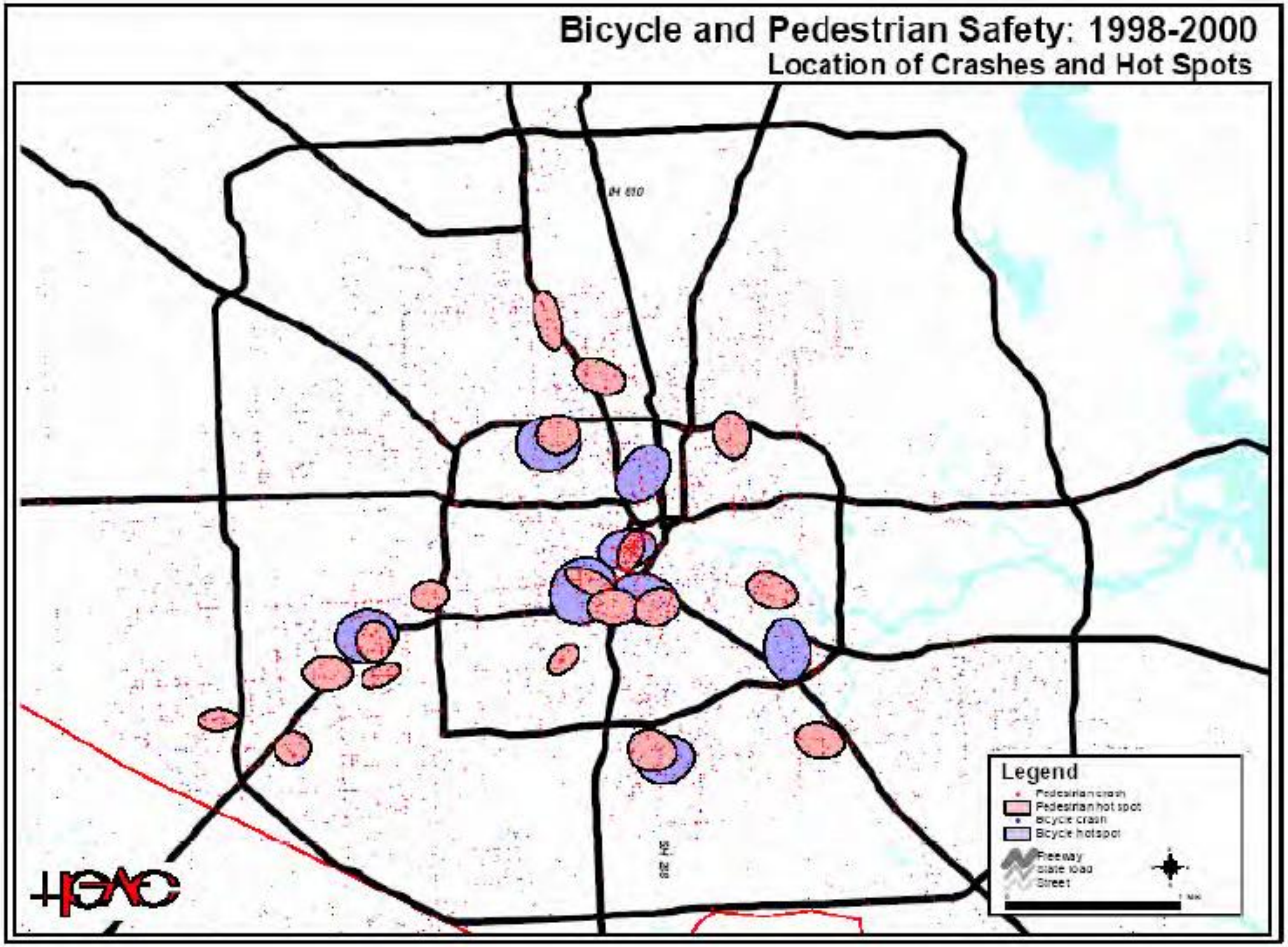


Exhibit 31: GIS map of bicycle and pedestrian crashes in a transportation network

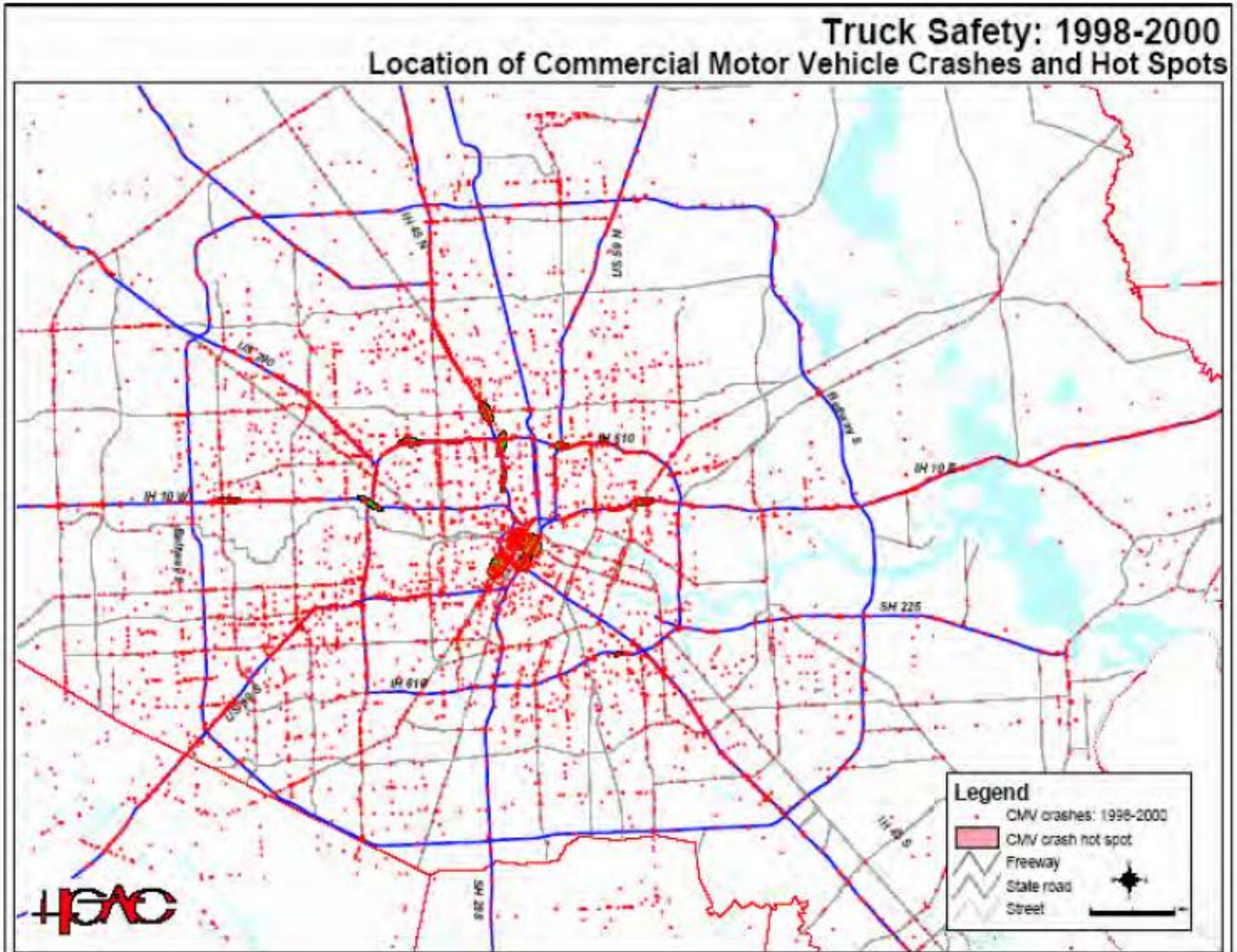


Exhibit 32: GIS map of commercial motor vehicle crashes in a transportation network

