

OUTLINE

- What is Traffic Calming
- Physical / Feedback Countermeasures
- Non-Physical Countermeasures
- Longitudinal
- Transverse
  - Peripheral Transverse Bars
    - Union, Iowa Treatments
  - Converging Chevrons
    - Roland, Iowa Treatments



WHAT IS TRAFFIC CALMING?

- Definition
  - Combination of mainly physical and non-physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users.

    -Institute of Transportation Engineers

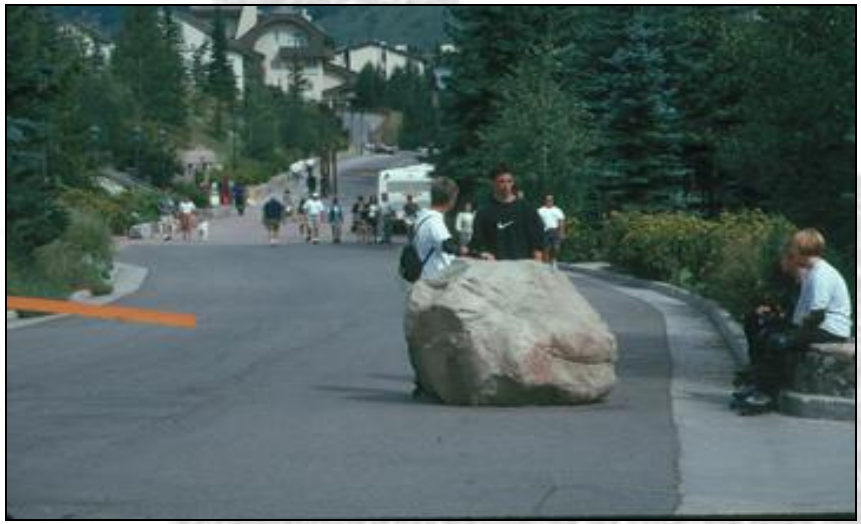


Image: Eric R. Petersen Defense



Image: Dr. Shauna Hallmark

IS IT A NEW IDEA?

- "Owing to great danger arising ofttimes from coaches, sleighs, chairs, and other carriages, on the Lord's days, as people are going to or coming from the several churches in this town, being driven with great rapidity, and the public worship being ofttimes much disturbed by such carriages, it is therefore voted and ordered that no coach, sleigh, chair, chaise, or other carriage shall at such times be driven at a greater rate than that of foot pace, on penalty … of the sum of 10 shillings."

- Boston's Board of Selectmen 1757



Image: Massachusetts Bay Transportation Authority

BENEFITS OF TRAFFIC CALMING

- GOAL: Overall Speed Decrease
  - **less** probability of an accident.
    - The risk of being in a crash doubles for every 3 mph over 30 mph.
  - **less** severity of accidents.
    - The probability of death or disfigurement doubles for every 10 mph over 50 mph.
    - A pedestrian struck at 20 mph has a 15% chance of fatality, a pedestrian struck at 40 mph has an 85% chance of fatality.

BENEFITS OF TRAFFIC CALMING

- Community interaction may **increase**
  - Bicycling, walking, and other forms of street life are encouraged
- Crime may **decrease**
  - In one study, violent crimes were reduced by 50% and non-violent crimes were reduced by 24% after traffic calming.
- Noise levels may **decrease**
  - Speed reductions from about 30 mph to about 20 mph typically reduce noise levels by 4-5 decibels.

Treatment Type Based on VPD

- < 600 vpd
  - Education
  - Enforcement
  - Non-physical measures
- 600 – 4,000 vpd
  - Education
  - Enforcement
  - Non-physical measures
  - Physical measures
- > 4,000 vpd
  - Education
  - Enforcement
  - Alternative actions
  - No traffic calming measures

