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STATE HIGHWAY ADMINISTRATION

PROJECT REPORT

STATEWIDE GIS MAPPING OF RECURRING CONGESTION CORRIDORS

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INFRASTRUCTURE STUDIES
MORGAN STATE UNIVERSITY

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FINAL REPORT

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EXECUTIVE SUMMARY

Recurring congestion occurs when travel demand reaches or exceeds the available roadway capacity. This project developed an interactive geographic information system (GIS) map of the recurring congestion corridors (labeled herein as hotspots) in the state of Maryland.

The GIS map was created with the ArcGIS platform and plotted the hotspots from a list of Maryland State Highway Administration (SHA) priority congestion locations, which included 95 intersections/ramp junctions and 31 highway segments. The interactive map allows users to obtain images, turning-movement counts, travel times, and roadway schematics for individual hotspots. The map was also converted to a keyhole mark-up list (KML) file so that it can be used in Google Earth's 3-D environment, which traffic managers can view through any computer with Internet access.

It is hoped that this study will lead to a statewide mapping of hotspots and help the SHA allocate the necessary resources for the mitigation and management of recurring congestion.

INTRODUCTION

Traffic congestion can be categorized as recurring or nonrecurring. Recurring congestion is caused by inadequate road capacity with respect to demand. Nonrecurring congestion can be triggered by an accident, construction projects, a disabled vehicle, or natural phenomena. However, the two are not mutually exclusive: Recurring congestion creates stress for the motorist and increases the likelihood of a vehicle or driver-related incident. Delays caused by traffic congestion are also associated with a loss of productivity and wages, air and noise pollution, and increased travel time.

A recent study showed how incidents can adversely affect freeways approaching the recurring congestion threshold (Saka, 2008). The study demonstrated that post-incident traffic recovery time increases exponentially as traffic intensity reaches its maximum, further establishing the need for swift incident response along corridors that experience traffic congestion and air pollution. This is especially necessary in the Baltimore-Washington area, which has been classified as a severe nonattainment area under the Clean Air Act (CAA) of 1990 (FHWA, 1992). Incident managers could respond more quickly if they could easily document the locations of recurring congestion on the statewide road network.

Objectives

This project will identify and map the priority congestion locations, or hotspots, that are under the jurisdiction of the SHA. (Roadways not maintained by the SHA, including the road network in Baltimore City, are excluded.)

A picture is worth a thousand words, and there is no better tool than GIS to capture, depict, query, and archive spatial phenomena and traffic congestion on highways and intersections. The interactive GIS map developed for this project will validate the plausibility of a statewide map of congestion corridors that is hyperlinked to respective images and traffic data. The images and data can assist SHA personnel with the prompt implementation of temporary congestion-relief initiatives while long-term mitigation measures are sought.

LITERATURE REVIEW

A review of existing literature on congestion mapping revealed two distinct approaches: static and dynamic.

Static mapping involves the use of historic empirical data or simulated data from a transportation model to determine the levels of service (LOS) on individual roadway segments. A roadway's LOS is evaluated on an A-F scale, with A being a free-flow situation and F representing jam-flow. Color-coded thematic maps that represent the congestion during peak periods are developed based on those six LOS categories (New Hampshire DOT, 2008). Thus, red might be used to represent LOS F and green to represent LOS A.

Dynamic mapping used on a widespread basis involves real-time and simulation applications. Real-time dynamic mapping uses sensors and/or cameras to capture the prevailing traffic-flow situation, and the information is relayed to a remote traffic management center for display on control-room monitors and a web-based roadway network. The congestion may be displayed as color-coded data, live traffic images, or a combination of both (Google, 2008; MN/DOT, 2000-2009; Seattle DOT, 1995-2005; IL DOT, 2009). An increasing number of congestion maps include camera icons that display the real-time traffic situation on individual roadway segments (Seattle DOT, 1995-2005).

In the absence of real-time information, data generated from multi-period microscopic simulation models, which are based on historical statistics, are occasionally used to depict congestion in animated or color-coded forms (Lee et. al., 2008).

These methods for depicting congestion serve as a guide in trip planning but provide very limited information for the development of mitigation measures. This project will employ a variation of static mapping that focuses on intersections, ramp junctions, and roadway segments with a history of recurring congestion. Ultimately, the map and the supporting traffic and spatial data will be used to perform follow-up studies that determine the factors contributing to congestion and possible mitigation factors on a case-by-case basis.

METHODOLOGY

Data Collection

The SHA's district offices provided the list of the 95 intersections/ramp junctions and 31 highway segments that were used in this project. The sites were selected from a list of hotspots that was compiled by each district office. A list of all the hotspots used in this study can be seen in Appendix 1.

There are seven SHA districts in the state of Maryland, and Figure 1 details the population distribution in each.

