MARICOPA ASSOCIATION of GOVERNMENTS

Strategic Transportation Safety Plan

MAG Contract No. 529 Project No. SP13-01

Technical Memorandum No. 4 – Network Screening Methodologies for Prioritization of Road Safety Needs

4.1 INTRODUCTION

The Lee Engineering/TTI Team is developing a comprehensive update of the 2005 Strategic Transportation Safety Plan (STSP) for the Maricopa Association of Governments. The new STSP will establish regional vision, goals, objectives, strategies, countermeasures, and performance measures for transportation safety. It is a data-driven, multi-year comprehensive plan that establishes goals, objectives, and key emphasis areas and integrates the four E's of highway safety – engineering, education, enforcement and emergency medical services (EMS). The STSP allows MAG safety programs and member agencies to work together in an effort to align goals, leverage resources, and collectively address the region's safety challenges. The STSP will also identify strategies for addressing new areas of transportation safety. The development of the STSP will be closely coordinated with the ongoing development of the state's Strategic Highway Safety Plan (SHSP) by the Arizona DOT. The recommendations included in the STSP will be incorporated in the next generation MAG Regional Transportation Plan.

The information included in this Technical Memorandum No. 4 addresses network screening methodologies for prioritization of MAG road safety needs.

4.2 NETWORK SCREENING BACKGROUND

As presented in the AASHTO *Highway Safety Manual (HSM)*, network screening is part of the roadway safety management process and is useful in the identification and ranking of sites based on the estimated reduction in crashes associated with the implementation of appropriate countermeasures. Through the application of network screening, systematic safety evaluations can be performed that will provide consistent and repeatable results which are useful in identifying candidate safety enhancement locations. A wide variety of analysis methods may be considered for site identification based on specific needs such as intersection improvement programs, safety policy evaluations, and similar[1].

The HSM identifies a five step process for network screening that consists of the following:

1. Establish Focus
2. Identify Network and Establish Reference Populations
3. Select Performance Measures
4. Select Screening Method
5. Screen and Evaluate Results

[1] *Highway Safety Manual, 1st Edition.* AASHTO, 2010. Page 4-1

The focus step is used to define the problem and determine the reason for applying a network screening effort. An example could be evaluating the merits of adding left-turn lanes at intersection locations. On a larger scale, a focus could simply be to evaluate all urban road segments with traffic volumes greater than some minimum value so that locations that require additional safety treatments can be identified.

Reference populations are then selected to help better define ways to evaluate the problem. For example, for the left-turn lane focus example the reference population would then be signalized intersections. This population could be further narrowed based on a variety of road characteristics, traffic conditions, and facility users. The selection of performance measures and a network screening technique suitable for evaluating the performance measures is then initiated. One common assessment approach is to identify road segments or intersections of interest and then divide these roadway components into groups with similar characteristics for a more detailed analysis. The results can then be collectively evaluated for corridor safety evaluations.

Currently MAG has developed a network screening procedure for evaluating intersections. At this time, a similar network screening approach is needed for roadway segments. This technical memorandum provides a review of the existing intersection network screening procedure and recommendations to consider for enhancing this approach. Also included in this memorandum is a recommendation for potential network screening techniques for roadway segments. In addition, non-motorized user issues are not always identified using traditional network screening methods. In many cases, the immediate response to an injured pedestrian or bicyclist is to seek emergency medical care as quickly as possible. As a result, it is likely that many crashes involving pedestrians and bicycles are not accurately reported or included in available crash statistics. This technical memorandum includes some additional recommendations to address how to identify locations where facilities intended to protect these vulnerable road users may benefit from additional safety assessment strategies.

4.3 MAG Network Screening Methodology for Intersections

The review of the MAG intersection screening techniques includes a brief overview of the current approach, recommendations for enhancing the procedure, and future supplementary network screening recommendations that merit consideration.

4.3.1. Current Approach

At this time, the MAG Network Screening Methodology for Intersections (NSM-I) includes several safety assessment techniques that are then weighted and combined into an Intersection Safety Score (ISS). The intent of this composite ISS approach is to minimize known biases in the analysis procedure. For example, using crash frequencies as a sole method for determining safety needs would introduce a bias towards locations with higher volumes. It is advisable, therefore, to select network screening methods that do not have a known bias or to develop techniques to minimize known biases. The MAG NSM-I approach currently uses the following four crash-related attributes for this purpose:

- Crash Frequency (CF),
- Crash Severity (CS),
- Crash Type (CT), and
- Crash Rate (CR).

The ISS is then developed by assigning weights to these four attributes with the CS value assigned a 40 percent weight and the CF, CT, and CR each assigned a 20 percent weight.

4.3.2. Recommendations to Consider for Enhancement of the Existing NSM-I Approach

The current NSM-I technique provides a well-constructed procedure for overcoming many of the known limitations associated with intersection network screening methods. The creation of a composite ISS is a very useful approach for an overall network screening evaluation. There are two modifications that MAG should consider for this approach: (1) removing or minimizing use of the CR in the ISS, and (2) aggregating the intersections by type or exposure so that comparable conditions are assessed. These two recommendations are discussed in the following sections.

Removing or Minimizing Use of the CR in the ISS

The known bias associated with crash frequency (biased towards locations with high volumes) is one reason why CRs have historically been consistently used in the network screening process. A CR, in simple terms, is a ratio of the number of crashes to the traffic volume at a location. It is noteworthy that the CF value is actually included in the CR calculation. Using a CR is intuitive and, if traffic volume is known, can be easy to apply. Unfortunately, a CR value also has a bias towards low volume locations. The ratio format of the CR also implies that the relationship between the number of crashes and the crash volume is linear (i.e. the CR calculation equates to the slope of a line). In recent years, safety research efforts have determined that the sometimes complex relationship between the number of crashes and the traffic volume is usually not linear but rather has a shape better represented by an equation for a curve that generally flattens as traffic volume increases. For these reasons, the use of CR values should be reserved for locations with similar traffic volumes if safety comparisons are based on CR values.

The current calculation for the ISS applies a 20 percent weight to the CF and CR. Because the CF is included in the CR calculation, the ISS may be skewed by the use of both values in the equation. In addition, the current NSM-I approach for the CR is time consuming because traffic volume values may not always be available for all intersections. As a result, MAG should consider removing one of these values from the ISS and redistributing the weights to the other components. One possible modified ISS equation is shown below:

$$ISS = \left(\frac{1}{4} \times \frac{CF}{Max(CF)}\right) + \left(\frac{1}{2} \times \frac{CS}{Max(CS)}\right) + \left(\frac{1}{4} \times \frac{CT}{Max(CT)}\right)$$

Aggregating the Intersections by Type or Exposure

The comparison of similar intersection types can help eliminate some of the biases attributed to traffic volumes at intersections. For example, a high volume signalized intersection (where rear-end collisions may be prominent) merits unique evaluation, and a direct comparison between this intersection and a low-volume intersection (where angle crashes may be prominent) would probably mask critical safety enhancement needs. If, on the other hand, intersection types can be evaluated separately based on functional purpose and user distributions, the result will be a more robust screening assessment that better targets key populations. For initial intersection categories, the following intersection types could be independently screened and ISS values developed for each:

- Low-volume STOP-controlled intersections,
- Moderate-volume STOP-controlled or signalized intersections,
- High-volume signalized intersections, and
- Interchange terminal intersections.