Source: Virginia DOT

Physical Countermeasures



Image: trafficcalming.org

Raised Median

Physical Countermeasures



Image: trafficcalming.org

Neighborhood Traffic Circle

Physical Countermeasures

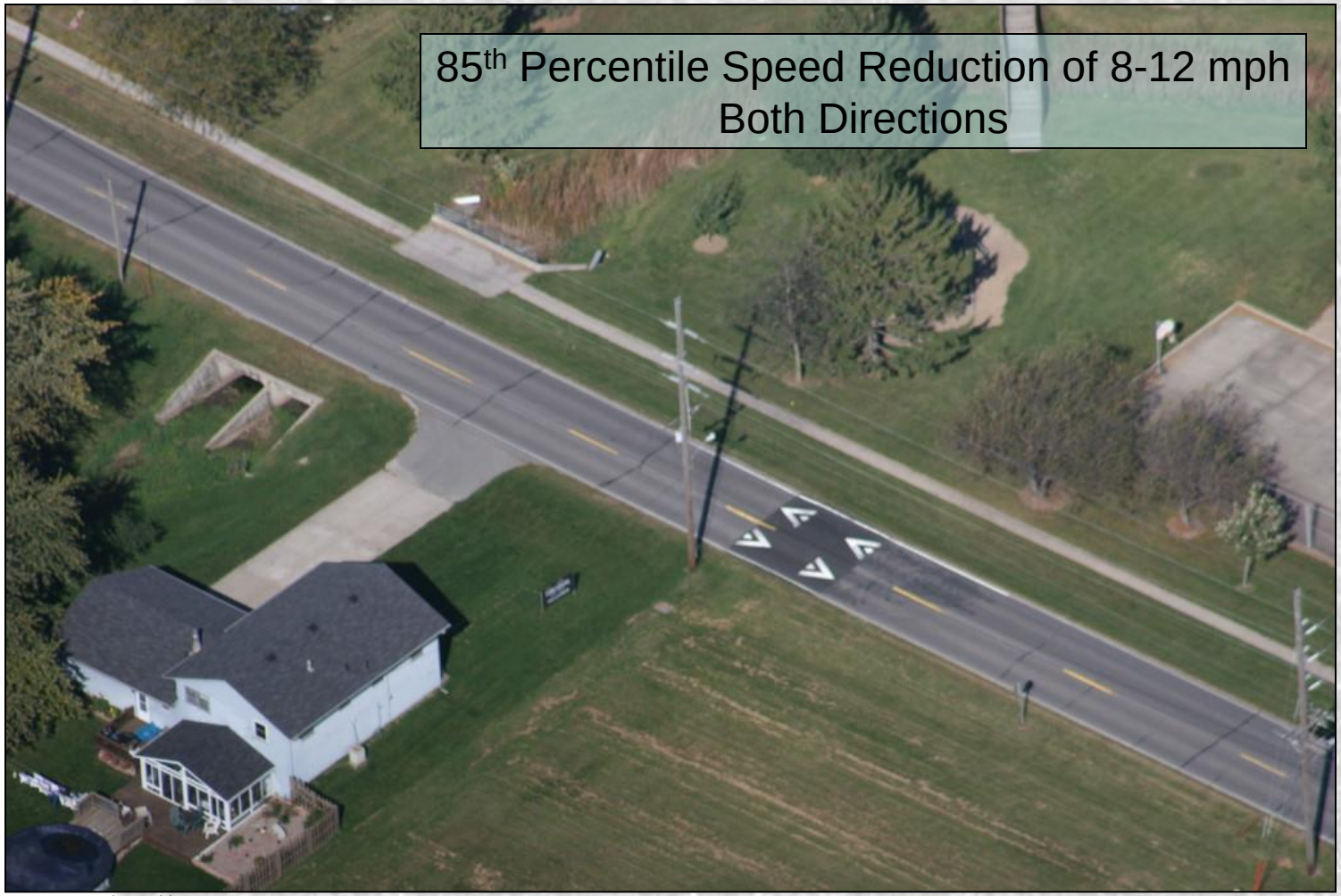


Image: Neal Hawkins

Speed Hump

Physical Countermeasures



Image: trafficcalming.org

Choker



Image: trafficcalming.org

Chicane

Feedback Countermeasures

- Lowered Southbound 85th Percentile Speed by 6-8 mph
- Northbound 85th percentile speed increased by 4-5 mph depending on time of day
- Expensive and hard to maintain
- Radar calibration needed every week with tuning forks
- Easily target for vandalism