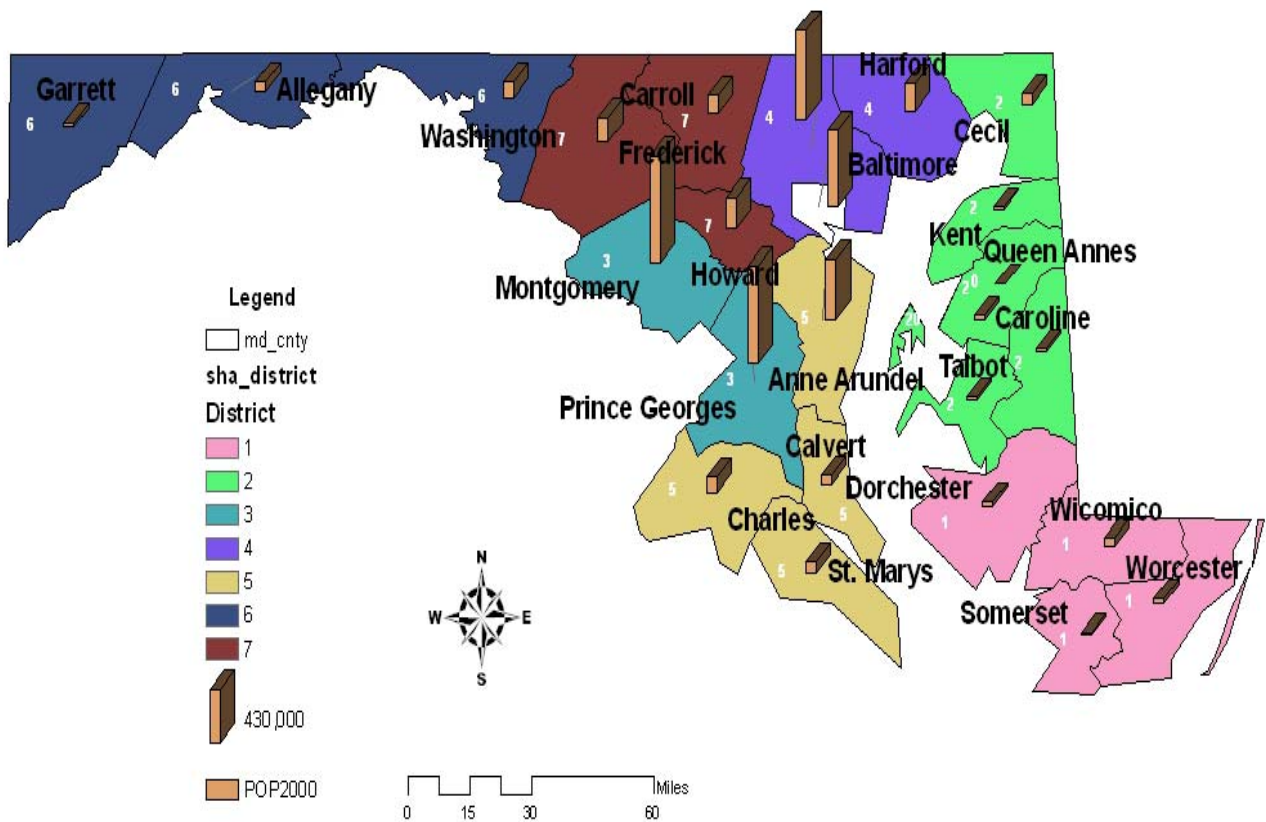


Figure 1: Thematic Map of the Seven SHA Districts and Population Bar Graphs

Figure 2 adds the hotspots to the population map. As expected, the congestion is concentrated in the most populated areas. Districts 3, 4, and 7 are predominately urban and experience heavy commuting traffic to and from Washington, D.C.

Traffic and spatial data were collected at various hotspots during the morning and evening peak periods. The traffic data included turning movements and travel times. The spatial data included photographs of the traffic congestion and roadways.

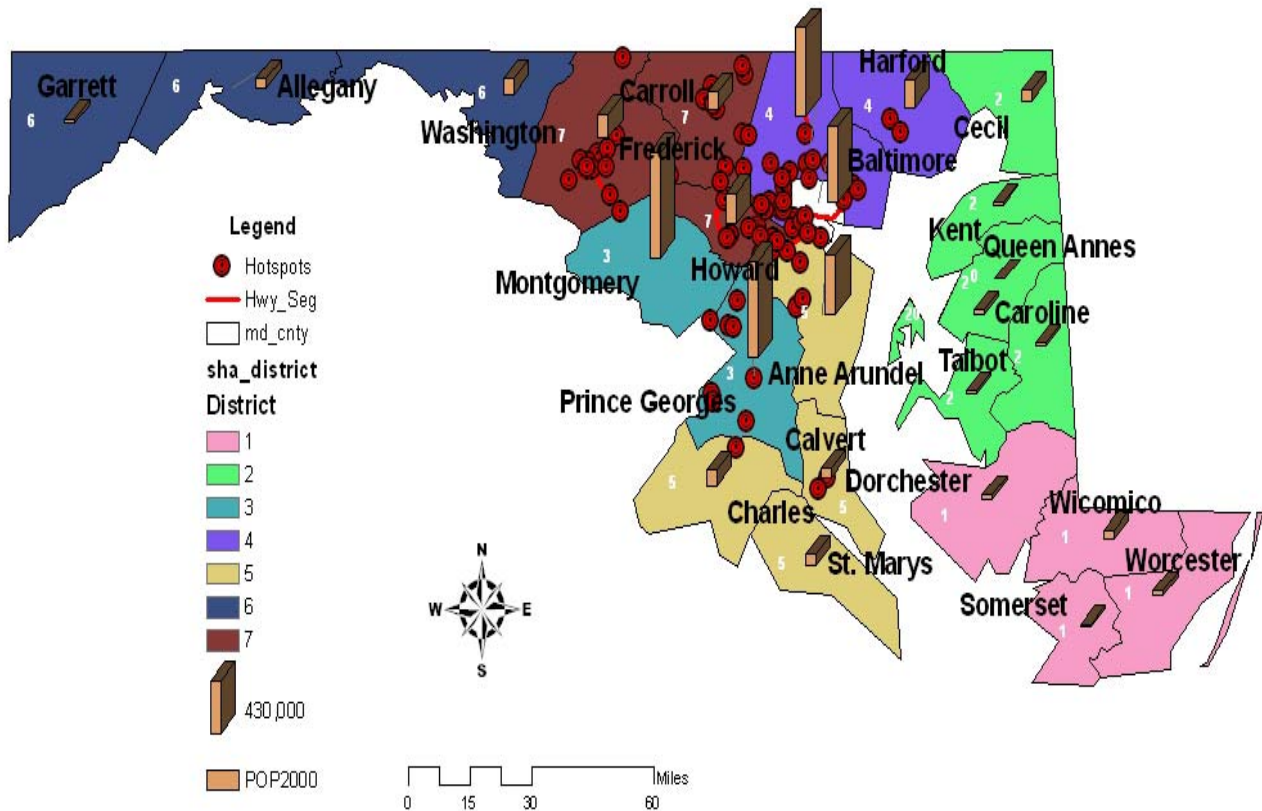


Figure 2: Overlay of Hotspots and Population

Data Analysis

The information supplied by the SHA was checked for accuracy (i.e., typographical errors and incorrect street names) and compatibility with the geodatabase format used to map the hotspots. We then analyzed the traffic data to find peak volumes, peak hour factors, and average speed, information which can support the development of temporary mitigation measures for congestion.