Interchanges in urban environments can include a single intersection (such as a single-point interchange), two intersections (common for an urban diamond), or multiple intersections. For this reason, it would be

advisable to consider intersections located within the influence area of the interchange. Currently research is underway at the national level (National Cooperative Highway Research Program (NCHRP) Project 7-23) to better identify access management in the vicinity of interchanges. As part of this effort, the research team is proposing to help define this interchange influence area based on the type of terminal intersection configuration. Until the NCHRP work is complete, MAG could use some basic assumptions regarding surface street influence area such as a one-fourth mile upstream and downstream buffer at the interchange.

4.3.3. Future Enhancements to the NSM-I

Recent enhancements to safety assessment techniques have resulted in evidence based and data driven statistical procedures known as safety performance functions (SPFs). The AASHTO HSM includes nationally derived SPFs for a variety of segment and intersection locations. These SPFs, in concert with companion crash modification factors (CMFs), act as tools for predicting crash performance for various highway types and associated characteristics. Because road and driver characteristics can vary between regions and since regional environmental and enforcement issues may also contribute to local safety conditions, the SPFs should be calibrated for the MAG region prior to widespread implementation. It would be optimal for the MAG partners to develop a strategy to systematically calibrate existing SPFs and develop MAG-specific SPFs for facilities with calibration factors that result in extreme values (optimal calibration factors should have a value of approximately 0.7 to 1.3).

The future integration of SPFs into the intersection network screening procedures would help reduce the known biases of using crash frequencies and rates. The SPF could be used to determine the number of crashes that can typically be expected for a particular type of intersection. Network screening would then identify locations where the historic (or observed) crashes exceeded the number of predicted crashes for that type of facility. SPF values can be based on total crashes or fatal and injury crashes, so specific crash severity thresholds could also be determined using this procedure. SPFs can also be used to apply Empirical Bayes (EB) procedures that further improve crash estimation quality. Until MAG is able to calibrate or develop region-specific SPFs, the HSM SPFs could be used for comparative purposes only.

A key input variable for all intersection SPFs is the traffic volume for the major and minor approaches. As noted in the existing NSM-I documentation, traffic volume is not always available for the crash rate calculation. Consequently, a future recommendation would also be to enhance the available traffic volume information for candidate network locations. It may be feasible to use a subset of traffic volume data to develop an estimation method for approximating missing traffic volume values.

Finally, the HSM SPFs are used in conjunction with CMFs as previously noted. A CMF is a multiplicative factor that represents the anticipated influence that an individual feature or a set of road characteristics may have on the predicted number of crashes. For example, a CMF equal to 0.97 would represent a three percent reduction in crashes (i.e. 1.00 – 0.97 = 0.03). Similarly, a CMF value greater than 1.0 represents an anticipated increase in the number of crashes. In many cases, a CMF can be very influential while other CMFs represent only minor changes in crash totals. In the event MAG elected to use the current HSM SPFs along with their companion CMFs for the purposes of network screening at intersections, the information shown in Table 1 identifies these CMFs and indicates those that will have the greatest impact on the predicted safety performance. The priority indications shown in the table are based on (1) CMFs that are dramatically influenced by their associated road characteristics, and (2) CMFs with values that are not close to a value of 1.0 (i.e. CMFs that do not substantially change the predicted number of crashes should not have high data collection priorities).

Table 1. Priority Data Needs for HSM Intersection CMFs

	Priority Level for Data Needs at Intersection Types											
	3-Leg STOP Controlled			3-Leg Signalized			4-Leg STOP Controlled			4-Leg Signalized		
CMF Description	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable
Urban and Suburban Arterial Intersections												
Left-turn lanes	✓					✓	✓					✓
Left-turn signal phasing			✓		✓				✓		✓	
Right-turn lanes			✓		✓				✓		✓	
Right-turn on red			✓			✓			✓			✓
Street lights		✓			✓			✓			✓	
Red light cameras			✓			✓			✓			✓
Rural Multilane Highway Intersections												
Skew angle	✓			HSM SPF Not Available			✓					✓
Left-turn lanes	✓						✓					✓
Right-turn lanes		✓					✓					✓
Street lights			✓						✓			✓
Rural Two-lane Highway Intersections												
Skew angle		✓		HSM SPF Not Available			✓					✓
Left-turn lanes	✓						✓			✓		
Right-turn lanes	✓						✓				✓	
Street lights		✓						✓			✓	

As shown in Table 1, identifying left-turn lane information at STOP controlled intersections should be given priority for urban and suburban arterial intersections. Similarly, left-turn lanes, skew angles, and right-turn lanes have high to medium priority for rural multilane and two-lane STOP controlled intersection locations. The rural two-lane 4-leg signalized intersection is the only signalized facility type where the left-turn lane information should receive priority data collection attention.

4.4 Recommendations for MAG Network Screening Methodology for Segments

Currently MAG does not have a comprehensive method for performing network screening for segment locations. Similar to concerns identified for the MAG NSM-I procedure, the application of segment screening methods based solely on crash frequency trends can be biased to high volume locations. A secondary issue common to segment analysis is the accurate reporting of crash locations. Evaluating very short segments may result in incorrect assumptions about the number of crashes along a segment location. Consequently, effective segment screening techniques should incorporate procedures that provide some flexibility for potentially imprecise location information.

Another item that must be considered is how to identify the segment related crashes that should be included in the segment network screening analysis. The NSM-I only uses crashes identified by the Arizona Department of Transportation's Accident Location Identification Surveillance System (ALISS) as "intersection related", so the network screening for segments should include all crashes **that are not**

designated as “intersection related” in the Arizona crash database. As noted in the NSM-I description, the ALISS data are assumed to be 100 percent accurate for the purposes of this network screening procedure.

4.4.1. Safety Network Screening Methodology for Segments (NSM-S)

Network screening for segment locations can be accomplished by selecting target performance measures accompanied by an effective screening method. The following summary addresses recommended target performance measures that can be reasonably evaluated with the existing MAG data. Section 4.4.2 provides a recommended future network screening approach as MAG data and region-specific SPFs become available.

Target Performance Measures

A wide variety of candidate performance measures are available for safety network screening; however, data requirements must be considered when defining practical and effective methods. Page 4-8 of the HSM provides a table (Table 4-1 of the HSM) that summarizes data needs for a wide variety of performance measures. Of course selection of candidate performance measures should also consider quality of data and stability of the analysis procedure. For this reason, an optimal performance measure that evaluates system-wide performance is one that compares proportions of crash type or severity that are typically observed at similar sites and ranks sites based on levels of excess proportions.

In addition, recent MAP-21 legislation stipulates performance measures that focus on total number of fatal crashes, total number of severe injury crashes, and rates attributed to these fatal and severe injury crashes. Consequently, the segment screening method should also evaluate these specific frequency values. [Note: The required rate values will be generalized rates where the frequency is divided by million vehicle miles traveled. This exposure information will be acquired from the FHWA Highway Performance Monitoring System (HPMS) and not evaluated on an individual site basis, so the rates are not included in this proposed analysis.] Therefore, the proposed NSM-S procedure recommends the following performance measures:

- Excess proportions of specific crash types (primary performance measure),
- Frequency of total crashes (secondary performance measure),
- Frequency of fatal crashes (secondary performance measure), and
- Frequency of severe injury crashes (secondary performance measure).