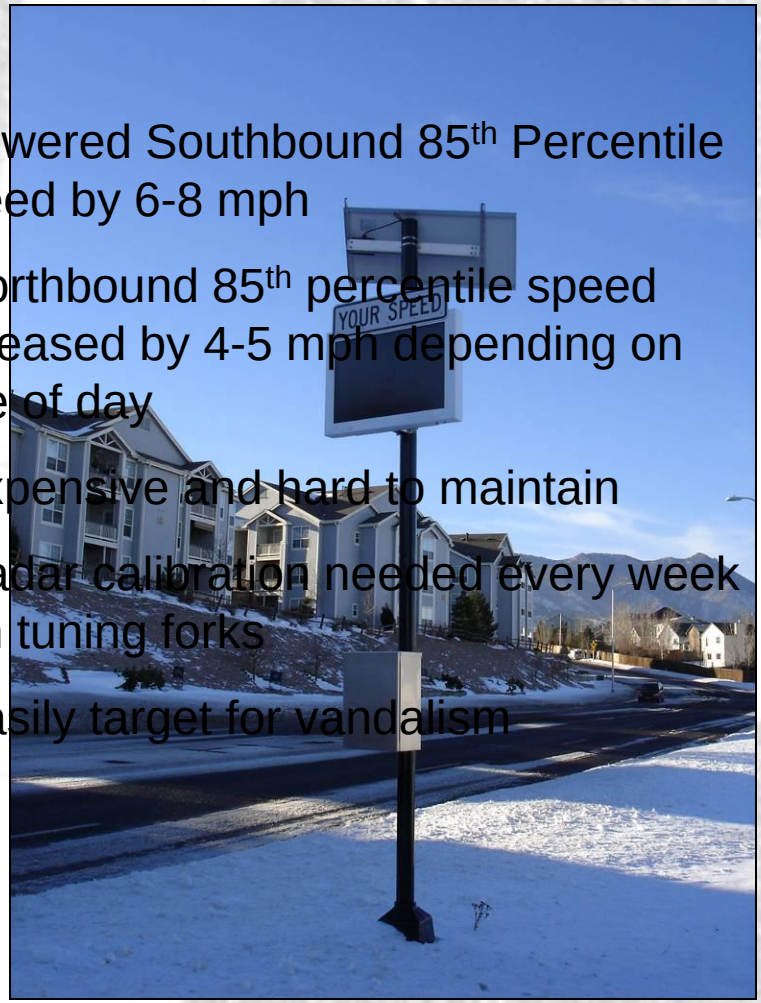


Image: Eric Fitzsimmons



Image: Eric Fitzsimmons

Radar Electronic Feedback Signs

Non-Physical Countermeasures

- Perceptual Countermeasures (passive speed control devices)
  - Serve to alter the driver's perception of the correct speed for a particular road
  - Intended to be self-enforcing
  - Relatively inexpensive with the use of pavement markings or small devices that are placed on or near the roadway

Perceptual Countermeasures

- Benefits
  - Inexpensive to install and maintain
  - Unobtrusive, less likely to frustrate drivers
  - Reduces speed without driver knowledge
- Disadvantages
  - Can be confusing to driver's unfamiliar with the area
  - Expensive to maintain depending on the amount of paint
  - Can be hard and expensive to remove or alter the treatment

Perceptual Countermeasures

- Two types of perceptual pavement markings
  - Longitudinal
    - Modification of edge or center lines in lanes of traffic
    - Would include lane narrowing, painted medians
    - Requires the driver to drive with accurate steering and vehicle control



Images: Hancook, K.L., and R. Risessman (2004)

Longitudinal Pavement Markings



Image: Eric Fitzsimmons

Lane Narrowing Towards the Center

Longitudinal Pavement Markings

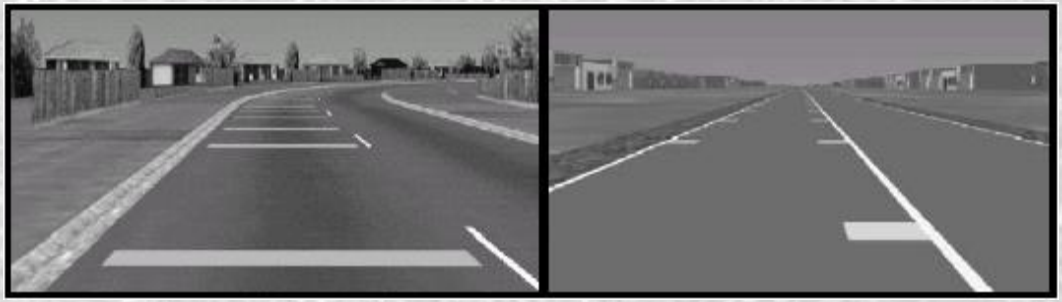


Image: Shauna Hallmark

Lane Narrowing Using a Center Median

Transverse Pavement Markings

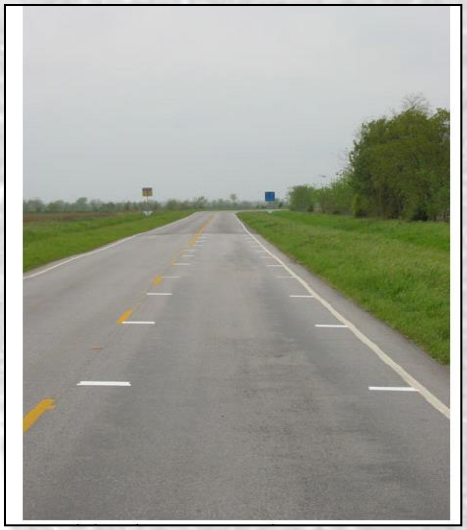
- Transverse (peripheral bars)
  - First experimented in 1971 by G.G. Denton with a simulated situation of converging lines that crossed perpendicular to the travel lane
  - In 1980, K.R. Agent found transverse bars helpful in reducing speeds entering a sharp horizontal curves in Kentucky
  - Found to reduce speed if the pavement markings are converging in the direction of movement
  - The idea is to give the driver the feeling of speeding up until the pavement markings would pass at a constant rate



http://www.massghsb.com/crashdata.html

Peripheral Transverse Pavement Markings

- Effectiveness
  - Brian Katz (SAIC, 2004) reported on use of the peripheral transverse markings at sites in New York (freeway exit), Mississippi (two-lane road) and Texas (two-lane road on curve). Overall he found a 4 mph reduction in average speeds and 5 mile reduction in 85th percentile speed. Differences were statistically significant.