Mapping of Congested Locations

Mapping the hotspots was a three-step process. The congested locations were first geocoded using the statewide geodatabase of streets, and then digitized. The hotspots can be seen in Figure 3. The hotspots at intersections and ramp junctions are depicted as red concentric icons (Layer 1), and hotspots along highway segments are shown as thick red lines (Layer 2).

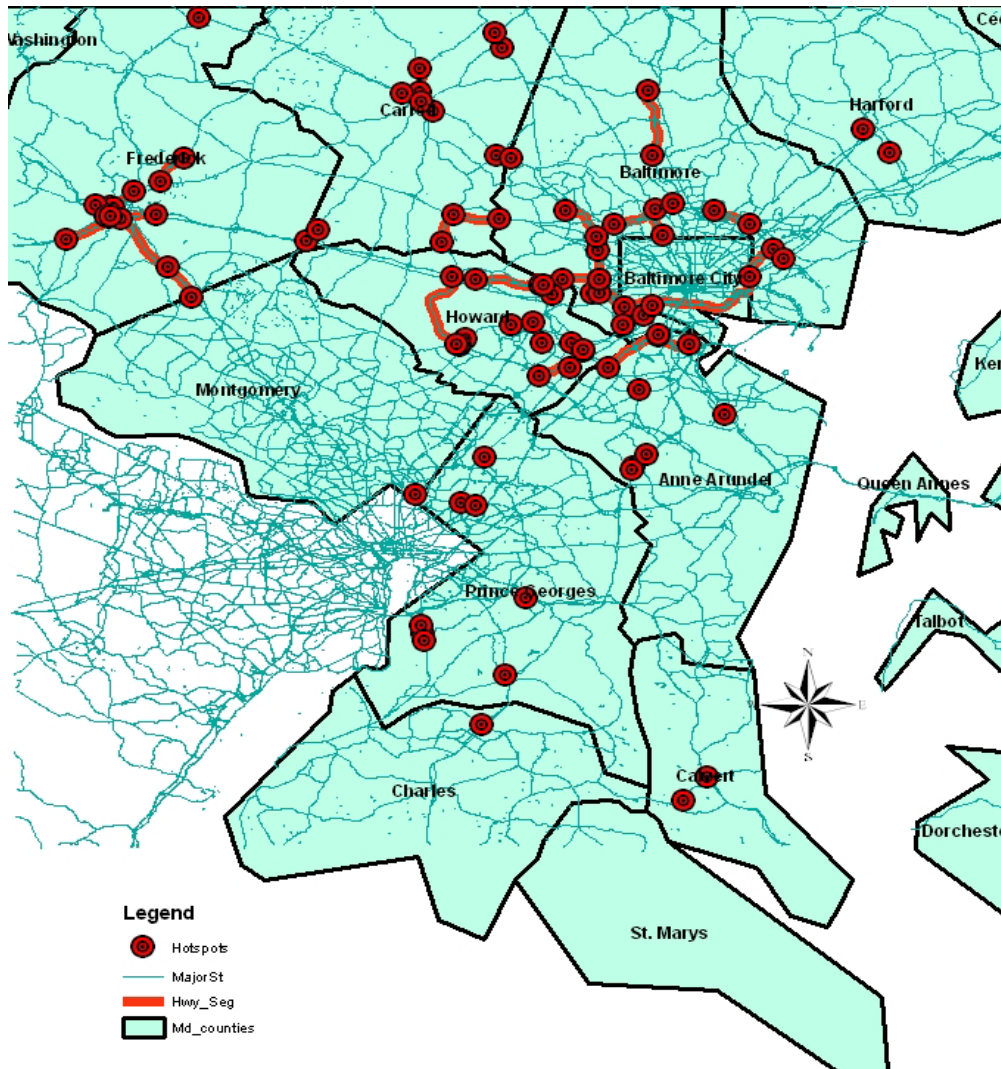


Figure 3: Map of Intersection and Highway Hotspots

As mentioned earlier, we took photographs of the peak-hour congestion at each hotspot, resulting in scores of images. We also collected traffic data for sample locations to help determine the prevailing levels of service. Each digitized hotspot was then hyperlinked to its traffic images and data. Figures 4a and 4b are examples of the hyperlinked congestion photos. Supplementary hyperlinked traffic images and data for the hotspot at MD 210 and Kerby Hill Road can be found in Appendix 2.



Figure 4a: Photo of the Hotspot at MD 210 and Kerby Hill Road



Figure 4b: Photo of the Hotspot on I-70 W before I-270

Finally, the two layers of hotspots were converted to KML files for display in Google Earth, the free, Internet-based map program. This file conversion eliminates the need for GIS software to view a GIS-layer file and makes it possible to leverage Google Earth's various features to display the recurring congestion locations. Figure 5 depicts the resulting map.