The “Excess Proportions of Specific Crash Types” method, as introduced in the HSM, is based on comparing the observed number of crashes at a study location to proportional distributions of crashes for similar locations. For example, a 0.5 mile long urban roadway segment with four lanes could be expected to have a variety of crashes including run-off-road, sideswipe, head-on, etc. These same crash types may occur for high, moderate, and low volume conditions, but their proportions are likely to change. Lower volume conditions would be less likely to have sideswipe or head-on crashes but more likely to have run-off-road crashes. Using the excess proportions approach, the various roadway segment types would be aggregated into corridor types and further subdivided by traffic exposure thresholds. A proportion of crash types would then be developed for each of the candidate corridors based on crash history for these facility types in the region. The network screening procedure would then compare the observed crash proportions to those commonly observed for similar locations and identify excess proportions that merit additional analysis. This procedure is not influenced dramatically by time sensitive fluctuations (making it a good screening candidate as it is not directly affected by regression to the mean biases). Some potential limitations to the procedure include the fact that traffic volume is not explicitly considered in the analysis (thus the aggregation by facility type and by volume thresholds). Of course, this means the procedure can be applied at all locations, even when traffic volume information is not available. The addition of secondary performance measures (frequency of total, fatal, and severe injury crashes) will help confirm locations that

merit additional safety evaluations. An example application of this method can be observed on page 4-40 of the HSM.

Screening Method

The AASHTO HSM[2] identifies the peak searching method and the sliding window method as the two recommended techniques for performing network screening along roadway corridor segments. Though in its early application stages, an additional and promising screening method known as the continuous risk profile has recently been introduced in California.[3] Segment screening methods can vary dramatically depending on the stability of the crash data, but as a general rule the use of both the peak searching method and the sliding window will insure the most reliable results.[4]

Peak Searching Method

To use the peak searching method, divide the roadway segment of interest into equivalent length windows that do not overlap and calculate a performance measure of interest. A small window length of 0.1 miles should first be evaluated, but this length is gradually adjusted to longer values. The coefficient of variation (CV) is evaluated for each segment. The CV helps determine the level of precision for window performance measures. An example application of this method can be observed on page 4-17 of the HSM.

Sliding Window Method

The sliding window approach helps to compensate for errors in crash location reporting by providing assessments of overlapping windows. For this reason, if only one screening method is selected, the sliding window provides this additional benefit that would make it a good choice. For this screening method, the user selects a window length (say 0.5 miles long), evaluates performance measures for the window, and then conceptually "slides" the window some small offset (say 0.1 miles) and repeats the analysis. By evaluating an individual location multiple times (for example the segment between the 0.4 and 0.5 mile location would be evaluated five times), inaccurate crash reporting locations are minimized. An example application of this method can be observed on page 4-16 of the HSM. This technique can be automated using GIS tools or spreadsheet tools.

4.4.2. Future Enhancements to NSM-S

As noted in Section 4.3.3, SPFs are powerful tools that can be used to predict the number of crashes for a particular type of facility. As a result, determining the expected number of crashes or crash types at a site can help agencies better define targeted safety expenditures. A key component for the use of SPFs is the study segment traffic volume. This critical data element may not always be available and so the recommendations for the near term safety network screening for segments do not include SPFs. A future enhancement to the recommended procedure, therefore, would be the following items:

- Develop a traffic volume database for corridor roadway segments,
- Calibrate the HSM SPFs with their companion CMFs for MAG-specific regions or develop new region-specific SPFs (as needed), and
- Systematically acquire information about supporting data elements for use with the various companion CMFs.

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[2] AASHTO. *Highway Safety Manual*, Washington, D.C. 2010.

[3] Chung, K., and D. R. Ragland. "A Method for Generating a Continuous Risk Profile for Highway Collisions," Paper UCB-TSC-TR-2007-6, Institute of Transportation Studies, UC Berkeley Traffic Safety Center, University of California, Berkeley.

[4] Hauer, E., J. Kononov, B. Allery, and M.S. Griffith. "Screening the Road Network for Sites with Promise", *Transportation Research Record 1784, pp. 27-32, 2002.*

Table 2. Priority Data Needs for HSM Segment CMFs

CMF Description	Priority Level for Data Needs at Segment Types														
	2-Lane Undivided Arterial			3-Lane Arterial with a TWLTL			4-Lane Undivided Arterial			4-Lane Divided Arterial			5-Lane Arterial with a TWLTL		
	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable	High	Medium	Negligible or Not Applicable
Urban and Suburban Arterial Segments															
On-Street Parking	✓			✓			✓			✓			✓		
Roadside Fixed Objects		✓			✓			✓			✓			✓	
Median Width			✓			✓			✓			✓			✓
Street Lights			✓			✓			✓			✓			✓
Automated Speed Enforcement			✓			✓			✓			✓			✓
Rural Multilane Highway Segments															
Lane Width	HSM SPF Not Available			HSM SPF Not Available				✓			✓		HSM SPF Not Available		
Right Shoulder Width								✓			✓				
Roadside Side Slope								✓				✓			
Median Width									✓			✓			
Street Lights									✓			✓			
Automated Speed Enforcement									✓			✓			
Rural Two-lane Highway Segments															
Lane Width	✓			HSM SPF Not Available											
Shoulder Width and Type	✓														
Horizontal Curves			✓												
Superelevation		✓													
Grades		✓													
Driveway Density	✓														
Centerline Rumble Strips			✓												
Passing Lanes	✓														
Two-Way Left-Turn Lane			✓												
Roadside Design	✓														
Street Lights		✓													
Automated Speed Enforcement		✓													

As noted in Section 4.3.3, a first step towards developing data for the HSM segment CMFs is to prioritize the influence of the various CMF elements in the overall crash prediction process. Table 2 identifies these CMFs and further determines those that are most influential in the overall safety assessment process (i.e. merit a higher priority in data collection plans) because they are either affiliated with road characteristics that substantially modify the CMF values or result in CMF values that are not close to a value of 1.0.

4.5 Potential MAG Screening for Non-Motorized Users

While the HSM and other literature provides a method and means of performing network screening on intersections and road segments, there is considerably less published information related to network screening of pedestrian and bicycle crashes. Many of the techniques described in the HSM to identify higher risk intersections or segments where measurable safety improvements are most likely to be achieved may be applicable to pedestrian and bicycle crashes.

Pedestrian and cyclist crashes are a point of emphasis with the MAG region. Figure 1 summarizes the pedestrian crash data for the region. The planning region has averaged approximately 1028 pedestrian crashes per year for the five years of data examined (2008 – 2012).