Images: Used with permission Bryan Katz, SAIC 2004



Peripheral Transverse Pavement Markings

- Design
  - 1.5 ft. x 1.5 ft. boxes near the center and edge lines
  - Thermoplastic or paint with reflective beads





Image: Eric Fitzsimmons

Calculations

	A	B	C	D	E	F	G	H	I
1	**Texas Site Peripheral Transverse Stripe Spacing**								
2									
3	Initial Speed	45	miles per hour	INPUTS		Markings		22	
4	Desired Speed	35	miles per hour			Width		3	stripe
5	Distance	293.75	feet			Amount of Material		198	feet
6	Required Decel	-2.94	ft/s^2			(-3 feet per second squared			
7	Bar Frequency	4	bars per second						
8									
9	Marking Number	Distance (Rounded For Design)	Distance Traveled	Desired Speed (mph)	Desired Speed (ft/s)				
10	1	0	0.00	45.00	66.15		ft	m	
11	2	16	16.54	44.98	66.12		15.54	5.04	
12	3	33	32.89	44.47	65.37		15.35	4.98	
13	4	49	49.43	43.49	63.93		16.17	15.17	4.98
14	5	65	65.04	42.99	63.19		15.98	14.98	4.87
15	6	81	80.84	42.48	62.45		15.80	14.80	4.82
16	7	96	96.45	41.98	61.71		15.61	14.61	4.76
17	8	112	111.88	41.48	60.97		15.43	14.43	4.70
18	9	127	127.12	40.97	60.23		15.24	14.24	4.65
19	10	142	142.18	40.47	59.49		15.06	14.06	4.59
20	11	157	157.05	39.97	58.75		14.87	13.87	4.53
21	12	172	171.74	39.46	58.01		14.69	13.69	4.48
22	13	186	186.24	38.96	57.27		14.50	13.50	4.42
23	14	201	200.55	38.45	56.53		14.32	13.32	4.36
24	15	215	214.69	37.95	55.79		14.13	13.13	4.31
25	16	229	228.64	37.45	55.05		13.95	12.95	4.25
26	17	242	242.41	36.94	54.31		13.76	12.76	4.19
27	18	256	255.96	36.44	53.57		13.58	12.58	4.14
28	19	269	269.37	35.94	52.83		13.39	12.39	4.08
29	20	283	282.58	35.43	52.09		13.21	12.21	4.03
30	21	296	295.60	34.93	51.34		13.02	12.02	3.97
31	22	308	308.43	34.42	50.60		12.84	11.84	3.91

$$\text{Deceleration Rate} = \frac{(1.47 \times V_2^{\,2}) - (1.47 \times V_1^{\,2})}{(2 \times Length / 5280\ ft.)} \rightarrow \frac{(1.47 \times 35^2) - (1.47 \times 45^2)}{(2 \times 293.75 / 5280)} = -2.94\ ft/s^2$$

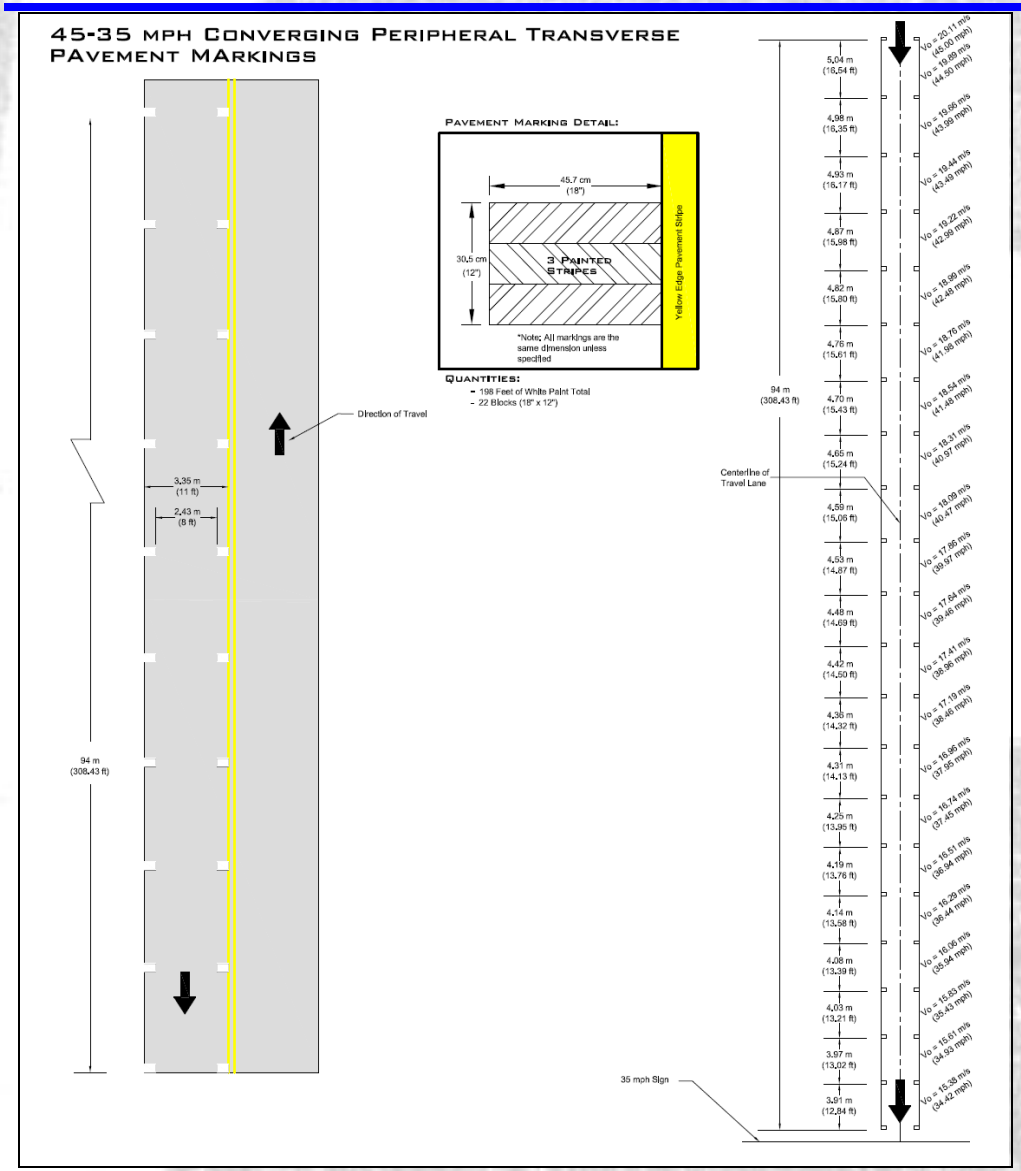
$$\text{Distance Traveled} = \frac{\text{Desired Speed}}{\text{Bar Frequency}} \rightarrow \frac{66.15\ ft/s}{4} = 16.54\ ft.$$