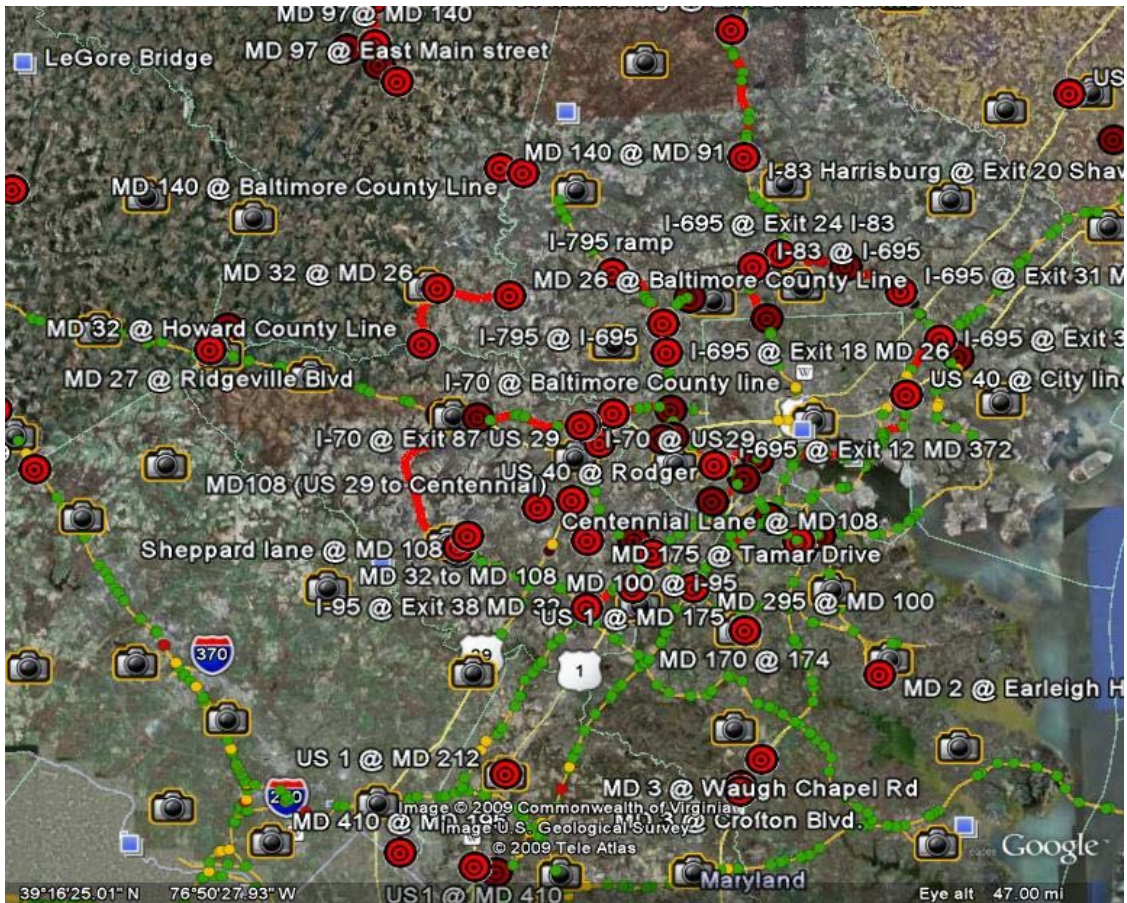


Figure 5: Google Earth Image of Hotspots in Central Maryland

Each camera icon symbolizes a 360-degree, street-level image of the camera location. These pictures can provide valuable spatial information to the traffic planners studying the contributing factors of congestion. Figure 6 provides an aerial view of the hotspot at US 40 and Rolling Road, and Figure 7 is a street-level image of the same location.