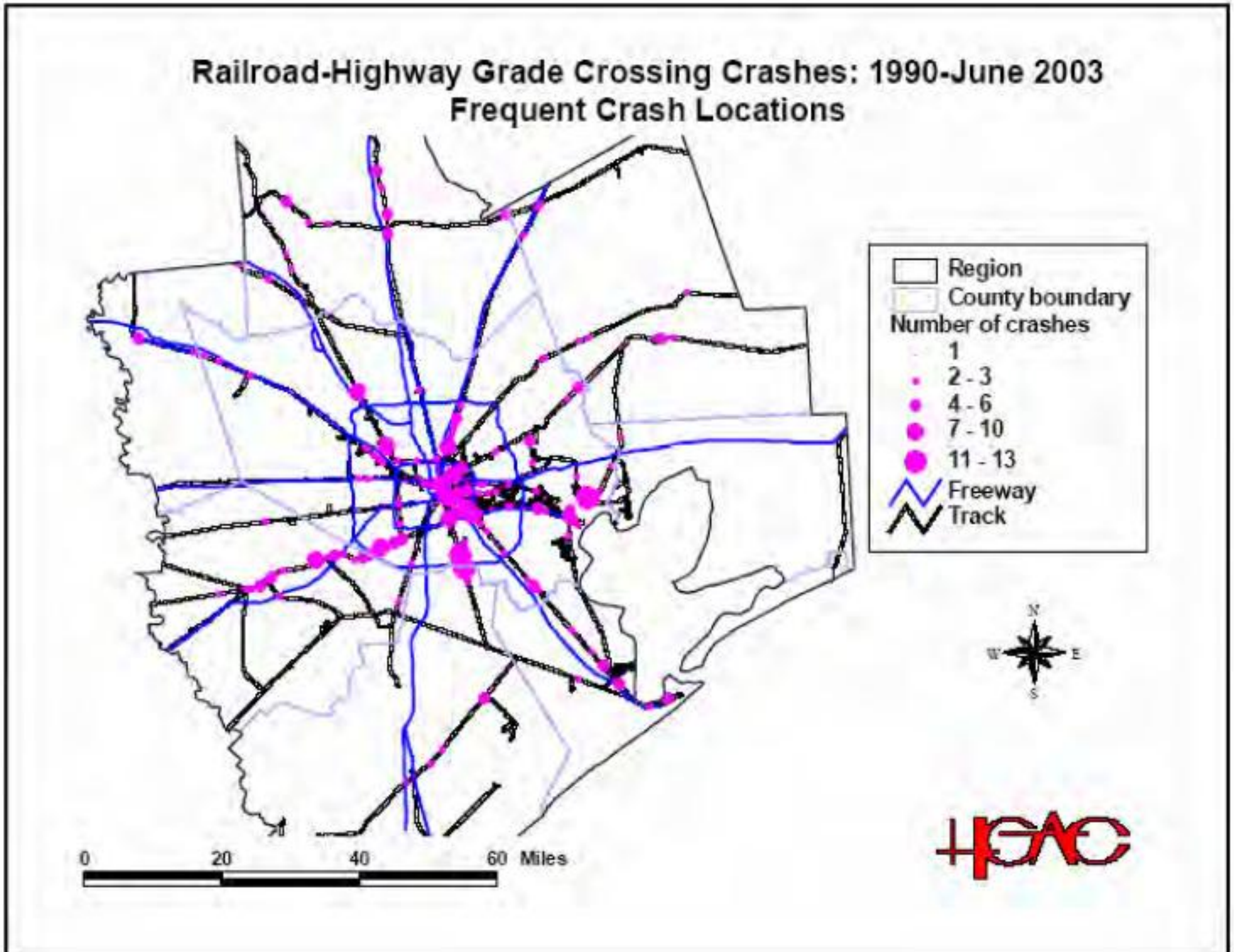


Exhibit 33: GIS map of railroad-highway crossing crashes

Some fundamental concepts in safety

that will serve as useful concepts for individuals not typically involved in safety analysis

- System safety is not accurately measured by one-time crash counts.
- Countermeasures typically affect specific types of crashes—called target crashes.
- Crash trends increase and decrease without interventions or countermeasures.
- Safety performance relative to underlying safety is critical.
- Safety performance functions are not typically straight lines.
- Accident modification factors are used to quantify countermeasure effectiveness.

Improvement Characteristics	Percentage Reduction in Relevant Accidents (Accident Modification Factor)	Target Accident Types
Curve Reconstruction	0.50	Run off road, head-on
Vertical Re-Alignment	0.45	Head-on, limited sight
Median Barriers	0.60 fatal, 0.10 injury	Head-on
Climbing/Passing Lane	0.15	Passing, rear-end
Lane Widening	0.20	Sideswipe (multi-lane)
Widen from 2-lane to 4-lane Road	0.30	Rear-end, head-on
Continuous Center-Left Turn Lane	0.30	Rear-end

Exhibit 36: Accident modification factors for highways in the Denver metropolitan area [Source: Denver Regional Council of Governments, 2002]

Step 5: Evaluating Alternative Projects and Strategies

Evaluation Criteria	Points	Scoring*
Congestion	0-16	Up to 16 points based on the current degree of congestion (V/C ratio) on the existing roadway
RTP Emphasis Corridors	0-4	4 points to projects on emphasized freeways or major regional arterials. 2 points to projects on emphasized principal arterial segments
Safety	0-7	Up to 7 points based on weighted accident rate compared to statewide average and estimated accident reduction.
Usage	0-9	Current AWDT/lane > 11,000 = 9 points; < 2,500 = 0 points

	Estimated Number of Accidents per Mile Eliminated per Three Years			
	Low 0-14 fewer	Medium 15-35	High 36-59	Very High 60+
Accident Range	**Safety Points To Be Awarded**			
State Average	0	1	3	4
1-2 x State Average	1	2	4	5
2-3 x State Average	2	4	5	6

Exhibit 40: Assigning points as an evaluation methodology in Denver [Source: Denver Regional Council of Governments, 2003]

Evaluation Criteria	Points	Scoring*
RTP Priority Corridors	0-4	4 points for bike projects on RTP Regional Bicycle Corridors 2 points for bike projects on Community Bicycle Corridors 4 points for pedestrian projects along RTP major regional arterials 2 points for pedestrian projects along RTP principal arterials
Safety	0-12	Projects evaluated on the anticipated improvement of existing safety problems
Potential Need	0-23	Up to 23 points for specific project attributes which address existing local or regional needs of non-motorized travel

- **Crash History**
  1 point award for each applicable injury accident, up to a maximum of 5
- **Conflict Factor**
  1 point if < 25 mph
  2 points if 26-34 mph
  3 points if 35-44 mph
  4 points if 45-54 mph
  5 points if > 55 mph
- **Facility Lighting**
  2 points to projects that facilitate non-motorized travel, if lighting is not available now

Exhibit 41: Scoring for pedestrian and bicycle projects in the Denver region

Exhibit 42: Federal Highway Administration estimates of cost to society of accidents

Urban Functional System	Death	Cost/Nonfatal Injury	Property Damage Cost/Accident
Interstate		$27,047	$5,148
Other freeway/expressway		$35,002	$6,435
Other principal arterial	$3 million	$28,638	$6,435
Minor arterial		$39,775	$6,435
Collector		$31,820	$5,148

Exhibit 43: North Carolina estimates of cost to society of accidents

	Fatal Injury	Incapacitating Injury	Moderate Injury	Minor Injury	PDO
Medical	$18,676	$14,656	$3,209	$1,721	$137
Emergency Services	$1,184	$292	$190	$123	$60
Lost Work	$1,020,469	$22,535	$6,917	$3,345	$366
Employer Cost	$8,055	$1,199	$493	$272	$88
Traffic Delay	$488	$212	$205	$174	$251
Property Damage	$11,064	$4,350	$3,697	$2,794	$2,505
Monetary Cost	$1,059,936	$43,245	$14,710	$8,431	$3,406
Quality of Life	$1,865,164	$101,551	$22,776	$8,431	$3,406
Comprehensive Cost	$2,925,100	$144,796	$37,486	$17,916	$3,904

Exhibit 44: Los Angeles estimates of cost to society of transit accidents

	Bus and Rail (per Million Vehicle Miles)		
Type of Accident	Bus Rate	Rail Rate	Cost per Event
Fatal	0.162	1.161	$2,710,000
Injury	25.800	11.600	$65,590

