Towards Ideal Hot Spot Analysis for Law Enforcement Safety Resource Allocation

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Introduction

Law enforcement agency resources are always under strain, as agencies are asked to "do more with less". Access to large, timely safety-related datasets allows agencies to utilize more **proactive**, **predictive policing** approaches.

A **Predictive Analytics hot spot detection tool** was developed in partnership with the Wisconsin State Patrol (WSP). The tool was an extension of an existing crash-mapping software, **Community Maps**, which has been used statewide for several years to support traffic safety analyses at the local level.

The new hot spot detection tool facilitates the automated detection of hazardous locations. **High Visibility Enforcement (HVE)** at these locations can deter unlawful, dangerous driving behavior.

Project Objectives

- Develop a **Predictive Analytics hot spot detection tool** to facilitate targeted enforcement for dangerous driver behaviors at dangerous locations.
- Aid in law enforcement resource allocation decision-making.
- Assess effectiveness of high visibility enforcement (HVE) pilot program.

Predictive Analytics Hot Spot Detection Tool

In 2017, a major update to Community Maps facilitated next-day crash updates with over 98% of crashes mapped statewide.

In 2018, a heatmap visualization layer and automated hot spot detection capabilities were added. The hot spot detection algorithm has two steps:

1. Hot Spot Detection
2. Compute Z-scores for Analysis Areas

Community Maps Algorithm

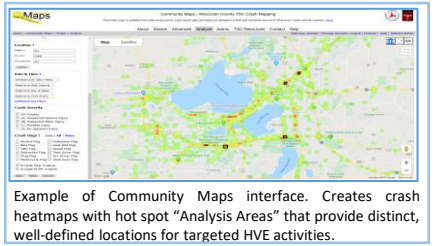
- **Parameters**
  - ***p:*** Total desired Analysis Areas
  - ***τ :*** Minimum crashes per Analysis Area
  - ***l:*** Minimum search distance
  - ***u:*** *Maximum search distance*
  - ***z:*** *Minimum z-score*
- **Definitions**

A crash neighborhood ***N(i,j)*** is defined as the smallest circle around a center crash ***i*** that contains its ***j*** closest crashes.

In its simplest form, the density of a crash neighborhood is given as: *# crashes/area*

- **Algorithm**

Given a set of ***n*** geocoded crashes returned from a dynamic database query, find the top ***p*** distinct set of crash neighborhoods, ranked by density.



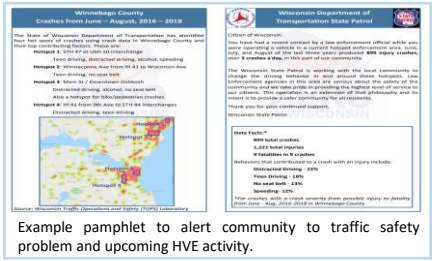
Example of Community Maps interface. Creates crash heatmaps with hot spot "Analysis Areas" that provide distinct, well-defined locations for targeted HVE activities.

Example of a crash neighborhood. The radius of the neighborhood is the distance from the center crash ***i*** to its ***j***-th closest neighbor.

Wisconsin State Patrol High Visibility Enforcement Pilot

In 2019, WSP conducted an HVE pilot using the Predictive Analytics tool.

- Identified 27 hot spots spanning 6 counties and 3 WSP jurisdictions.
- Patrolled in Summer (Jun-Aug),Fall (Sep-Nov), or both.
- Targeted specific dangerous driving behaviors:
  - Seatbelt usage,
  - distracted driving,
  - speed, and
  - alcohol-related crashes.
- A concerted community outreach effort included media events, and pamphlet distribution at local establishments and traffic stops.

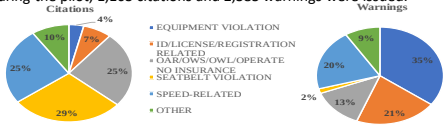


Example pamphlet to alert community to traffic safety problem and upcoming HVE activity.

To assess the effectiveness of the HVE pilot a review of citations and crash data was conducted.

Citation Analysis

During the pilot, 1,163 citations and 2,385 warnings were issued.



- Compared citations related to driver behavior hot spot issues from before and during HVE pilot.
  - Seatbelt usage, speed had large enough sample for statistical testing.

	Citations			Warnings		
Driver Behavior	**Hotspot**	**Total**	**% of Total**	**Hotspot**	**Total**	**% of Total**
Alcohol-Related	3	36	8.3%	0	0	0.00%
Distracted Driving	3	7	42.9%	9	17	52.9%
Seatbelt Usage	26	334	7.8%	3	37	8.1%
Speed Related	50	297	16.8%	121	486	24.9%

- Twice as likely to issue seatbelt- and speed-related citations and warnings during HVE pilot.