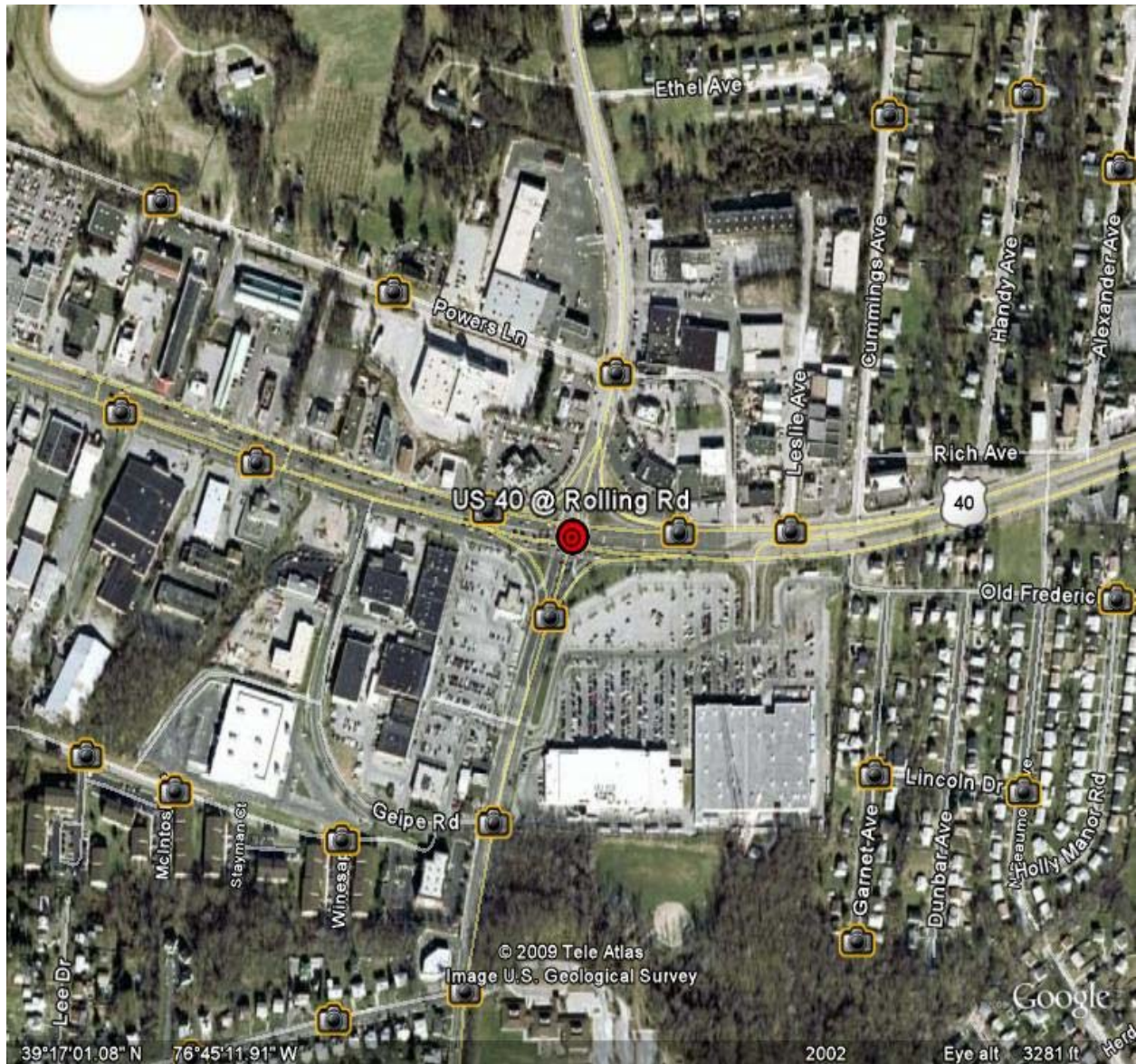
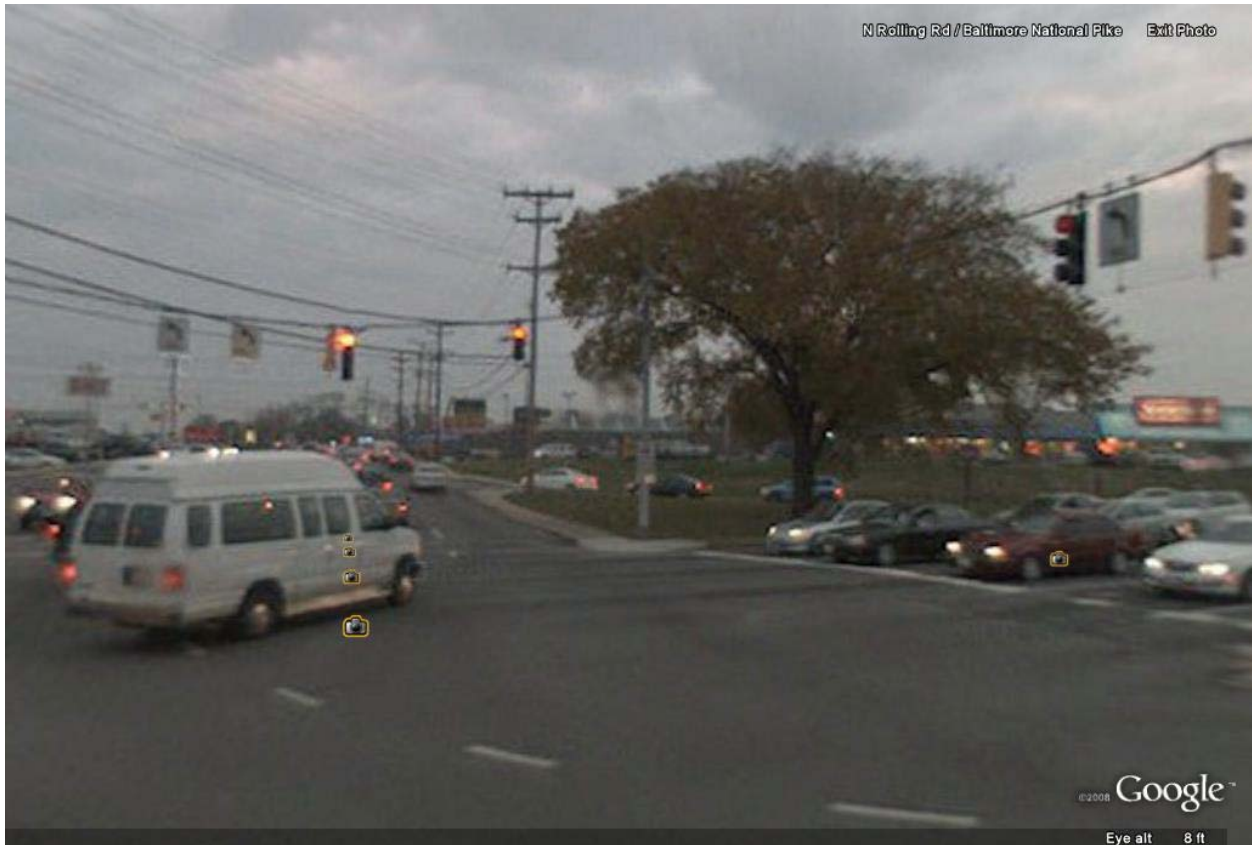


Figure 6: Google Earth Aerial View of the Hotspot at US 40 and Rolling Road



Source: Google Earth™

Figure 7: Google Earth Street-Level Image of the Hotspot at US 40 and Rolling Road

From Figure 7, for example, a traffic planner could deduce that the congestion is caused by the many commercial centers lining the two roads. Possible mitigation measures include proper access planning for the commercial buildings, and optimization of the traffic signal timing.

Management of Hotspots Database

The hotspots database and the maps presented here are not exhaustive, but intended for demonstrating the plausibility of a comprehensive statewide study. For that to happen, the database must be upgraded regularly to incorporate new information. A step-by-step description of how to access, edit, and archive the GIS-based hotspots and maps can be found in Appendix 3.

RESEARCH FINDINGS

Mitigation of recurring congestion is a priority issue receiving widespread attention in metropolitan areas experiencing heavy commuter traffic. Web-based congestion mapping is extensively and effectively used by trip makers to decide when and where to travel. The majority of the web-based congestion maps are for urban freeway corridors with heavy commuter traffic. However, these maps play an advisory role and are not mitigation measures.