Step 6: Develop Plan and Program

	Yes (%)	No (%)	Not included, but discussed in planning (%)
Safety Education Programs			
Motor-Vehicle Safety Education	13.4	**60.8**	25.8
Safety Publicity	26.8	**48.5**	24.7
Bicyclist/Pedestrian Safety Education	**59.8**	15.5	24.7
Transit Safety Education	19.6	**50.5**	29.9
Work Zone Safety Education	8.2	**77.3**	14.4
Education Policy	14.4	**71.1**	14.4
Elderly Driver Evaluation Programs	7.2	**81.4**	11.3
Mature Driver Education	5.2	**80.4**	14.4
Engineering and Operations			
Traffic Management	**88.5**	2.1	9.4
Safety Audits of Existing/Rehabilitated/New Roadways	25.0	**42.7**	32.3
Traffic Safety Studies	**55.2**	14.6	30.2
Traffic Safety Measures in Construction Zones/"Work Zones"	7.3	**59.4**	33.3
Personal Vehicle Safety			
Seat Belt / Restraint Use	4.2	**80.0**	15.8
Child Safety Seat Use	1.1	**86.3**	12.6
Aggressive Driving	6.3	**70.5**	23.2
Distracted Driving (i.e. Cell Phones While Driving)	5.3	**75.8**	18.9
Older Driver Safety and Mobility	13.7	**63.2**	23.2
Winter (Snow and Ice) Driving	1.1	**80.0**	19.0
Drinking and Driving / DWI Prevention / Impaired Driving	5.3	**75.8**	19.0
Graduated Driver Licensing / Restricted Driving	3.2	**87.4**	9.5
Multi-modal Safety Programs			
School Bus Safety	8.4	**72.6**	19.0
Motorcycle Safety	3.2	**90.5**	6.3
Commercial Truck Safety	24.2	**44.2**	31.6
Bicyclist Safety	**70.5**	9.5	20.0
Pedestrian Safety	**69.5**	8.4	22.1
Intermodal Junction Safety (i.e. Roadway/Railway Crossings)	**46.3**	26.3	27.4
Alternative Transportation Education Programs			
Information Kits on How to Use Public Transportation	20.0	**46.3**	33.7
Information/Call Centers with Comprehensive Information on Safety/Incidents	28.4	**50.5**	21.1
Enforcement and Other Programs			
Speeding	16.8	**60.0**	23.2
Legislation	27.4	**48.4**	24.2
Safe Communities	17.9	**63.2**	18.9
Emergency Medical Services	18.9	**61.1**	20.0

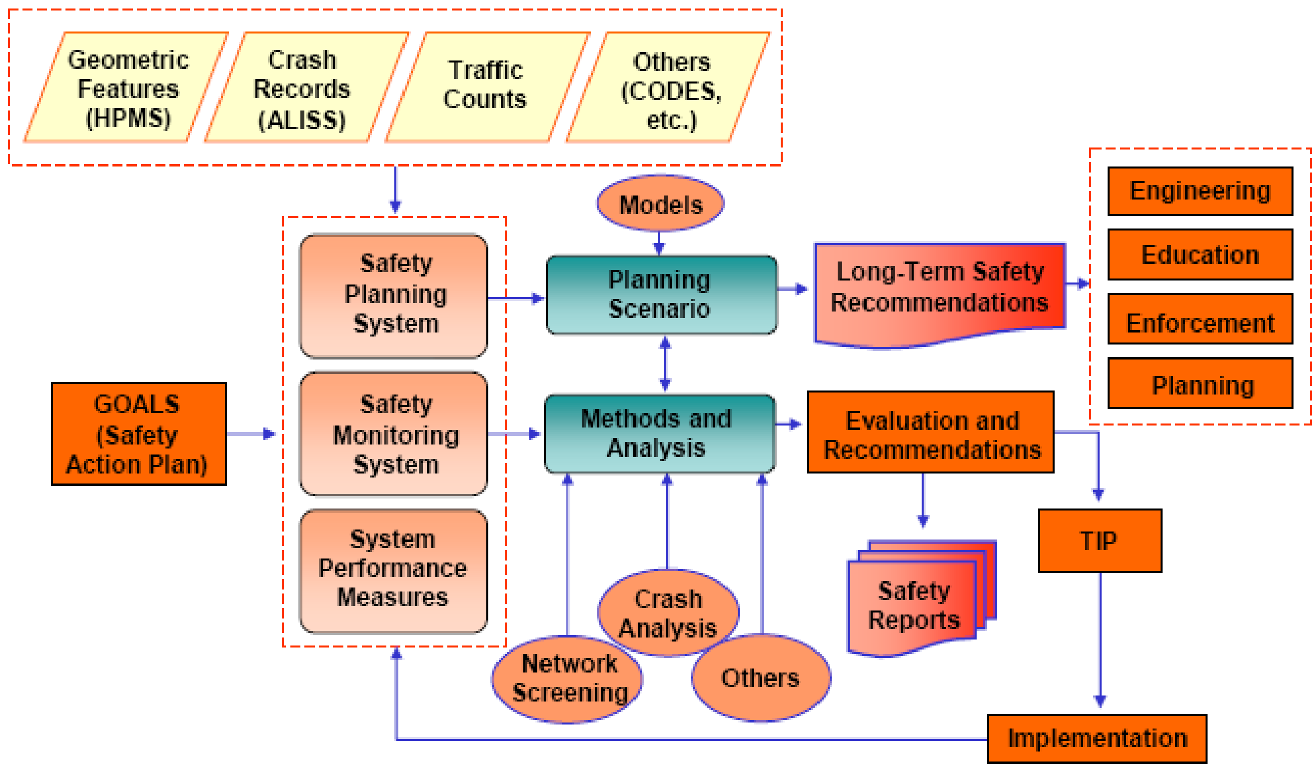
Exhibit 47: Inclusion of concepts in long-range transportation plans

Exhibit 48: Contents of Iowa's safety management system toolbox

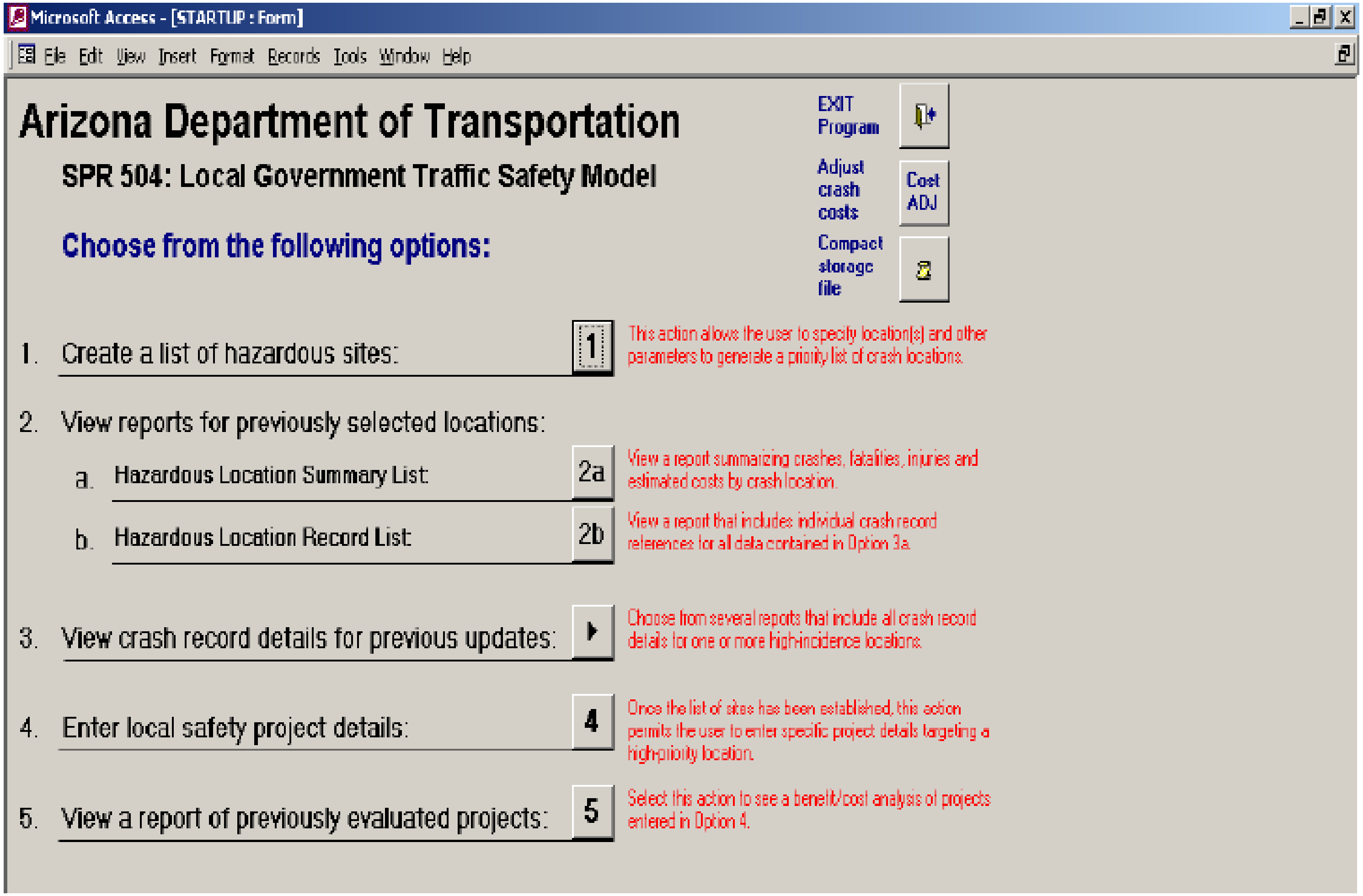
- Increasing Driver Safety Awareness
- Increasing Safety Belt and Child Restraint Usage
- Preventing Drowsy and Distracted Driving
- Curbing High-Risk Driving Behaviors
- Ensuring Drivers Are Fully Licensed, Competent, and Insured
- Reducing Impaired Driving
- Education and Licensing for Young Drivers
- Sustaining Safe Mobility in Older Drivers
- Making Walking and Street Crossing Safer
- Ensuring Safer Bicycle Travel
- Making School Bus Travel Safer
- Making Public Transit Travel Safer
- Improving Motorcycle Safety and Increasing Motorcycle Awareness
- Making Large Truck Travel Safer
- Reducing Farm Vehicle Accidents
- Improving the Design and Operation of Roadway Intersections
- Keeping Vehicles on the Roadway and Minimizing the Consequences of Leaving the Road
- Reducing Head-On and Across-Median Accidents
- Improving Work Zone Safety
- Accommodating Older Drivers
- Reducing Train-Vehicle Accidents
- Reducing Vehicle-Animal Accidents
- Implementing Road Safety Audits
- Enhancing Emergency Response Capabilities to Increase Survivability
- Improving Information and Decision Support Systems
- Using Intelligent Transportation Systems (ITS) to Improve Highway Safety
- Creating More Effective Processes and Safety Management Systems
- Developing and Encouraging Multidisciplinary Safety Teams