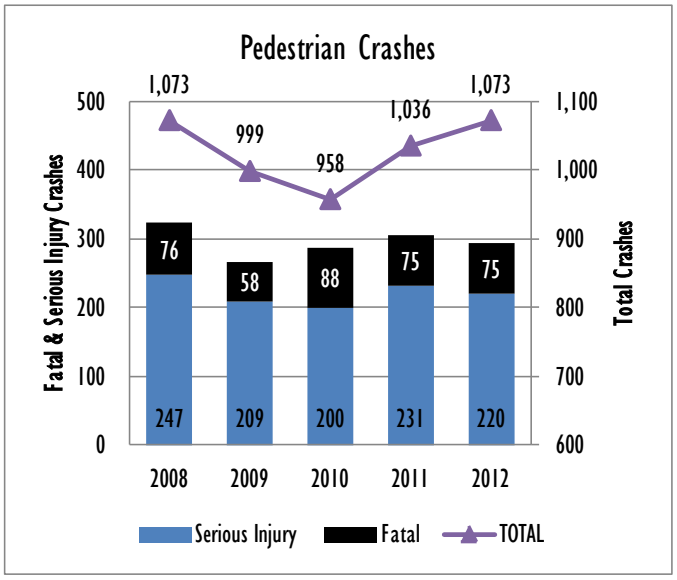

Figure 1. Pedestrian Crashes in the MAG Planning Area

Bicyclist crashes have a similar level of occurrence in the MAG planning region with an average of approximately 1435 cyclist crashes occurring per year as shown in Figure 2. Bicyclist crash data indicates that a lower percentage of crashes involve severe and fatal injuries compared to pedestrian crashes.

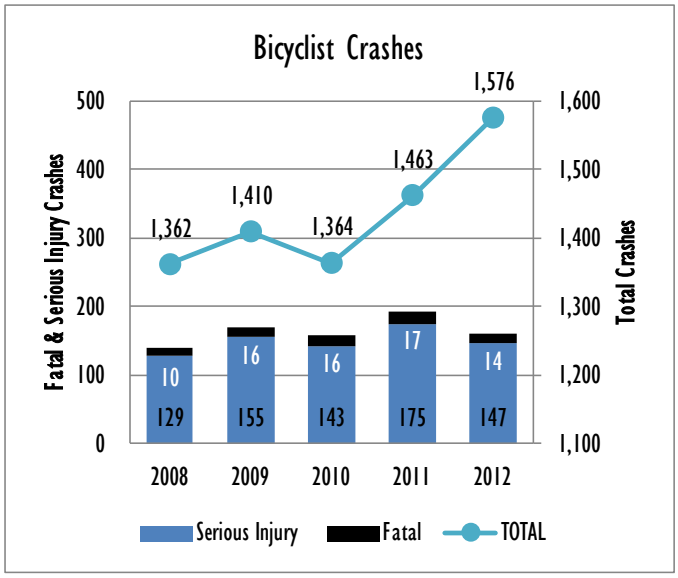

Figure 2. Bicyclist Crashes in the MAG Planning Area

Pedestrian and bicycle crashes are infrequent and less repeatable making it more difficult to identify high crash locations for these vulnerable road users. This section of the memorandum first reviews background information related to bicycle and pedestrian crashs and then demonstrates how some of these concepts may apply to the MAG region.

4.5.1. Background

The Florida Department of Transportation developed a statistical model to identify a threshold number of pedestrian crashes per mile of roadway to allow a segment-based screening of the roadway network on

a systemic basis[5]. This type of methodology would be a segment-based approach similar to the sliding window or peak searching methods described in the HSM except the statistical process allows the identification of a critical crash frequency.

Some researchers have had success using GIS-based clustering analysis to determine common factors in pedestrian crashes. Information contained on the PEDSAFE website (www.pedbikesafe.org) indicates that the mapping of crash locations is an important first step in improving pedestrian safety. Density maps of reported crashes can be a useful tool but care must be taken to recognize that exposure data related to total pedestrian numbers and traffic volumes can affect the reported crash densities. Additionally, the website points out that crash experience may not necessarily match the locations with highest risk. Much of this information is also relevant to the identification of high crash locations for bicycle crashes.

In a study of pedestrian crashes in New York and Toronto, researchers used GIS-based clustering to determine the commonality between fatal and injury crashes. This methodology allowed the researchers to identify policy recommendations in an effort to improve pedestrian safety[6].

In a study from the Las Vegas metropolitan area, Pulugurtha and Nambisan used GIS to assist in the identification of high crash locations[7]. The methodology used to screen the metro area's pedestrian crashes was based on a seven-step methodology that included breaking the study area down into zones. In this case, zip codes were used as analysis zones and the pedestrian crashes from the heavily urbanized areas were address matched and then overlaid onto the analysis zones. Through the use of zip code or census block data, demographic data can be easily included in the analysis to allow a more focused pedestrian study that looks at a subset of the pedestrian crash data (e.g. senior citizens). The pedestrian crashes were then ranked using two crash indices, one based on the number of pedestrian crashes at the location, the population of the analysis zone, and percentage relationships for both. The research also used a second ranking index based strictly on the percentage of crashes within the study area that the specific study location comprised. Ultimately in this instance, the selection of treatment locations were based strictly on their percentage of the total pedestrian data set.

In Ottawa, Canada, the city developed a Pedestrian Safety Evaluation Program for use in improving pedestrian safety by prioritizing pedestrian safety improvements throughout the city[8]. The program included a prioritization / network screening element that used a modified version of the Pedestrian Intersection Safety Indices (Ped ISI) originally developed by FHWA[9]. The Ped ISI tool allows the ranking of intersections based on their traffic control, number of lanes, 85th percentile speeds, average daily traffic, and the predominant land use in the area. The Ped ISI tool is not based on the number of crashes at a location, but is instead focused on the characteristics that contribute to a lower level of pedestrian safety. In performing the network screening for the Pedestrian Safety Evaluation Program in Ottawa, city staff combined the results of the Ped ISI rankings with crash histories and public input to develop their ranked locations for safety improvements. In the Ottawa study, crash data was utilized in a deemphasized fashion due to the relative rarity of pedestrian crashes as compared to vehicle crashes as a whole.

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[5] *Identifying Pedestrian High-Crash Locations as Part of Florida's Highway Safety Improvement Program.* Transportation Research Record 1828. Transportation Research Board, Washington, DC, 2003.

[6] A clustering regression approach: A comprehensive injury severity analysis of pedestrian–vehicle crashes in New York, US and Montreal, Canada. Safety Science, Volume 54, April 2013.

[7] Pulugurtha, S. S., and S. S. Nambisan. *A methodology to identify high pedestrian crash locations: An illustration using the Las Vegas Metro Area. TRB 2003 Annual Meeting CD Rom.*

[8] Tanaka, Krista. *Ottawa Pedestrian Safety Evaluation Tool*. Paper presented at 2012 Conference of the Transportation Association of Canada.