Recurring congestion on freeways is usually a manifestation of capacity deficiency that requires long-term capital projects, which can include capacity expansion or the building of new roads. Conversely, recurring congestion on non-freeways, such as arterial and collector roads, can be caused by poor sight distance, the plan/design of access points, traffic signing, and signal timing.

CONCLUSIONS

This project effectively demonstrated that GIS can be used as a decision-support system for the identification and development of strategies for congestion management.

Standard traffic engineering practice requires site reconnaissance, data collection, and analysis before the recommendation of viable mitigation measures for congestion. The interactive GIS map developed in this study allows traffic managers to view images and data for an individual hotspot from any computer through Google Earth. As a result, traffic managers have the spatial information they need for preliminary assessments, can allocate resources for swift response to congestion-related events, and prioritize mitigation programs at these locations.

Recommendations

Based on the outcome of this pilot study, we believe that the SHA should do a comprehensive mapping of hotspots.

APPENDIX 1
LIST OF RECURRING CONGESTION LOCATIONS

Recurring Congestion List

District 7: Counties: Carroll, Frederick, and Howard

Howard County

1. I-70 EB from US 40/I-70 split to US 29 (a.m. delay)
2. I-70 WB at US 29 (p.m. delay)
3. MD 32 SB from I-70 to MD 108 (a.m. delay)
4. MD 32 NB from MD 108 to I-70 (p.m. delay)
5. MD 108 from US 29 to Centennial Lane (p.m. delay)
6. MD 108 from Guilford Road to Sheppard Lane (a.m. and p.m. delay)
7. MD 100 EB from MD 103 to I-95 (a.m. delay)
8. US 1 at MD 175 (a.m. and p.m. delay)

Frederick County

1. I-270 SB from I-70 to MD 109 (a.m. delay)
2. I-270 NB from MD 109 to I-70 (p.m. delay)
3. US 15 SB from MD 26 to US 340 (a.m. delay)
4. US 15 NB from US 340 to MD 26 (p.m. delay)
5. MD 26 WB at US 15 (a.m. delay)
6. US 40 from US 15 to Waverly Drive (p.m. delay)
7. MD 180/MD 351 at US 340 (a.m. and p.m. delay)
8. MD 194 from MD 26 to Daysville Road (p.m. delay)
9. MD 140 at US 15 Business/S. Seton Ave. (a.m. and p.m. delay)

Carroll County

1. MD 140 EB from MD 91 to Baltimore County Line (a.m. delay)
2. MD 140 WB from Baltimore County Line to MD 91 (p.m. delay)
3. MD 97 SB from MD 496 to MD 140 (a.m. delay)
4. MD 97 NB from MD 140 to MD 496 (p.m. delay)
5. MD 97 ND from East Main St. to MD 27 (p.m. delay)
6. MD 30 from MD 86 to Beaver St.– Manchester – (a.m. and p.m. delay)
7. MD 32 SB from MD 26 to Howard County line (a.m. delay)
8. MD 32 NB from Howard County line to MD 26 (p.m. delay)
9. MD 26 EB from MD 32 to Baltimore County line (a.m. delay)
10. MD 26 WB from Baltimore County line to MD 32 (p.m. delay)
11. MD 27 from Ridgeville Blvd. to Watersville Road (p.m. delay)

From TOC 4 - Baltimore County

I. MORNING RUSH HOUR

O/L I-695 from Exit 31 MD 147 to Exit 28 Providence Road [6:30 a.m. to 9:00 a.m.]

O/L I-695 from Exit 18 MD 26 to Exit 12 MD 372 [6:00 a.m. to 9:00 a.m.].

I/L I-695 from Exit 21 MD 129 to Exit 24 I-83 North [7:00 a.m. to 9:00 a.m.]

EB I-70 ramp to O/L I-695 [6:30 a.m. to 9:00 a.m.]

SB I-795 ramp to O/L I-695 [6:30 a.m. to 9:00 a.m.]

SB I-83 JFX from I-695 to Baltimore City Line [7:00 a.m. to 9:00 a.m.]

SB I-95 from Exit 43 MD 100 to Exit 38 MD 32 [7:00 a.m. to 9:00 a.m.]

NB I-97 ramp to I/L I-695 [7:00 a.m. to 9:00 a.m.]

I/L I-695 from Exit 3 MD 2 to Exit 7 MD 295 [7:00 a.m. to 9:00 a.m.]

SB MD 295 from I-695 to MD 100 [7:00 a.m. to 9:00 a.m.]

II. AFTERNOON RUSH HOUR

I/L I-695 (stop and go) from Exit 12 MD 372 to Exit 33 I-95 [4:00 p.m. to 7:00 p.m.]

O/L I-695 from Exit 16 I-70 to Exit 12 MD 372 [4:30 p.m. to 7:00 p.m.]

O/L I-695 from Exit 31 MD 147 to Exit 28 Providence Road [4:30 p.m. to 7:00 p.m.]

WB I-70 from Exit 91 I-695 to Exit 87 US 29 [4:30 p.m. to 7:00 p.m.]

EB US 40 Pulaski Hwy from City Line to Rossville Blvd. [4:30 p.m. to 7:00 p.m.]

NB I-95 from Exit 47 I-195 to Exit 49 I-695 [4:30 p.m. to 7:00 p.m.]

SB I-95 from Exit 50 Caton Ave. to Exit 49 I-695 [4:30 p.m. to 7:00 p.m.]

NB I-83 JFX from Baltimore City Line to I-695 [4:30 p.m. to 7:00 p.m.]

NB I-83 Harrisburg from Exit 20 Shawan Road to Exit 27 Mt. Carmel Road [4:30 p.m. to 7:00 p.m.]

Note: All times listed are approximate. The times listed can be affected by: weather, traffic accidents, police activity, special events (sport events), debris on the roadway, disabled vehicles on the roadway, vehicle fires, etc.