Step 7: Monitoring System Performance

Phoenix Safety Management System



Some Tools



Microsoft Access - [STARTUP : Form]
File Edit View Insert Format Records Tools Window Help
Arizona Department of Transportation
SPR 504: Local Government Traffic Safety Model
Choose from the following options:
EXIT Program
Adjust crash costs
Cost ADJ
Compact storage file
1. Create a list of hazardous sites:
1
This action allows the user to specify location(s) and other parameters to generate a priority list of crash locations.
2. View reports for previously selected locations:
a. Hazardous Location Summary List:
2a
View a report summarizing crashes, fatalities, injuries and estimated costs by crash location.
b. Hazardous Location Record List:
2b
View a report that includes individual crash record references for all data contained in Option 3a.
3. View crash record details for previous updates:
Choose from several reports that include all crash record details for one or more high-incidence locations.
4. Enter local safety project details:
4
Once the list of sites has been established, this action permits the user to enter specific project details targeting a high-priority location.
5. View a report of previously evaluated projects:
5
Select this action to see a benefit/cost analysis of projects entered in Option 4.

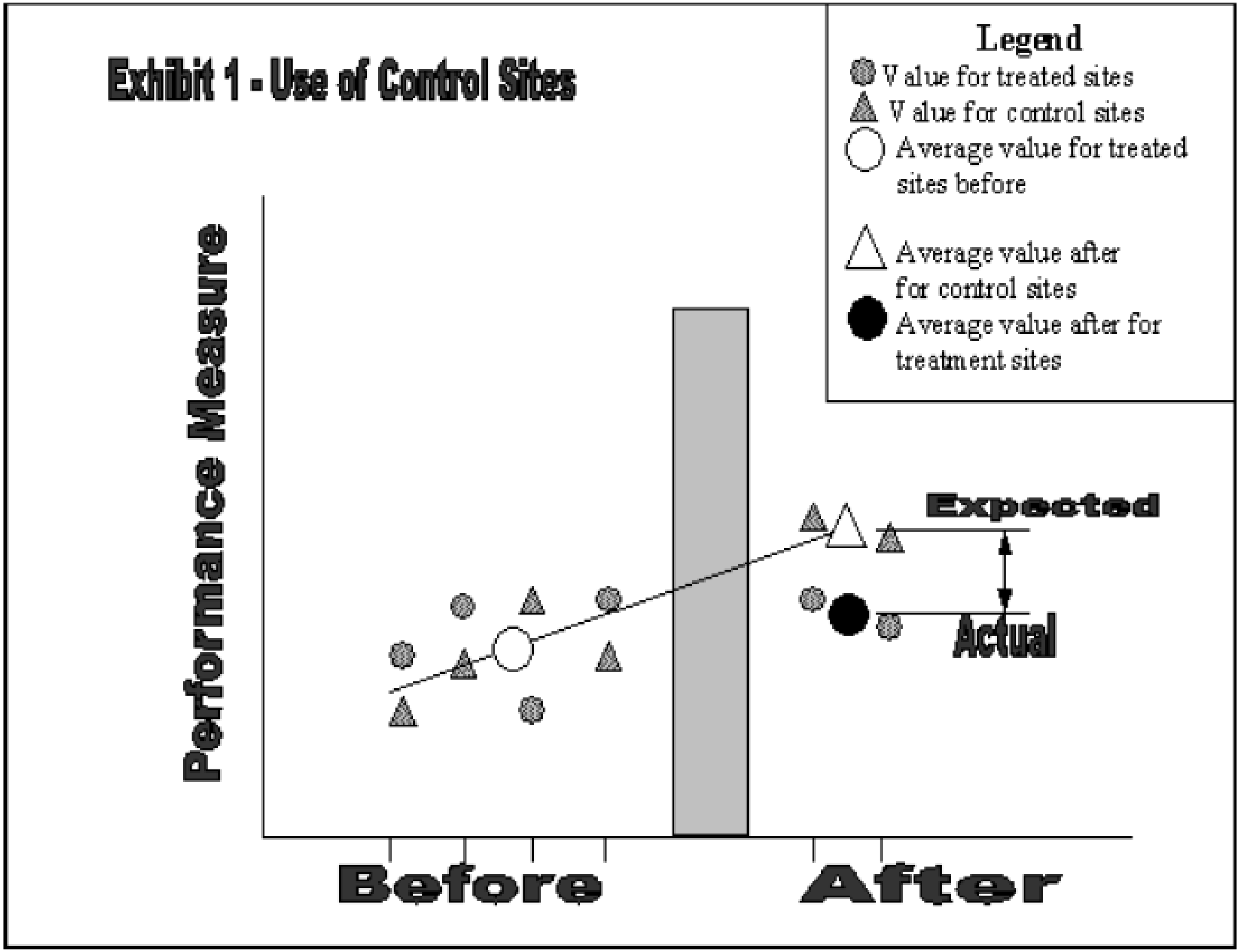


Exhibit 1 - Use of Control Sites
Legend
Value for treated sites
Value for control sites
Average value for treated sites before
Average value after for control sites
Average value after for treatment sites
Performance Measure
Expected
Actual
Before
After