Crash Analysis

- Empirical Bayes (EB) Observational before and after study.
  - Crash data during pilot months in 2019 compared to same months of three years prior to HVE pilot (2016-2018).

		Fatal & Injury				Property Damage Only				Total			
Site	Location	Obs.	Exp.	SE (%)	p-value	Obs.	Exp.	SE (%)	p-value	Obs.	Exp.	SE (%)	p-value
1	Main St & University Ave	0	4	-	-	10	6	-58	.320	10	10	-3	.931
2	Dousman/Walnut St & N Broadway	0	5	-	-	8	6	-27	.598	8	11	27	.598
3	W Mason St	6	4	-36	.560	24	8	-215	.015**	30	12	-157	.011**
4	STH 172 (Ashwaubenon)	6	4	-59	.422	24	8	-190	.017**	30	12	-157	.011**
5	Main Ave (STH 32)	10	9	-6	.881	2	4	54	.096*	12	14	12	.669
6	STH 124/USH51 & USH 29	9	10	14	.666	3	8	64	.003**	12	19	35	.079*
7	Grove/Superior St & River/Elm St	0	8	-	-	16	11	-47	.281	16	19	15	.513
8	Main/Vine St & 17th Ave	12	13	7	.805	13	7	-78	.189	25	20	-24	.414
9	E Canal St & Bridge St/Park Ave	4	4	-6	.916	18	17	-3	.913	22	21	-5	.835
10	US 53 & Hogarth St/E Melby St	2	7	71	<.001**	0	16	-	-	2	22	91	<.001**
11	S Macy St/S Park Ave & 4th St	2	7	71	<.001**	0	16	-	-	2	22	91	<.001**
12	N Main St & E Johnson St	6	6	-6	.903	12	17	31	.146	18	23	21	.300
13	STH 45	6	6	-6	.903	12	17	31	.146	18	23	21	.300
14	E Johnson St (STH 23)	6	8	27	.376	15	19	20	.376	21	27	22	.252
15	STH 441 & College Ave	2	10	80	<.001**	12	21	44	.011**	14	31	55	<.001**
16	Northland Ave (STH 15) & US 41	16	12	-33	.390	4	20	80	<.001**	20	32	38	.013**
17	STH 12 (Lake Delton)	10	12	17	.563	25	20	-22	.432	35	32	-8	.704
18	STH 12 & I94	10	11	7	.833	14	22	37	.047**	24	33	27	.106
19	Main St (Reedsburg)	12	11	-6	.871	37	49	28	.262	49	40	-22	.290
20	W Pike St & Linn St	25	19	-32	.302	36	26	-38	.162	61	45	-35	.091**
21	STH23 & I94	13	13	0	.990	36	35	-3	.869	49	48	-2	.889
22	Bdr/Water St. & STH 33/113	8	13	37	.125	44	42	-4	.835	52	55	6	.704
23	Phillips Blvd. (US 12)	10	14	28	.255	72	45	-60	.010**	82	59	-39	.035**
24	STH 47 & USH 10 Interchange	6	16	63	<.001**	33	44	25	.092*	39	60	35	.002**
25	Winneconne Ave from I41 to Wisconsin Ave	37	27	-38	.160	101	68	-48	.007**	138	96	-44	.003**
26	Main St (Downtown)	32	33	4	.851	66	62	-6	.678	98	96	-2	.879
27	I41 from 9th Ave to STH 44 Interchange	40	38	-5	.810	117	111	-6	.613	157	150	-4	.641
All Sites		290	325	10.8	.070*	754	708	-6.5	.149	1044	1032	-1.1	.761

*Results significant at 90% level of confidence
**Results significant at 95% level of confidence

- Fatal and Injury (FI) crashes decreased significantly by 10.8%.
  - 15/27 sites experienced decrease in FI crashes.
  - No sites had a significant increases in FI crashes.
- No significant change in property damage only crashes.

Conclusions

- Deterrence from HVE effective during pilot.
  - High rate of target citations and warnings.
  - Significant reduction in crashes
- HVE aided by Predictive Analytics Hot Spot Detection Tool
  - Tool is operational and provides a template for other agencies.
  - Quick, easily identifiable hot spots
  - Results are reproducible.
- Considerations for "ideal" hot spot detection algorithms:
  - Law enforcement must have confidence in results
  - Inclusion of local roads
  - Law enforcement need a well-defined set of locations; a heatmap is not enough.
  - Support real-time, dynamic queries based on fast algorithms
  - Automated and adaptive thresholds
  - Inclusion of citation and warning data

Acknowledgements

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