$$\text{Estimated Speed Reduction} = \sqrt{((66.15^2) + (2 \times -2.94) \times (16.54 - 0))}$$

$$= 65.41\ ft./s \text{ or } 44.50 \text{ mph}$$

Program: Bryan Katz, SAIC & Eric Fitzsimmons, CTRE

Design


45-35 mph Converging Peripheral Transverse Pavement Markings
Pavement Marking Detail:
45.7 cm (18")
30.5 cm (12")
3 Painted Stripes
Yellow Edge Pavement Stripe
*Note: All markings are the same dimension unless specified
Quantities:
- 198 Feet of White Paint Total
- 22 Blocks (18" x 12")
Direction of Travel
3.35 m (11 ft)
2.43 m (8 ft)
94 m (308.43 ft)
Centerline of Travel Lane
35 mph Sign
5.04 m (16.54 ft)
4.98 m (16.35 ft)
4.93 m (16.17 ft)
4.87 m (15.98 ft)
4.82 m (15.80 ft)
4.76 m (15.61 ft)
4.70 m (15.43 ft)
4.65 m (15.24 ft)
4.59 m (15.06 ft)
4.53 m (14.87 ft)
4.48 m (14.69 ft)
4.42 m (14.50 ft)
4.36 m (14.32 ft)
4.31 m (14.13 ft)
4.25 m (13.95 ft)
4.19 m (13.76 ft)
4.14 m (13.58 ft)
4.08 m (13.39 ft)
4.03 m (13.21 ft)
3.97 m (13.02 ft)
3.91 m (12.84 ft)
Vo = 20.1 m/s (45.00 mph)
Vo = 19.89 m/s (44.50 mph)
Vo = 19.66 m/s (43.98 mph)
Vo = 19.44 m/s (43.49 mph)
Vo = 19.22 m/s (42.98 mph)
Vo = 18.99 m/s (42.48 mph)
Vo = 18.76 m/s (41.96 mph)
Vo = 18.54 m/s (41.46 mph)
Vo = 18.31 m/s (40.97 mph)
Vo = 18.09 m/s (40.47 mph)
Vo = 17.86 m/s (39.97 mph)
Vo = 17.64 m/s (39.46 mph)
Vo = 17.41 m/s (38.96 mph)
Vo = 17.19 m/s (38.46 mph)
Vo = 16.96 m/s (37.95 mph)
Vo = 16.74 m/s (37.45 mph)
Vo = 16.51 m/s (36.94 mph)
Vo = 16.29 m/s (36.44 mph)
Vo = 16.06 m/s (35.94 mph)
Vo = 15.83 m/s (35.43 mph)
Vo = 15.61 m/s (34.93 mph)
Vo = 15.38 m/s (34.42 mph)