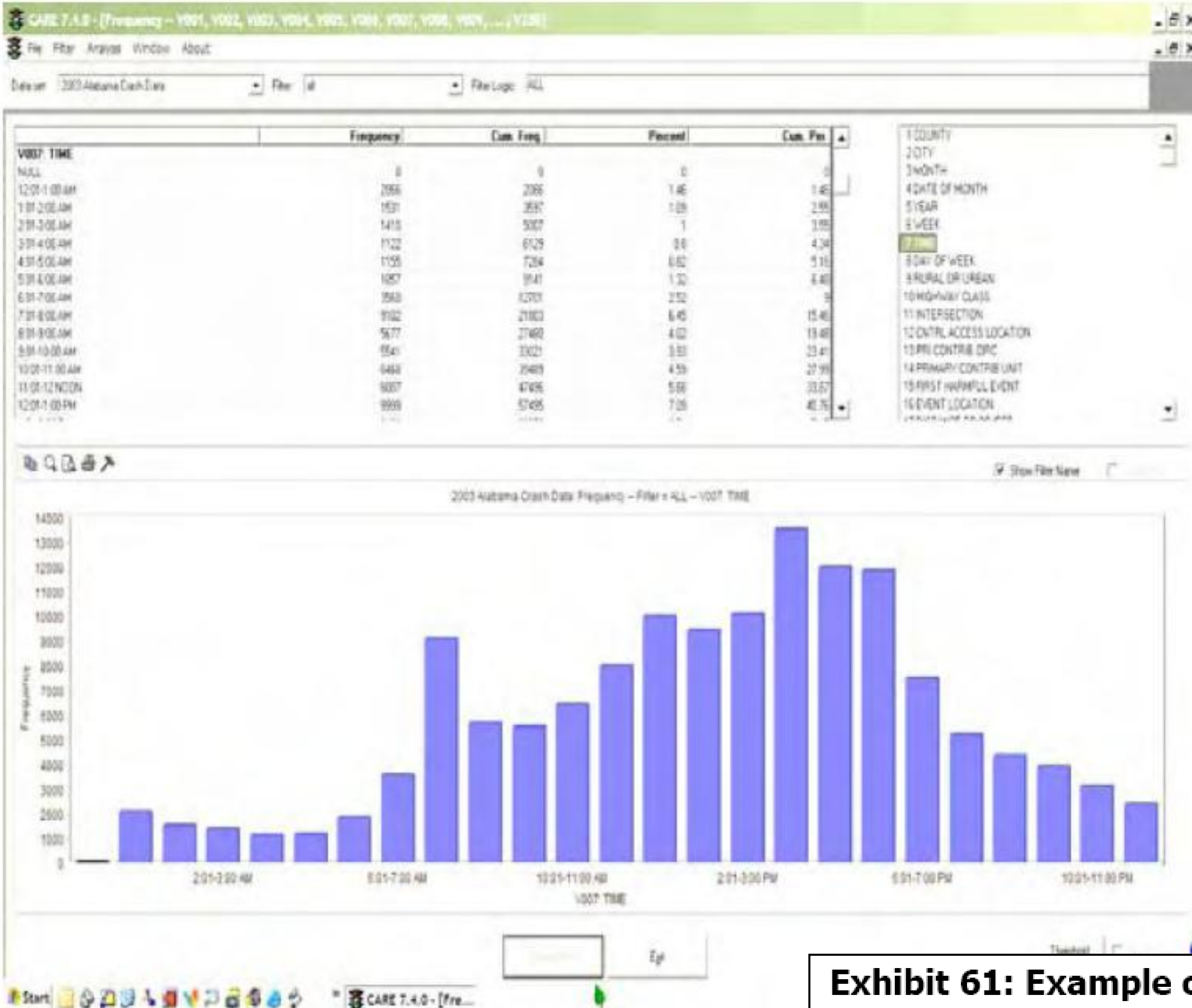


Exhibit 61: Example output from CARE

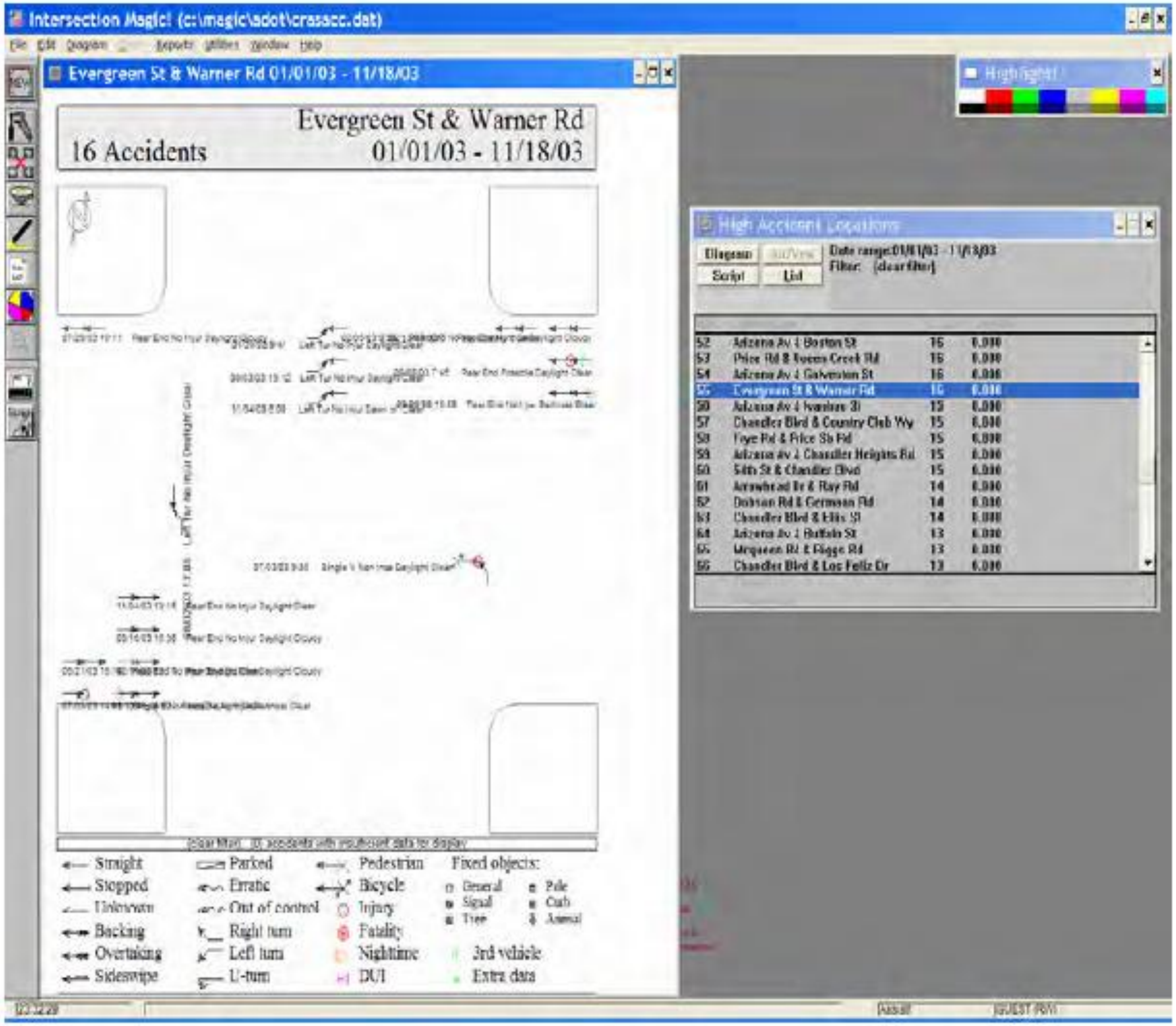
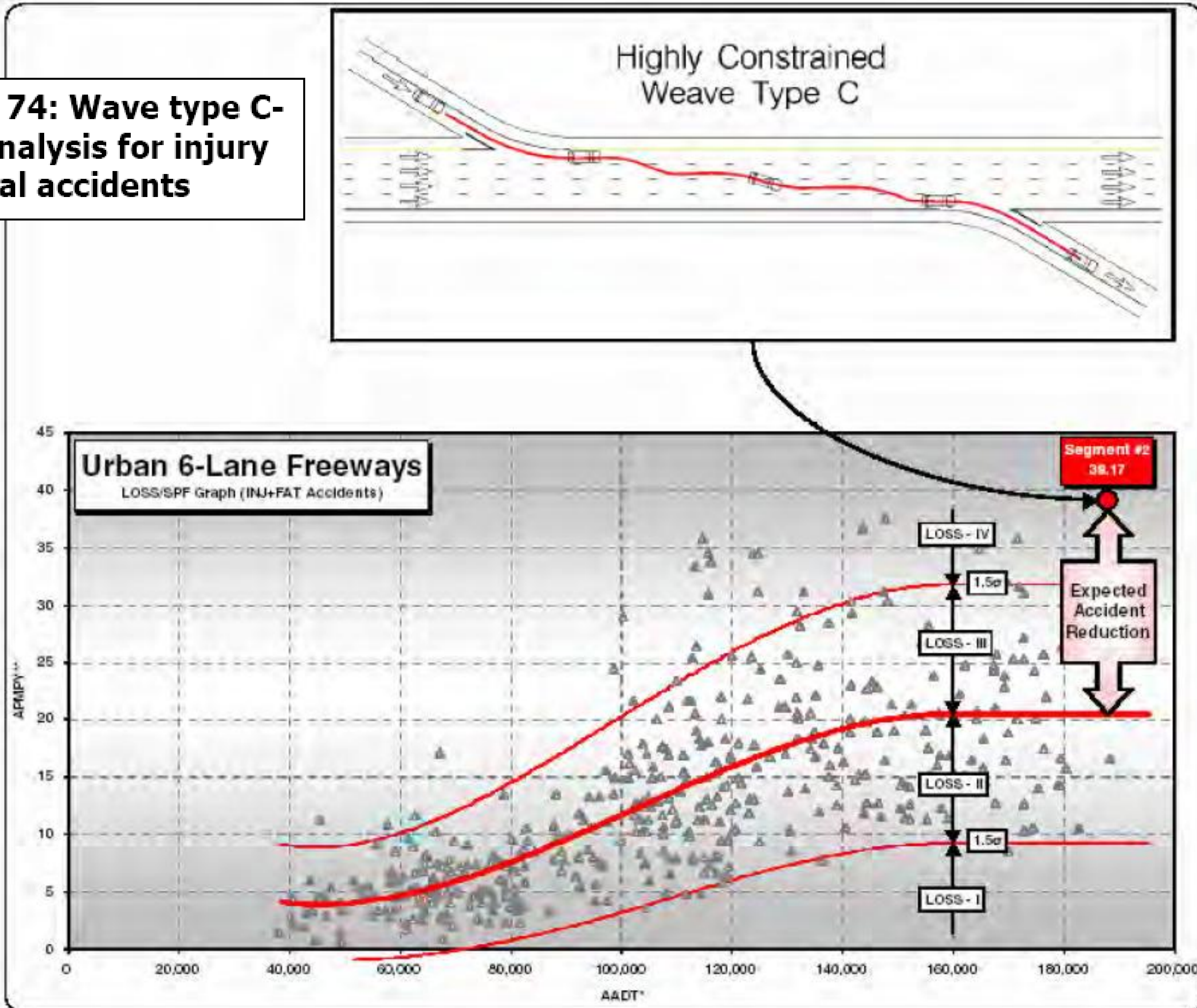