From TOC 7 - Frederick and Montgomery County

I. MORNING RUSH HOUR

US 15 South at I-70

I-270 South at MD 80

I-70 East prior to I-270 (some mornings)

II. EVENING RUSH HOUR

I-270 North coming into Frederick County from Montgomery

US 15 North just north of I-70

I-70 West past Exit 56 heading into Frederick (contributed to current roadwork on I-70 right now)

I-70 East between US 40 and US 29

I-70 East between US 29 and Baltimore County line

From Woody Hood: Office of Traffic & Safety (OOTS)

District # 2

US 40 @ MD 213

District #3

MD 4 @ Dowerhouse Road

MD 5 @ MD 381

US 1 @ MD 212

MD 210 @ Kerby Hill Road

MD 210 @ Palmer Road

MD 210 @ Old Forth Road – North

MD 201 @ MD 410

US 1 @ MD 410

District #4

US 1 Bus. @ MD 24

US 40 @ Winter's Lane

US 40 @ Rolling Road

US 40 @ Rossville Blvd.

MD 24 @ Belair South Pkwy.

MD 22 @ Thomas Run Road

District #5

MD 2 @ Earleigh Heights Road

US 301 @ MD 228/MD 5 Bus.

MD 2/4 @ MD 231

MD 2/4 @ MD 402

MD 3 @ MD 424

MD 3 @ Waugh Chapel Road

MD 3 @ Crofton Blvd.

District #7

US 40 @ Baughman's Lane

MD 175 @ Tamar Drive

US 1 @ MD 175

MD 97 @ Airpark Road

MD 108 @ MD 32/Ten Oaks Road

From Benjamin Myrick: Office of Traffic & Safety (OOTS)

MD 170 @ 174 D-5

MD 140 @ Royer D-7

MD 410 @ MD 195 D-3

US 40 @ Rodger D-7

List of Counties

County NAME	County #	SHA District #
Dorchester	9	1
Somerset	19	1
Wicomico	22	1
Worcester	23	1
Caroline	5	2
Cecil	7	2
Kent	14	2
Queen Anne	17	2
Talbot	20	2
Montgomery	15	3
Prince George's	16	3
Baltimore	3	4
Hartford	12	4
Anne Arundel	2	5
Calvert	4	5
Charles	8	5
St. Mary's	18	5
Allegany	1	6
Garrett	11	6
Washington	21	6
Carroll	6	7
Frederick	10	7
Howard	13	7

APPENDIX 2

**HYPERLINKED CONGESTION IMAGES AND TRAFFIC DATA FOR
MD 210 & KERBY HILL ROAD**



MD 210 & Kerby Hill Road



Livingston Road (Westbound Traffic)



MD 210/Indian Highway (Southbound Traffic)



Kerby Hill Road (Eastbound Traffic)



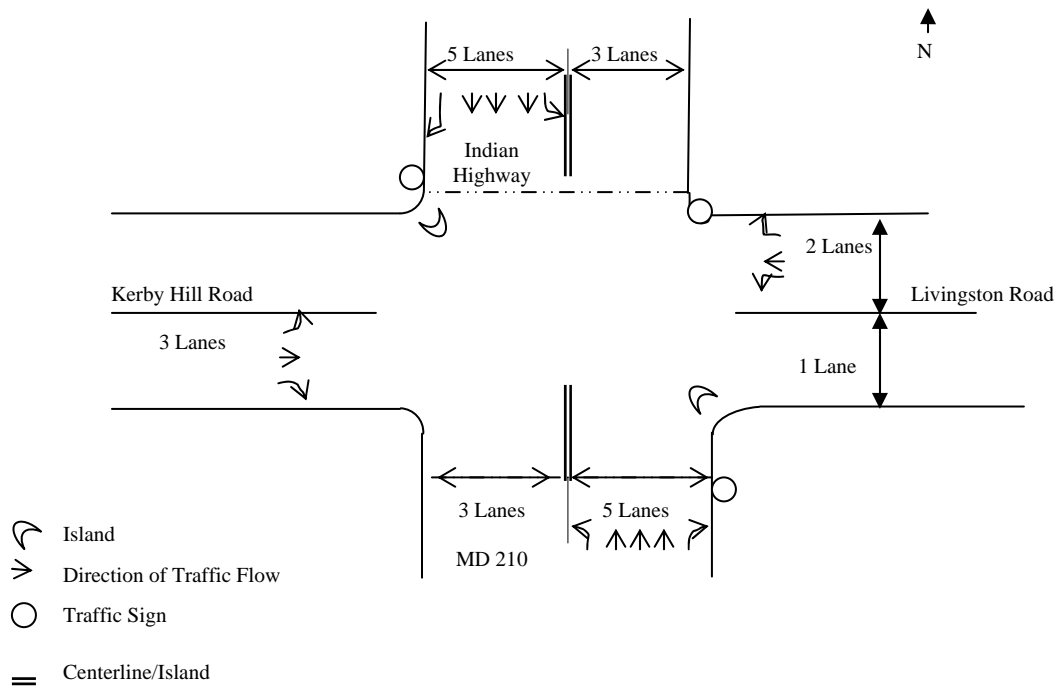
Kerby Hill Road (Eastbound Traffic) and MD 210 (Southbound Traffic)



MD 210/Indian Highway (Southbound Traffic)



Kerby Hill Road Traffic (North- and Southbound Traffic)