[9] *Pedestrian and Bicyclist Intersection Safety Indices: User Guide.* FHWA Report No. FHWA-HRT-06-130. April 2007

One thing that is evident with respect to pedestrian and bicycle crash screening is the desirability to use a more lengthy number of years of crash data. The FHWA Document "How to Develop a Pedestrian Safety Action Plan" states "*to identify high crash corridors or areas, three year of crash data is ideal, but as little as one year of crash data may be sufficient*."[10] The training materials designed for the FHWA Designing for Pedestrian Safety courses recommend five years of pedestrian crashes to identify high-crash spot locations. The FHWA "How-To" document also indicates that "b*ecause some pedestrian crashes are rarely repeatable, other types of data should be used to identify where pedestrians safety improvements are needed, specifically pedestrian count and behavior studies.*"

The Massachusetts DOT produces a pedestrian and bicycle crash cluster map in their annual crash report. The crash cluster analysis uses data from the most recent nine-year (9) period instead of three years as used in vehicular intersection crash analysis. Additionally, the cluster analysis is composed of a greater clustering distance using a 100 meter search distance instead of a 25 meter search distance as used for vehicular intersection crashes[11].

Metroplan, the central Arkansas MPO published the CARTS Pedestrian/Bicycle Crash Analysis. Due to the relatively low number of crashes, they evaluated crashes for years 2001 through 2010. Crash clusters were independently assessed for pedestrian and bicycle crashes and utilized a 1000 foot search radius around each crash[12]. Sample output from the Metroplan analysis is shown in Figure 3.

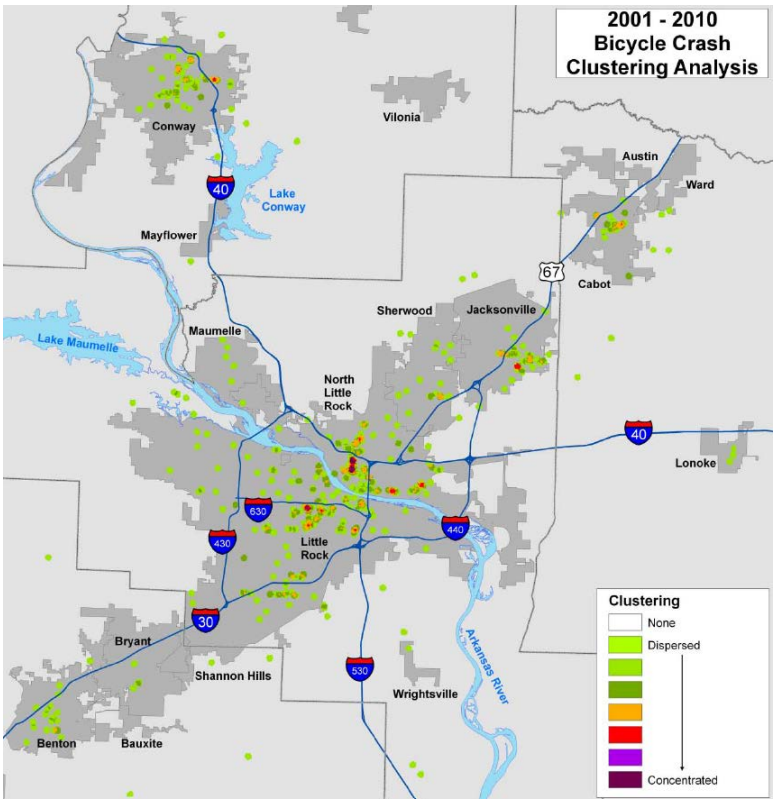

Figure 3. Bicyclist Crash Clustering

Various clustering analysis techniques appear to hold some promise in identifying high crash areas for additional review. The larger cluster radius used in the Arkansas study appears to hold promise at a regional level. This type of clustering analysis would potentially allow for quick identification of sub-areas for more focused study using more rigorous techniques.

As a whole, pedestrian and bicycle crash network screening appears to be a developing element in highway safety. One point that stands out is the need to use longer timeframes for the data sets for identifying high pedestrian or bicyclist crash sites. Because the MAG region has been rapidly growing and changing, nine years of crash data may be excessive. Five years of crash data seems more appropriate for this activity.

[10] How to Develop a Pedestrian Safety Action Plan, FHWA, Office of Highway Safety, Washington, DC, reprinted May 2008
[11] *2010 Top Crash Locations Report*. Massachusetts Department of Transportation. September 2012.
[12] CARTS Pedestrian/Bicycle

4.5.2. Recommendations for MAG Bicycle and Pedestrian Screening

The consideration of land use and socioeconomic information may be incorporated into the network screening process for evaluating bicycle and pedestrian crash distributions. As noted in the background section (see Section 4.5.1), spatial analysis is becoming one of the most common techniques for assessing candidate locations where bicycle or pedestrian crashes may be occurring. The occurrence of a pedestrian and bicycle crash is a rare event when contrasting frequency values to motor vehicle crashes. One option may be to consider the average number of pedestrian and bicycle crashes based on vehicle miles traveled. Figure 4 demonstrates how pedestrian and bicycle crashes that occurred from 2008 to 2010 generally increased by vehicles miles traveled on urban arterial roads in the MAG region. The figure also includes a standard error indication for each exposure threshold. As exposure increases it becomes clear that crash dispersion also increases. Ideally the preferred option would be to develop a SPF from the data shown, but due to the small number of these crash types it is not practical to statistically develop a rigorous SPF for this purpose.