Intersection Magic! (c:\magic\adot\crasacc.dat)
Evergreen St & Warner Rd 01/01/03 - 11/18/03
Evergreen St & Warner Rd
16 Accidents
01/01/03 - 11/18/03
High Accident Locations
Diagram
Script
List
Chandler Blvd & Country Club Wy
Straight
Stopped
Backing
Overtaking
Sideswipe
Parked
Erratic
Out of control
Right turn
Left turn
U-turn
Pedestrian
Bicycle
Injury
Fatality
Nighttime
DUI
Fixed objects:
3rd vehicle
Extra data

Exhibit 74: Wave type C-LOSS analysis for injury and fatal accidents



Safety Analyst

Intersection	Total Accident Frequency (1995-99)	Average Annual Daily Traffic (veh/day)	Accident Frequency Ranking	Potential for Safety Improvement (PSI) Ranking
A	131	63502	1	2
B	104	35284	2	3
C	77	57988	3	11
D	75	46979	4	6
E	66	51933	5	10
F	51	48427	6	1
G	51	20423	7	15
H	46	34759	8	5
I	42	53396	9	61
J	38	25223	10	17

Exhibit 84: Comparison of rankings by accident frequency and PSI for signalized intersections in a particular city

PLANSAFE: PLANNING LEVEL SAFETY PREDICTION MODEL

PLANNING LEVEL SAFETY PREDICTION MODEL

Vendor name and address: Simon Washington and Ida van Schalkwyk, Arizona State University. Tempe, Arizona, 85287. simon.washington@asu.edu.

Brief description of transportation safety applications: The Planning Level Safety Prediction Model is a planning-level model used to predict motor vehicle accidents per traffic analysis zone (TAZ) area or larger sub-areas of a jurisdiction. Thus, the smallest unit of analysis is the TAZ, whereas the largest unit of analysis is collections of TAZs such as neighborhoods, those TAZs affected by a major transportation project, etc. Crashes of various types are modelled as functions of various predictors such as the distribution and mileage of the functional classifications of highways, vehicle miles traveled, socio-economic and demographic factors, and population characteristics.

For development of the models under NCHRP 8-44, data from Pima and Maricopa Counties in Arizona and the state of Michigan were used. These regions represent a fairly diverse range of geography and driving populations in order to derive models that may approximate aggregate relationships across the U.S..

Types and sources of data needed: TAZ level data regarding population, travel, schools, infrastructure (e.g., residential units, commercial units, etc.), and crashes.

Expertise required: Knowledge of GIS, some statistical modelling, or statistical model interpretation skills.

Hardware requirements: Desktop PC with database and GIS software.

Example application of tool: The tool can be used to forecast the projected increase (over baseline totals) in fatal, injury, pedestrian, and total crashes expected in 10 years given population growth, the provision of new schools, and other changes under the 'no-build' scenario and various 'build' scenarios (refer to the section titled When to use the PLANSAFE (and when not to).

MODEL FORMS
Total Accident Frequency Model
$Log(Accident\_Frequency + 1) = 5.020 + 0.474 \times 10^{-1}(POP\_PAC) + 0.196 \times 10^{-3}(POP16\_64) + 0.151 \times 10^{-2}(TOT\_MILE)$
Property Damage Only Accident Frequency Model
$Log(PDO\_accident\_frequency + 1) = 4.762 + 0.515(PH\_URB) + 0.566 \times 10^{-1}(POP\_PAC) + 0.392 \times 10^{-5}(VMT)$
Fatal Accident Frequency Model
$Log(Fatal\_accident\_frequency + 1) = 0.652 - 0.924 \times 10^{-1}(INT\_PMI) + 1.762(PNF\_0111) + 1.389(PNF\_0512) + 0.263 \times 10^{-3}(POP00\_15) + 0.319(PPOPMIN)$
Incapacitating and Fatal Accident Frequency Model
$Log(Incpacitating\_and\_Fatal\_accident\_frequency + 1) = 2.257 - 0.659 \times 10^{-1}(INT\_PMI) + 3.328(PNF\_0111) + 3.674(PNF\_0512) + 0.512 \times 10^{-3}(POP00\_15)$
Nighttime Accident Frequency Model
$Log(Nighttime\_accident\_frequency + 1) = 4.092 - 19.167(MI\_PACRE) + 3.524(PNF\_0111) + 1.414(PNF\_0214) + 3.588(PNF\_0512) + 0.861(PPOPMIN) + 0.238 \times 10^{-3}(WORKERS)$
Pedestrians Accident Frequency Model
$Log(frequency\_of\_accidents\_involving\_pedestrians + 1) = 1.443 - 0.706 \times 10^{-5}(HH\_INC) + 0.129(POP\_PAC) + 0.884 \times 10^{-4}(POPTOT) - 0.902(PWTPRV)$
Injury Accident Frequency Model
$Log(frequency\_of\_injury\_accidents + 1) = 3.108 + 0.153(HU\_PACRE) + 0.768(PPOPURB) + 0.443 \times 10^{-5}(VMT)$
Accidents Involving Bicycles Frequency Model
$Log(frequency\_of\_Accidents\_involving\_bicyclists + 1) = 0.655 \times 10^{-1} + 0.252 \times 10^{-3}(HU) + 0.162 \times 10^{-2}(TOT\_MILE) + 0.292 \times 10^{-5}(VMT) + 1.539(WORK\_PAC)$