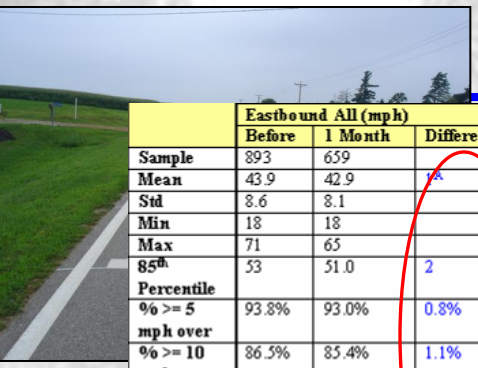


Peripheral Transverse Pavement Markings



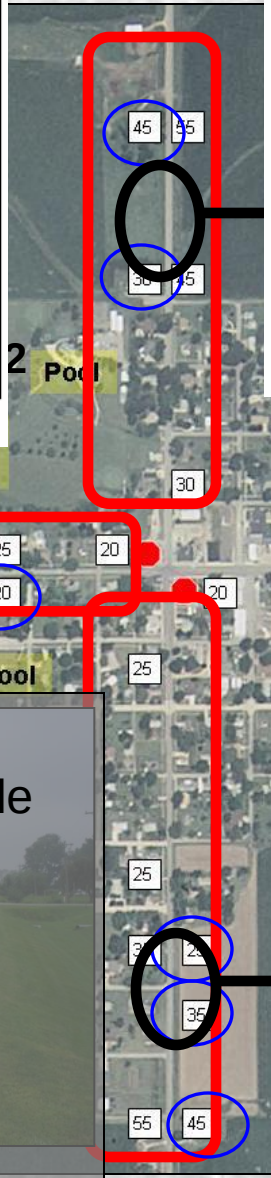
Video: Used with permission from the Virginia DOT (2006)

Union, Iowa



	Eastbound All (mph)			Westbound All (mph)		
	Before	1 Month	Difference	Before	1 Month	Difference
Sample	893	659		863	672	
Mean	43.9	42.9	-1.0[A]	42.7	44.5	-1.8[A]
Std	8.6	8.1		8.1	7.5	
Min	18	18		16	14	
Max	71	65		69	66	
85th Percentile	53	51.0	2	50	52.0	-2
% >= 5 mph over	93.8%	93.0%	0.8%	94.6%	97.3%	-2.7%[C]
% >= 10 mph over	86.5%	85.4%	1.1%	85.2%	93.0%	-7.8%[C]
% >= 15 mph over	71.8%	69.3%	2.5%	68.6%	76.9%	-8.3%[C]
% >= 20 mph over	49.8%	43.9%	5.9%[C]	44.6%	51.5%	-6.9%[C]
% >= 25 mph over	24.6%	21.4%	3.2%[D]	19.0%	25.6%	-6.6%[C]

*statistically significant at 95% CI using t-test

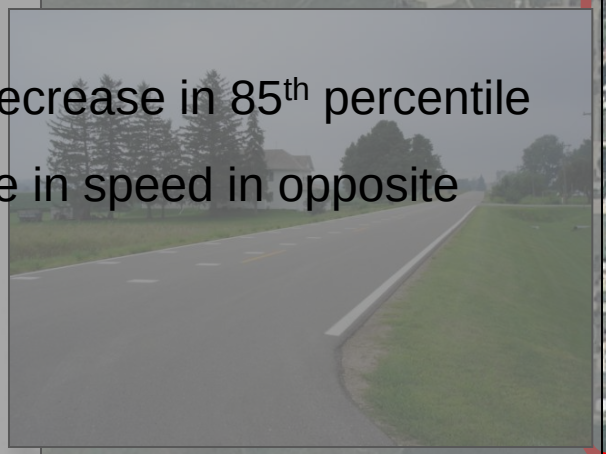


	Northbound All (mph)			Southbound All (mph)		
	Before	1 Month	Difference	Before	1 Month	Difference
Sample	1,836	1,678		1,870	1,785	
Mean	34.2	35.6	1.4[A]	33.8	33.9	0.1
Std	7.6	7.7		7.3	6.8	
Min	9	8		7	10	
Max	64	61		65	62	
85th Percentile	42	43	1	41	41	0
% >= 5 mph over	51.5%	61.1%	9.6%[C]	48.4%	48.2%	0.2%
% >= 10 mph over	24.0%	29.8%	5.8%[C]	21.0%	19.7%	1.3%
% >= 15 mph over	6.9%	10.9%	4.0%[C]	5.8%	5.1%	0.7%
% >= 20 mph over	1.5%	2.4%	0.9%[C]	1.3%	0.4%	0.9%[C]
% >= 25 mph over	0.4%	0.3%	0.1%	0.3%	0.2%	0.1%