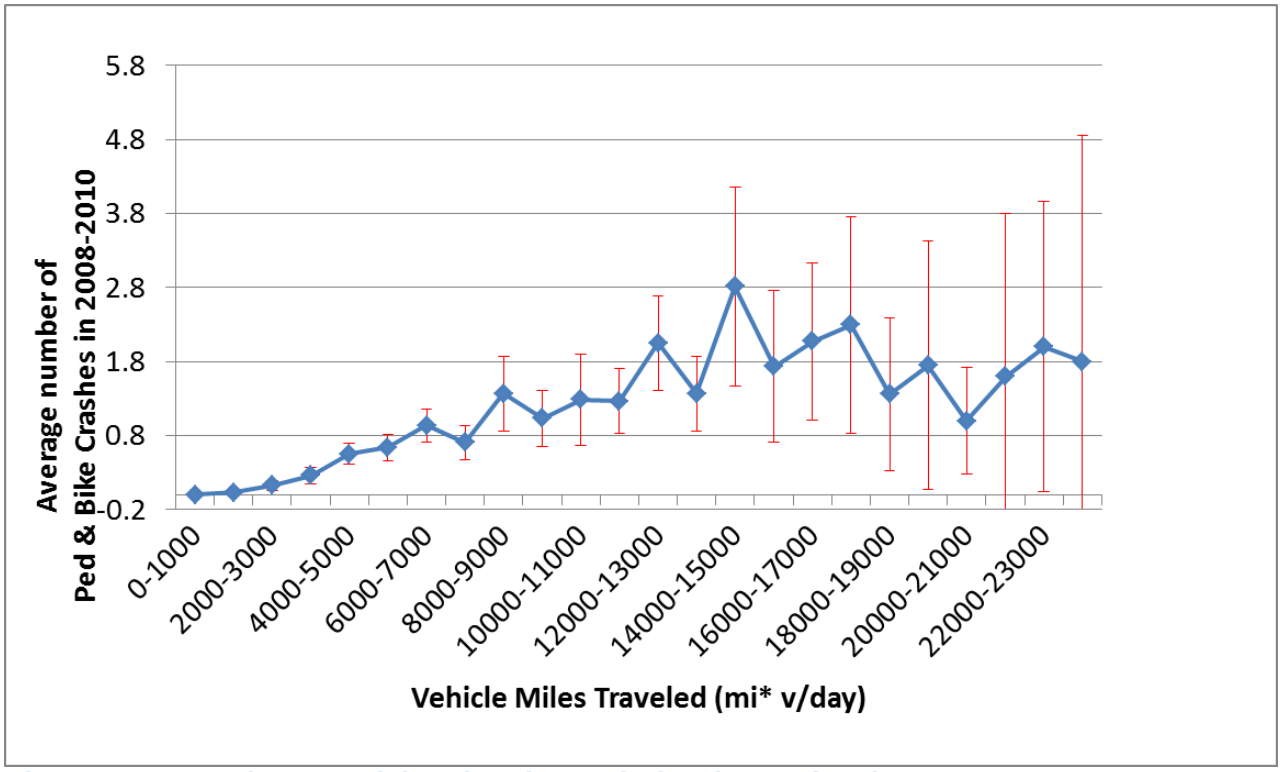

Figure 4. MAG Urban Arterial Pedestrian and Bicycle Crashes by Exposure

It is possible to identify extreme examples of locations that merit a more detailed engineering study for pedestrian and bicycle crashes. For example, Figure 5 shows how a spatial evaluation of MAG data could be used to locate unusually high crash frequency locations; however, this approach does not explicitly consider land use and is likely to have a bias towards high motor vehicle volume locations.

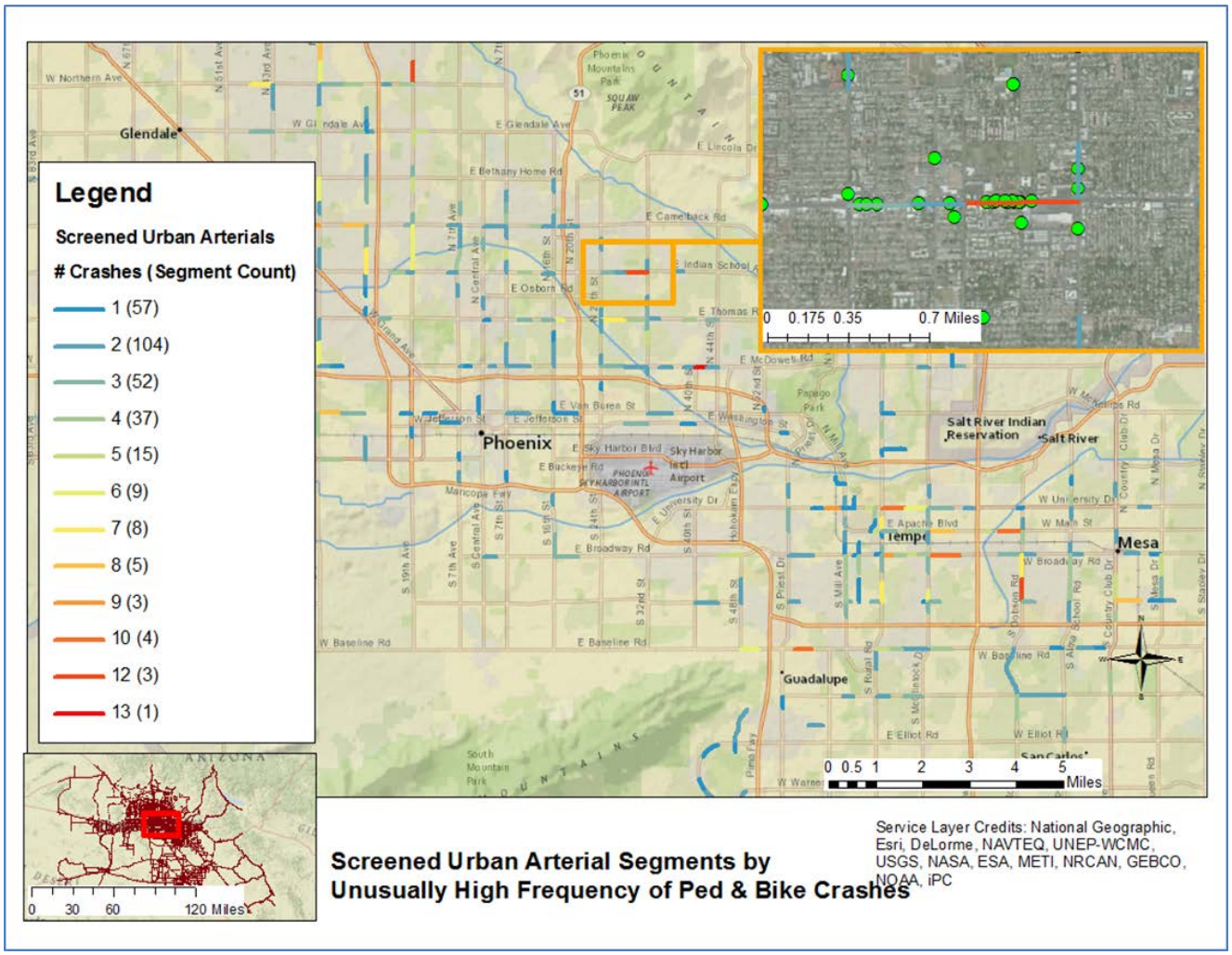

Figure 5. Unusually High Pedestrian and Bicycle Crash Locations

An interesting GIS feature that could be used to further analyze crash conditions for pedestrians and bicycles is the "Optimized Hot Spot Analysis" approach. This method creates a grid and assigns a "score" for each cell based on the number of crashes within the cell in combination with the number of crashes in neighboring cells. The resulting map is a crash density map where the red regions are those with the "higher than average" crashes and blue areas represent "lower than average" crash conditions (see Figure 6).

Alternative spatial screening can evaluate the number of pedestrian and bicycle crashes by population density (see Figure 7) and by age (see Figure 8). Screening by land use, however, simply reflected increased pedestrian and bicycle crashes in regions of high traffic volume and so is not recommended for diagnostic purposes, but could be useful for public outreach efforts.