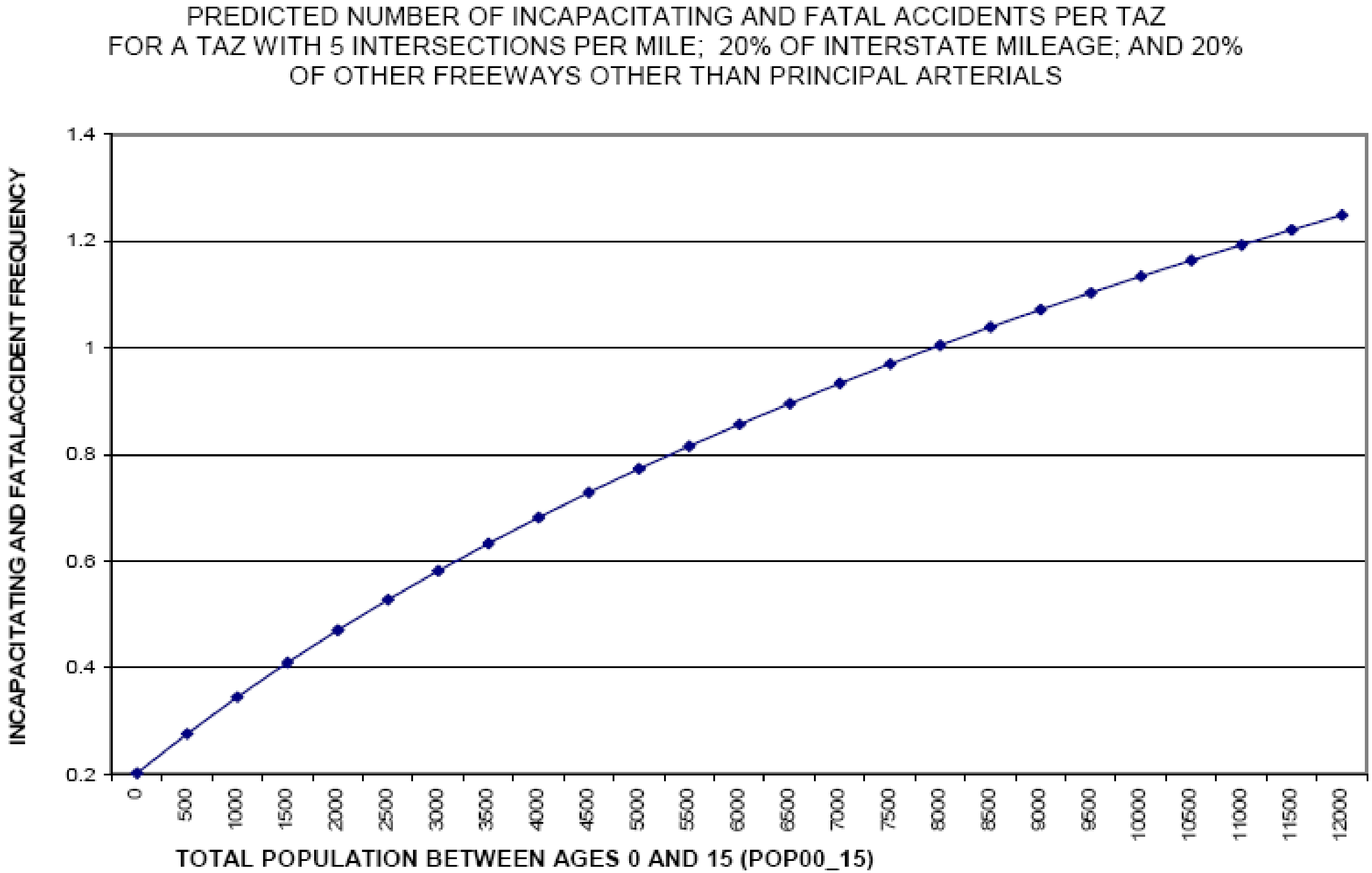


Exhibit 92: Predicted number of incapacitating and fatal injury crashes by population count ages 0 to 15 by TAZ:- PLANSAFE incapacitating and fatal model

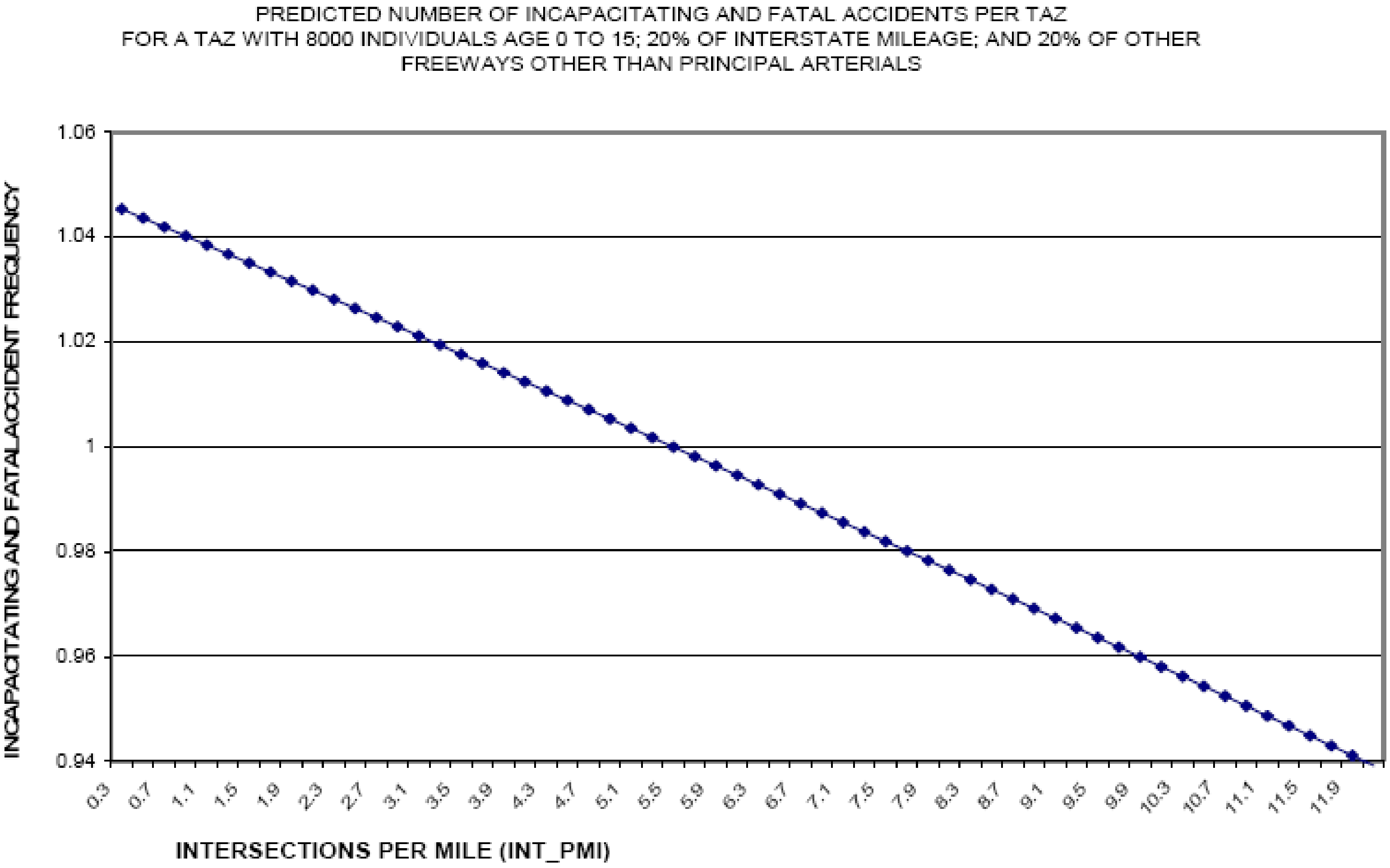


Exhibit 93: Predicted number of incapacitating and fatal injury crashes by intersection count per mile by TAZ:- PLANSAFE incapacitating and fatal model