*statistically significant at 95% CI using t-test



- Slight decrease in 85th percentile
- Increase in speed in opposite direction



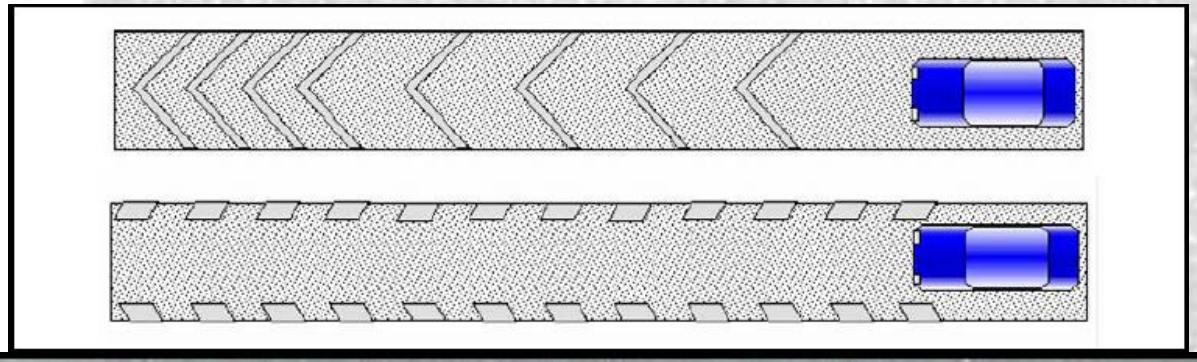
	Northbound All (mph)			Southbound All (mph)		
	Before	1 Month	Difference	Before	1 Month	Difference
Sample	886	783		900	936	
Mean	37.8	37.0	0.8[A]	38.5	38.7	-0.2
Std	8.4	8.9		8.2	8.7	
Min	14	7		13	10	
Max	61	63		67	59	
85th Percentile	46	45	1	46.0	47	1
% >= 5 mph over	84.5%	81.5%	3.0%[D]	87.8%	85.8%	2.0%[D]
% >= 10 mph over	69.6%	65.9%	3.7%[D]	73.6%	74.5%	-0.9%
% >= 15 mph over	45.3%	42.7%	2.6%	49.4%	52.7%	-3.3%[D]
% >= 20 mph over	20.8%	19.8%	1.0%	22.4%	26.7%	-4.3%[C]
% >= 25 mph over	5.9%	5.0%	0.9%	5.6%	6.7%	-1.1%

*statistically significant at 95% CI using t-test

Converging Chevrons

- Transverse (Converging Chevrons)
  - Look like the roof of a house
  - *Chevron* French word meaning “Rafter”
  - Only 5 cases of implementation with positive results
  - Designed using the same velocity derived equations as the peripheral transverse pavement markings
  - Can be used to inform drivers about spacing between cars
    - *i.e. “2 Chevrons between cars” (Japan)*
  - Common application is at the end of runways to direct commercial aircraft to centerline of the runway

Examples





Images: Drakopoulos A. and Vergou G. (2003)