Typical Section of Indian Highway/MD 210 Intersection

Time (a.m.)	SBT	SBL	SBR	NBT	NBL	NBR	EBT	EBL	EBR	WBT	WBL	WBR	Intersection Subtotal
7:00-7:15	285	14	3	392	11	22	13	33	9	16	12	4	814
7:15-7:30	301	11	14	489	21	29	17	55	10	16	13	23	999
7:30-7:45	389	26	14	649	22	32	32	67	11	35	28	26	1331
7:45-8:00	443	27	28	908	30	33	55	88	21	63	36	36	1768
8:00-8:15	606	29	42	1220	31	48	72	95	27	37	63	54	2324
8:15-8:30	384	32	19	1002	34	84	58	113	26	26	73	44	1895
8:30-8:45	330	33	13	813	24	64	23	131	37	18	45	42	1573
8:45-9:00	296	22	9	568	22	30	19	66	13	15	45	27	1132
Subtotal	3034	194	142	6041	195	342	289	648	154	226	315	256	11836
% Trucks	21.62	7.22	6.34	22.55	5.58	4.97	3.81	3.54	5.23	4.17	5.57	5.47	18.17
Peak Hour Factor	0.75	0.92	0.61	0.81	0.88	0.68	0.72	0.81	0.75	0.64	0.77	0.81	0.61
Peak Hour	7:30-8:30= 1822	7:45-8:45= 121	7:30-8:30= 103	7:45-8:45= 3943	7:45-8:45= 119	7:45-8:45= 229	7:45-8:45= 208	7:45-8:45= 427	7:45-8:45= 111	7:30-8:30= 161	8:00-9:00= 226	7:45-8:45= 176	7:45-8:45= 7560

Note: SBT= southbound turn; SBL= southbound left; SBR= southbound right; NBT= northbound turn; NBL= northbound left; NBR= northbound right; EBT= eastbound turn; EBL eastbound left; EBR= eastbound right; WBT= westbound turn; WBL= westbound left; WBR= westbound right.

Indian Highway (MD 210) and Kerby Hill/Livingston Road: Morning Turning-Movement Data

Time (p.m.)	SBT	SBL	SBR	NBT	NBL	NBR	EBT	EBL	EBR	WBT	WBL	WBR	Intersection Subtotal
4:00-4:15	551	5	11	266	10	19	9	15	1	12	23	15	937
4:15-4:30	821	12	10	360	10	20	18	26	2	14	47	26	1371
4:30-4:45	839	15	18	385	11	22	26	31	1	26	50	33	1455
4:45-5:00	875	16	21	401	11	30	32	44	1	27	52	36	1553
5:00-5:15	879	25	28	467	20	33	40	47	6	41	52	38	1666
5:15-5:30	881	28	26	393	16	47	29	60	2	46	71	43	1642
5:30-5:45	829	21	21	390	13	37	12	22	3	20	37	19	1424
5:45-6:00	673	5	11	276	11	28	11	18	3	17	30	15	1098
Subtotal	6348	127	146	2938	102	236	177	263	19	203	362	225	11,146
% Trucks	25.20	5.51	6.16	19.20	8.82	4.66	16.78	14.94	10.53	3.94	3.59	5.33	20.25
Peak Hour Factor	0.99	0.80	0.83	0.88	0.75	0.78	0.79	0.74	0.58	0.76	0.79	0.87	0.95
Peak Hour	4:30-5:30= 3474	4:45-5:45= 90	4:30-5:30= 93	4:45-5:45= 1651	4:45-5:45= 60	4:45-5:45= 147	4:30-5:30= 127	4:30-5:30= 177	5:00-6:00= 14	4:30-5:30= 140	4:30-5:30= 225	4:30-5:30= 150	4:30-5:30= 6316

Note: SBT= southbound turn; SBL= southbound left; SBR= southbound right; NBT= northbound turn; NBL= northbound left; NBR= northbound right; EBT= eastbound turn; EBL eastbound left; EBR= eastbound right; WBT= westbound turn; WBL= westbound left; WBR= westbound right.

Indian Highway (MD 210) and Kerby Hill Road/Livingston Road: Evening Turning-Movement Data

APPENDIX 3
HOTSPOT DATABASE INSTRUCTIONS

Instructions for Editing the Hotspot Database

The hotspot database must be updated regularly to incorporate new data as it becomes available. Below is a step-by-step description of how to access, display and query, update, and archive the GIS-based hotspots database and maps. ArcGIS™ or compatible software must be installed in order to access, use, and update the database and maps. Users also need to have basic knowledge of GIS.

Accessing the Hotspots Map and Database

- Execute the Arc Map™ module of ArcGIS™, and open the existing map-file named “hotspots.mxd” by specifying the complete path information (e.g., C:\sha_congestion\hotspots.mxd. This assumes the map and supporting database files reside in sha_congestion folder in the C: drive). If the step is successfully executed, the map of the hotspots will be displayed.
- Additional layers (e.g., major highways, streets, population, etc.) may be added to the hotspots map as supplementary information if available and deemed important (see Figures 1, 2, and 3).

Using the Hotspots Map and Database

- Use the available Arc Map tools in ArcGIS™ to perform the needed display and query operations, including, but not limited to, zooming-in and zooming-out, panning, proximity analysis, and retrieving hyperlinked images and data.
- Hyperlinked images and data for the individual hotspots can be retrieved by clicking on the lightning-bolt shaped tool. This activates the hyperlink feature, as characterized by the blue-dotted centroids of the hotspot icons and the lightning-bolt (hyperlink) cursor. Place the bottom-tip of the hyperlink cursor directly on the center of the blue-dotted centroid of a hotspot icon. The path-address (i.e., drive-name/folder-name/filename.ext) of the hyperlinked image/traffic data will display near the icon when the tip of the lightning-bolt shaped cursor is directly on the centroid. Keeping the mouse motionless while the path-address is displayed, left-click to retrieve and display the hyperlinked information. Repeat the process for the retrieval of each hotspot’s hyperlinked information.

Editing the Hotspots Map and Database

The hotspots layer and the associated attribute data can easily be edited to include new hotspots and their data. To add new hotspots, select editing mode, and follow geocoding process (i.e., locate the hotspots using their associated intersecting/crossing roadways and digitizing them with the pencil-shaped sketching tool). Editing the database also requires you to be in editing mode: Open the attribute table of the hotspots layer, and add new data or edit the existing information.

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