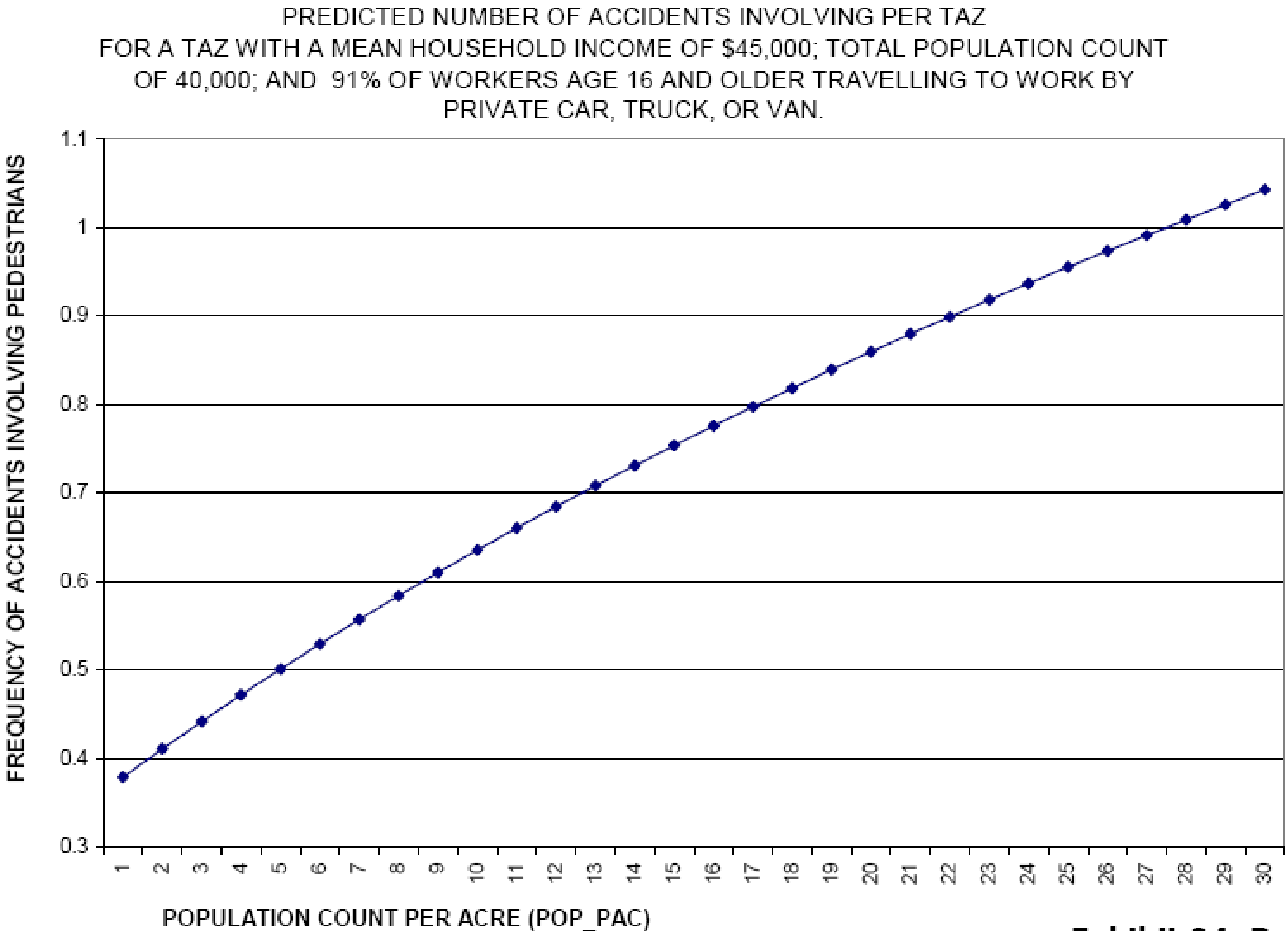


Exhibit 94: Predicted number of crashes involving pedestrians by TAZ by population count per acre by TAZ:- PLANSAFE pedestrian model

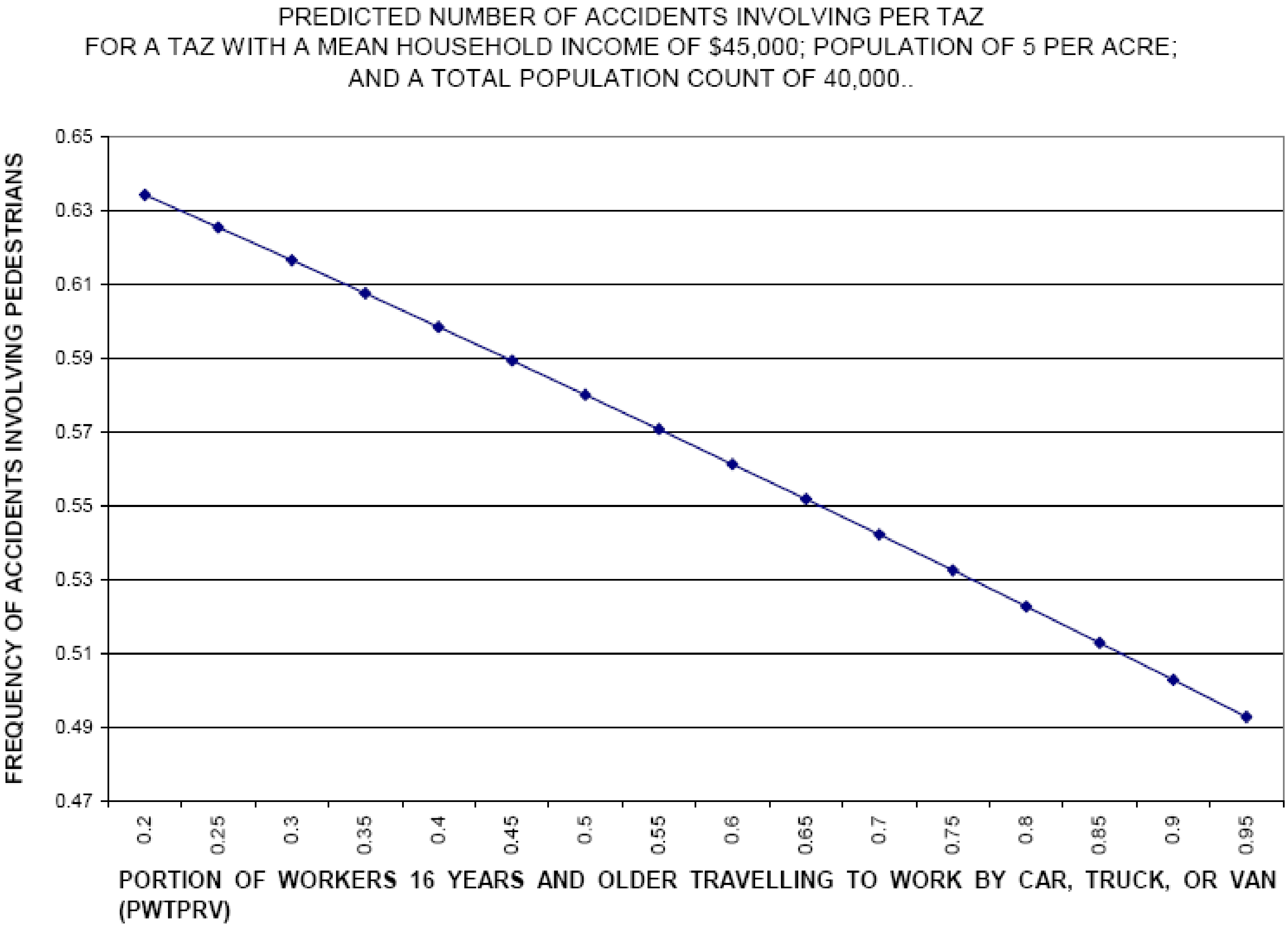


Exhibit 95: Predicted number of Crashes involving pedestrians by TAZ by portion of workers age 16 and older traveling to work by car, truck, or van, by TAZ:- PLANSAFE pedestrian model

PLANSAFE Example

TAZ NUMBER	INT_PMI	PNF_0111	PNF_0512	POP00_15
Base Year Data for Existing Conditions				
1	1	0.12	0.15	2500
2	4	0.09	0.12	6500
3	5	0.12	0.16	2780
4	2	0.17	0.2	8000
5	4	0.03	0.04	5400
6	6	0.023	0.035	2000
7	2	0.095	0.1	3526
8	1	0.045	0.06	4578
9	2	0.014	0.025	3278
10	7	0.021	0.3	6900
Data for Future Conditions at Implementation of Planned Project				
1	3	0.15	0.15	6500
2	5	0.09	0.15	10000
3	6	0.15	0.16	6400
4	2	0.17	0.25	12000
5	5	0.03	0.04	5400
6	7	0.028	0.044	2600
7	4	0.095	0.1	3526
8	3	0.045	0.075	4578
9	4	0.018	0.025	9500
10	7	0.021	0.3	6900

Base Year Data for Status Quo			
TAZ	**Observed Crashes**	**Predicted Crashes**	**BCF**
1	4	3.4207	1.169
2	8	5.0598	1.581
3	5	3.3369	1.498
4	10	6.5194	1.534
5	7	4.0033	1.749
6	3	2.0798	1.442
7	8	5.9589	1.343
8	8	3.8539	2.076
9	6	2.9276	2.049
10	9	5.4950	1.638
Totals	68	42.6552	
		unbiased BCF	1.594
		average BCF	1.607
		std.dev. BCF	0.287
		CV BCF	0.179

TAZ	Predicted Project Scenario Crash Frequency	BCF	Adjusted Project Scenario Crash Frequency
1	5.70	1.594	9.09
2	7.39	1.594	11.79
3	5.36	1.594	8.54
4	9.02	1.594	14.37
5	4.34	1.594	6.91
6	3.28	1.594	5.24
7	3.83	1.594	6.11
8	3.84	1.594	6.13
9	6.25	1.594	9.96
10	5.76	1.594	9.18
		Total	87.31