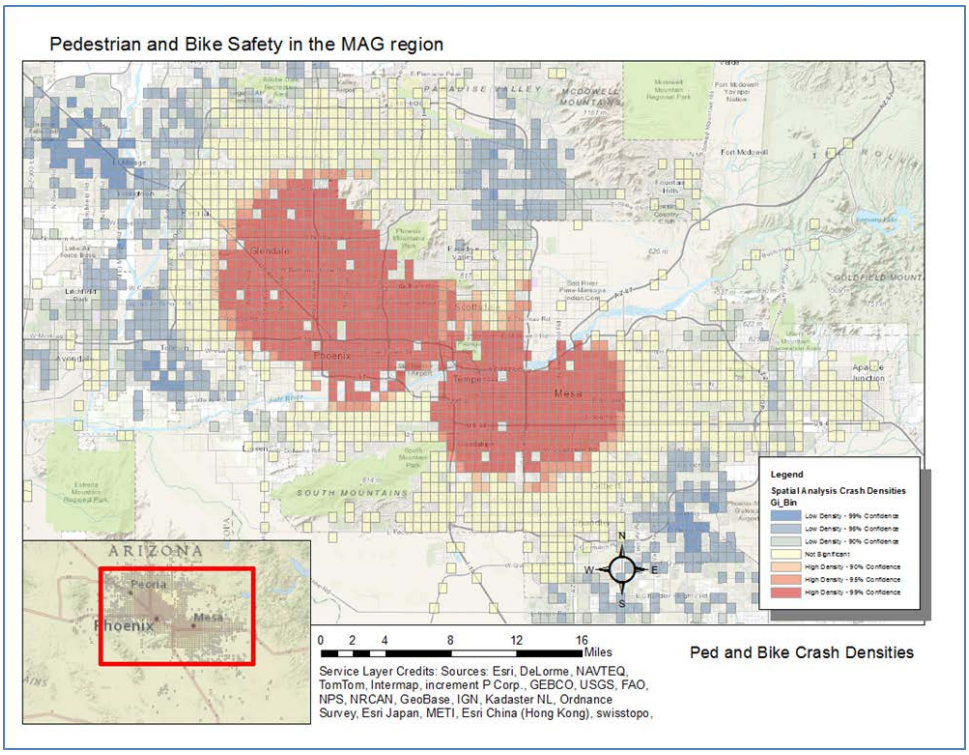

Figure 6. Pedestrian and Bicycle Crash Densities

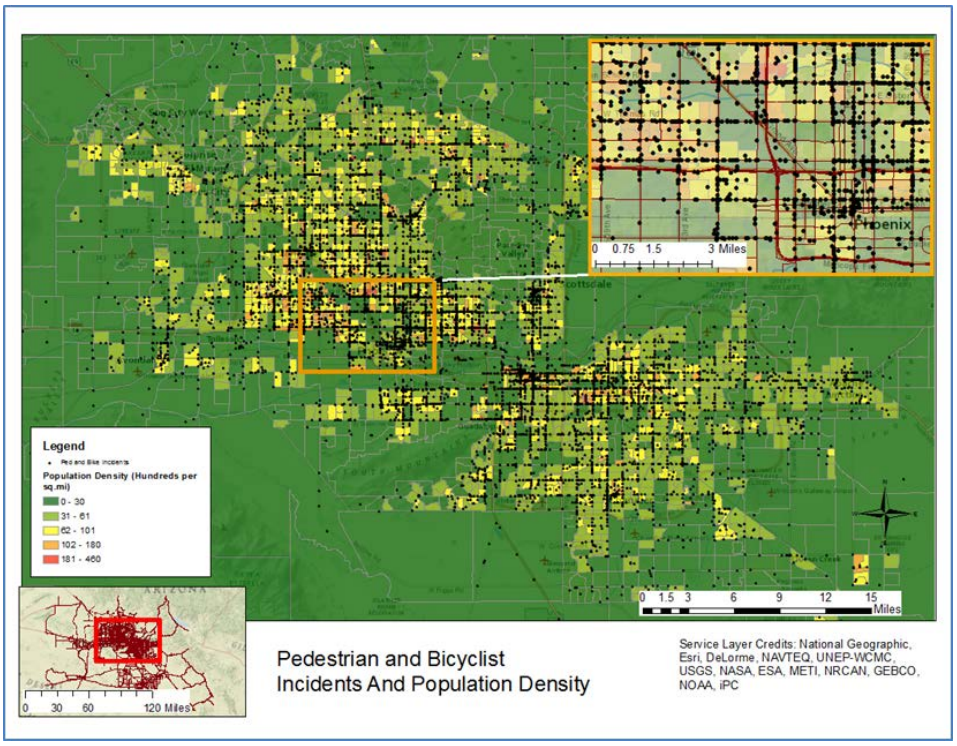

Figure 7. Pedestrian and Bicycle Crashes by Population Density

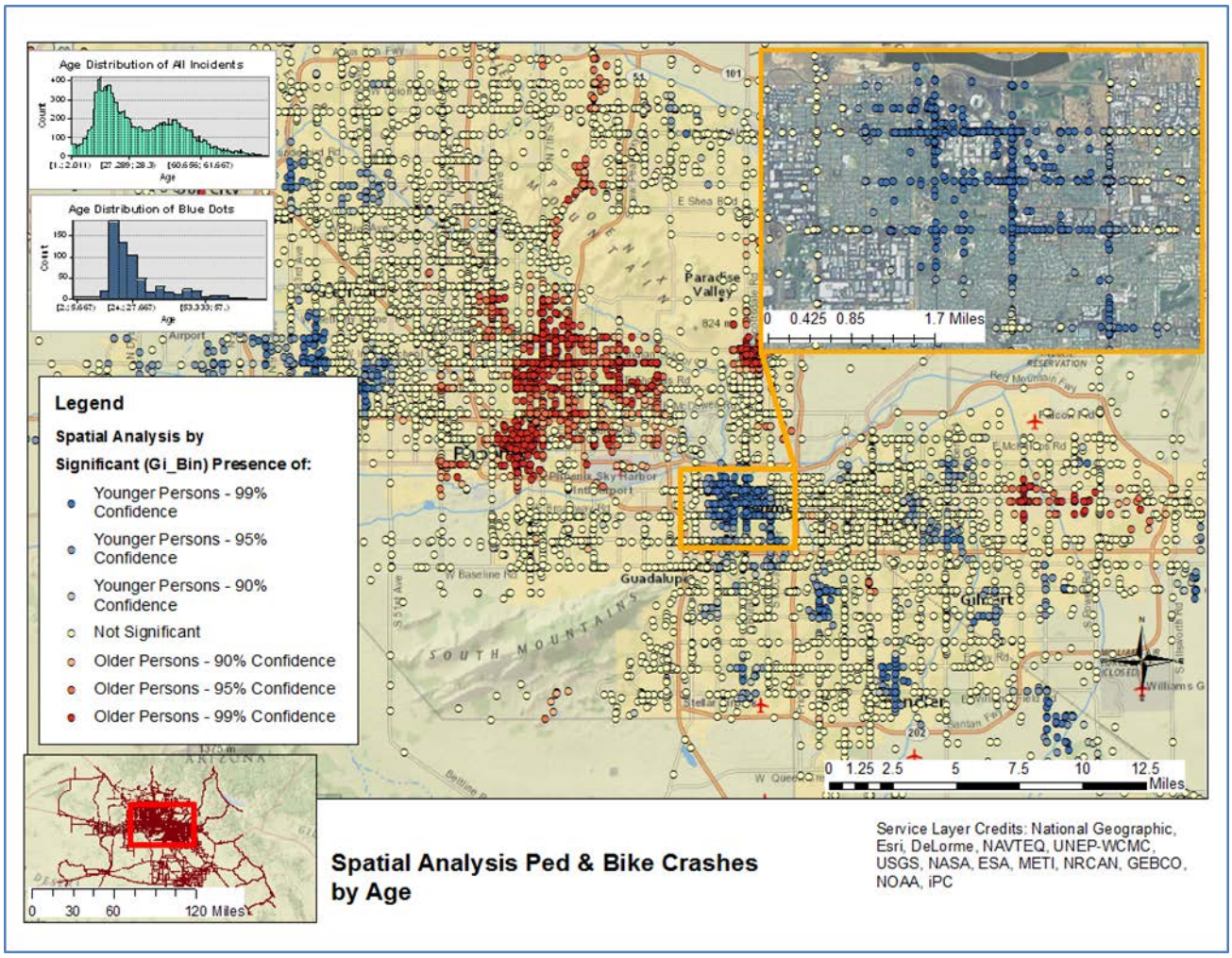

Figure 8. Pedestrian and Bicycle Crashes by Age

An additional diagnostic technique may be to contrast pedestrian and bicycle crashes against specific topographic features in the region. As an example, Figure 9 shows a map of waterways located in the Phoenix area (many of which are canals with mid-block street crossings). The pedestrian and bicycle crashes are shown as they relate to these locations. This type of analysis can be used to help pinpoint targeted improvement projects such as grade separated canal crossings.

As shown, there are a wide variety of ways to evaluate pedestrian and bicycle crashes using spatial analysis tools. The use of density maps shows promise as an initial screening tool. Once dense crash locations are known, contrasting the crashes to exposure, population density, age, and unique features can collectively help identify key locations that merit safety enhancement efforts.

A future enhancement to pedestrian and bicycle screening may be to adopt an indices technique similar to the Ottawa, Canada example (see Section 4.5.1). Because this indices approach requires significant infrastructure data (traffic control information, speeds, volumes, etc.), it may not be practical to implement at this time; however, a framework could be established so that MAG can begin to acquire this data for future implementation efforts.

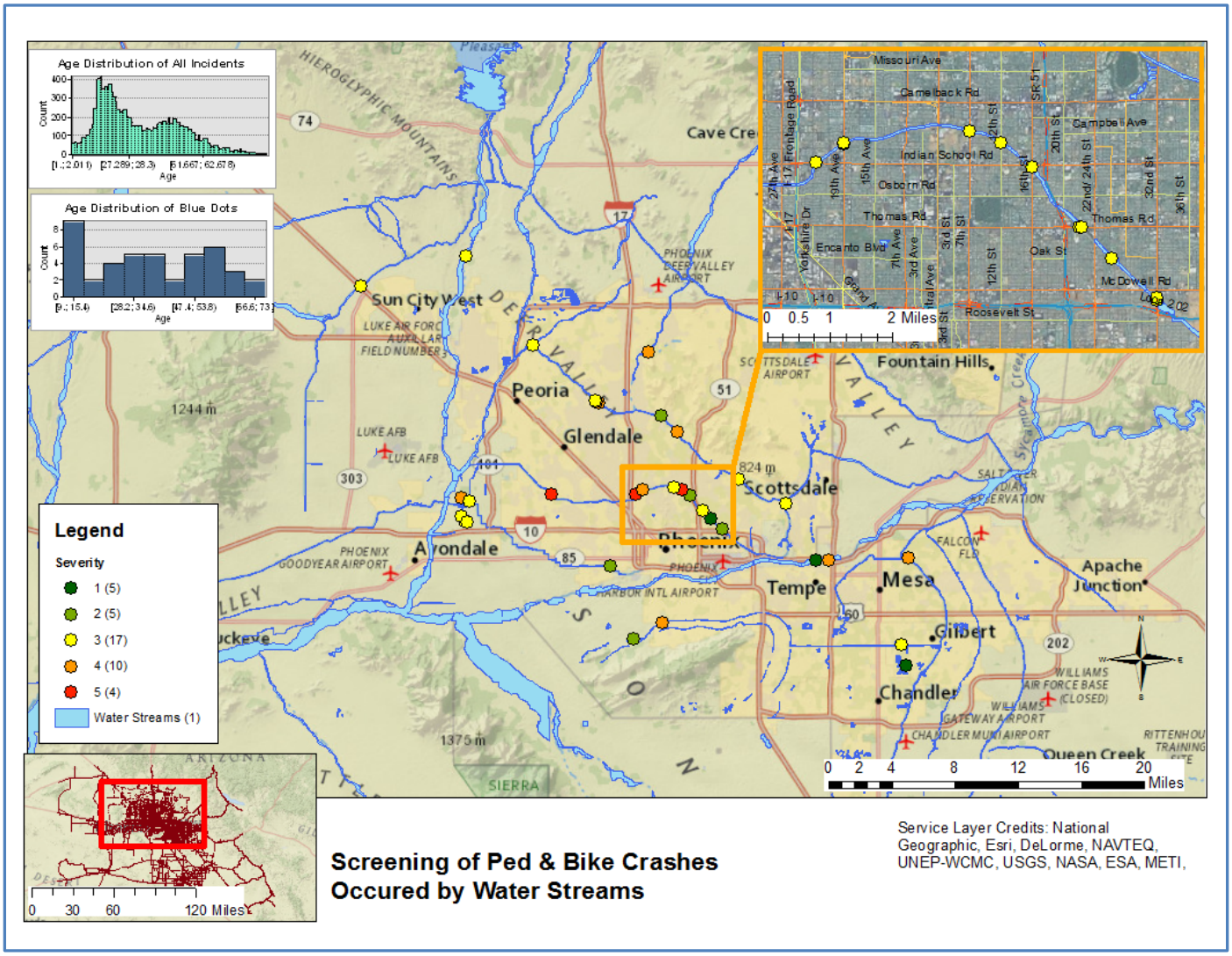

Figure 9. Pedestrian and Bicycle Crashes Contrasted to Waterways

4.6 Appendix I

Acronyms and Definitions

A	Incapacitating Injury (Serious Injury) Crash
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ALISS	Arizona DOT Accident Location Identification Surveillance System
CF	Crash Frequency
CMF	Crash Modification Factor
CV	Coefficient of Variation
CS	Crash Severity
CT	Crash Type
CR	Crash Rate
DOT	Department of Transportation
EB	Empirical Bayes
EMS	Emergency Medical Services
FARS	(USDOT) Fatal Analysis Reporting System
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
HPMS	(FHWA) Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
HSM	(AASHTO) Highway Safety Manual
ISS	Intersection Safety Score
K	Fatal Crash
KABCO	Crash severity scale where “K” represents fatal crash, “A” represents serious injury crash, “B” & “C” represent descending levels of crash severity, and “O” represents property damage only
MAG	Maricopa Association of Governments
MAP-21	Moving Ahead for Progress in the 21st Century
MEV	Million Entering Vehicles (Intersection Crash Rate)
MPO	Metropolitan Planning Organization. MPOs are designated by the governor to coordinate transportation planning in an urbanized area of the state. MAG is an MPO
MVMT	Million Vehicle Miles Traveled (Roadway Segment Crash Rate)
NCHRP	National Cooperative Highway Research Program
NSM-I	(MAG) Network Screening Methodology for Intersections
NSM-S	(MAG) Proposed Network Screening for Segments
PAR	Police Accident Report
PDO	Property Damage Only
Ped ISI	Pedestrian Intersection Safety Indices
SHSP	(ADOT) Strategic Highway Safety Plan
SPF	Safety Performance Function
SSS	Segment Safety Score
STSP	(MAG) Strategic Transportation Safety Plan
VMT	Vehicle miles traveled