Osaka, Japan: Converging Chevrons, Constant Comb Markings

Examples

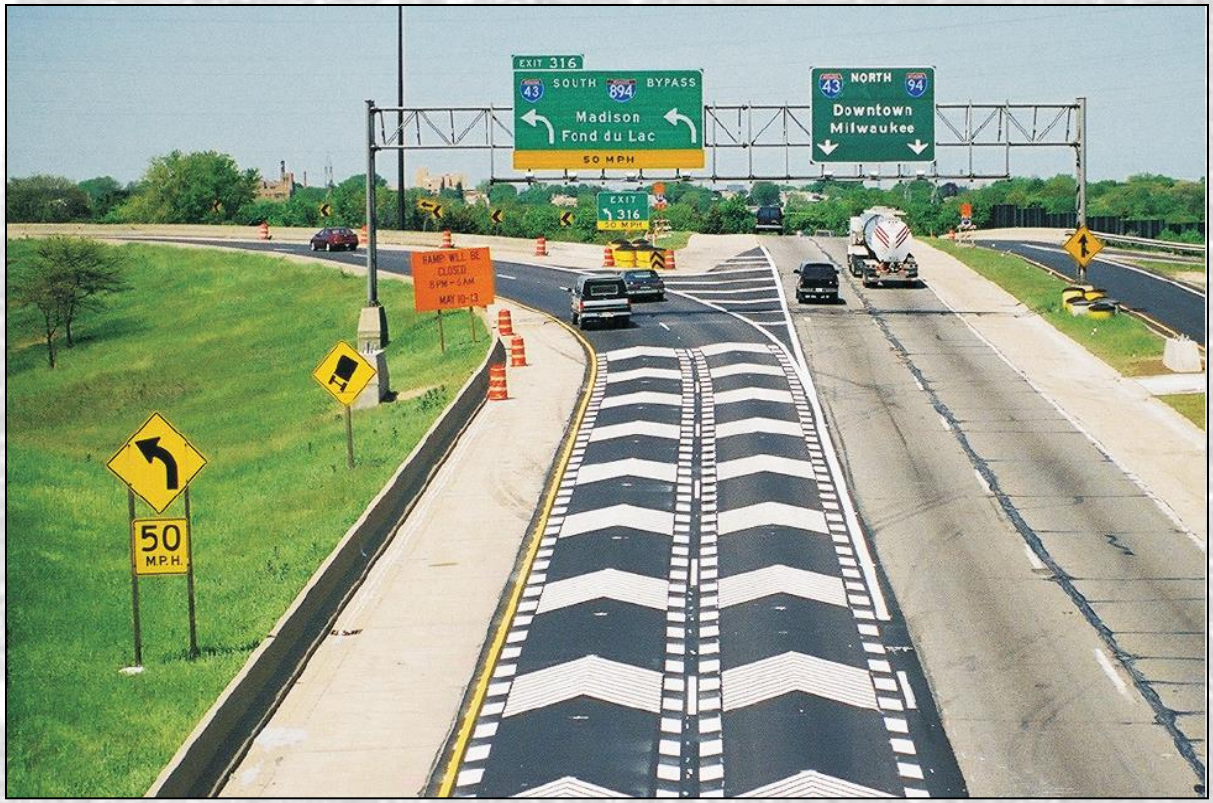


Image: aaa foundation: L.I. Griffin, R.N. Reinhardt (1995)

Milwaukee, Wisconsin: Converging Chevrons, Constant Comb Markings

- $40,000 installation cost
- 17 mph reduction in 85th percentile speed
- 43% reduction in crashes on or near the ramp

Examples

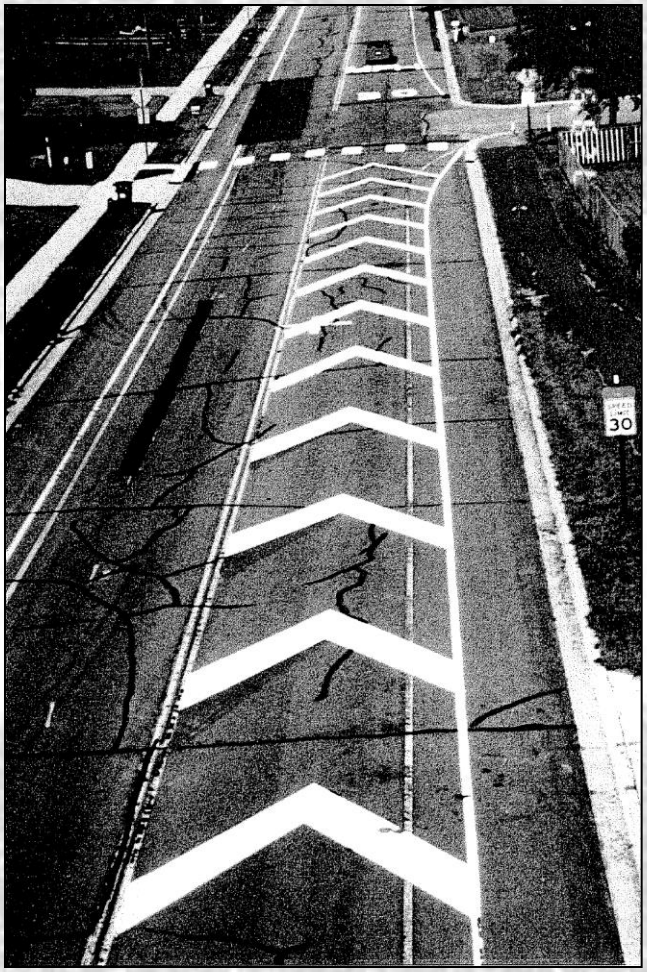


Image: City of Eagan, Minnesota (1998)

Eagan, Minnesota: Converging Chevrons

- Installed on a community collector (Deerwood Drive)
- 85th percentile speed decrease by 4 mph in each direction
- Speeding citations went from 42 to 28

Calculations (# of Chevrons in a Systems)

- Equation Taken from Minnesota: $L = v_1 * t_b + \frac{(v_1^2 - v_2^2)}{2a}$
- Entering System Speed **(v1)** = 45 mph → 45 mph x 1.4667 = **66.0015 fps** → 20.1173 m/s
- Entering System Speed **(v2)** = 35 mph → 35 mph x 1.4667 = **51.3345 fps** → 15.6468 m/s

Assumptions:

- Reaction time **(tb)** = **0.5 sec.**
- Deceleration braking **(a) =** -1 m/s2 → **3.3 fps2**
- Length $(L) = (66.0015) * (0.5) + \frac{(66.015^2 - 51.3345^2)}{2 * (3.3)}$ = **293.75 ft.**
- Average speed through system: $\frac{(v_1 + v_2)}{2}$ = $\frac{(66.0015 + 51.3345)}{2}$ = **58.668 fps** → 40 mph
- Time to get through system: **$t = t_b + t_a$** , **tb=0.5 sec.**

$$-a = \frac{v_2 - v_1}{t_a} \rightarrow t_a = \frac{v_2 - v_1}{-a} = \frac{15.6468\,m/s - 20.1173\,m/s}{-1\,m/s^2}$$ **= 4.4705 sec.**

t = 0.5 sec + 4.4705 sec = 4.9705 sec ≈ **5.0 sec**.

Assumptions:

- (2.2 Chevrons per second) * (Seconds) = # Chevrons

# of Chevrons = (2.2 chevrons / sec)*(5.0 sec) = **11 Chevrons**

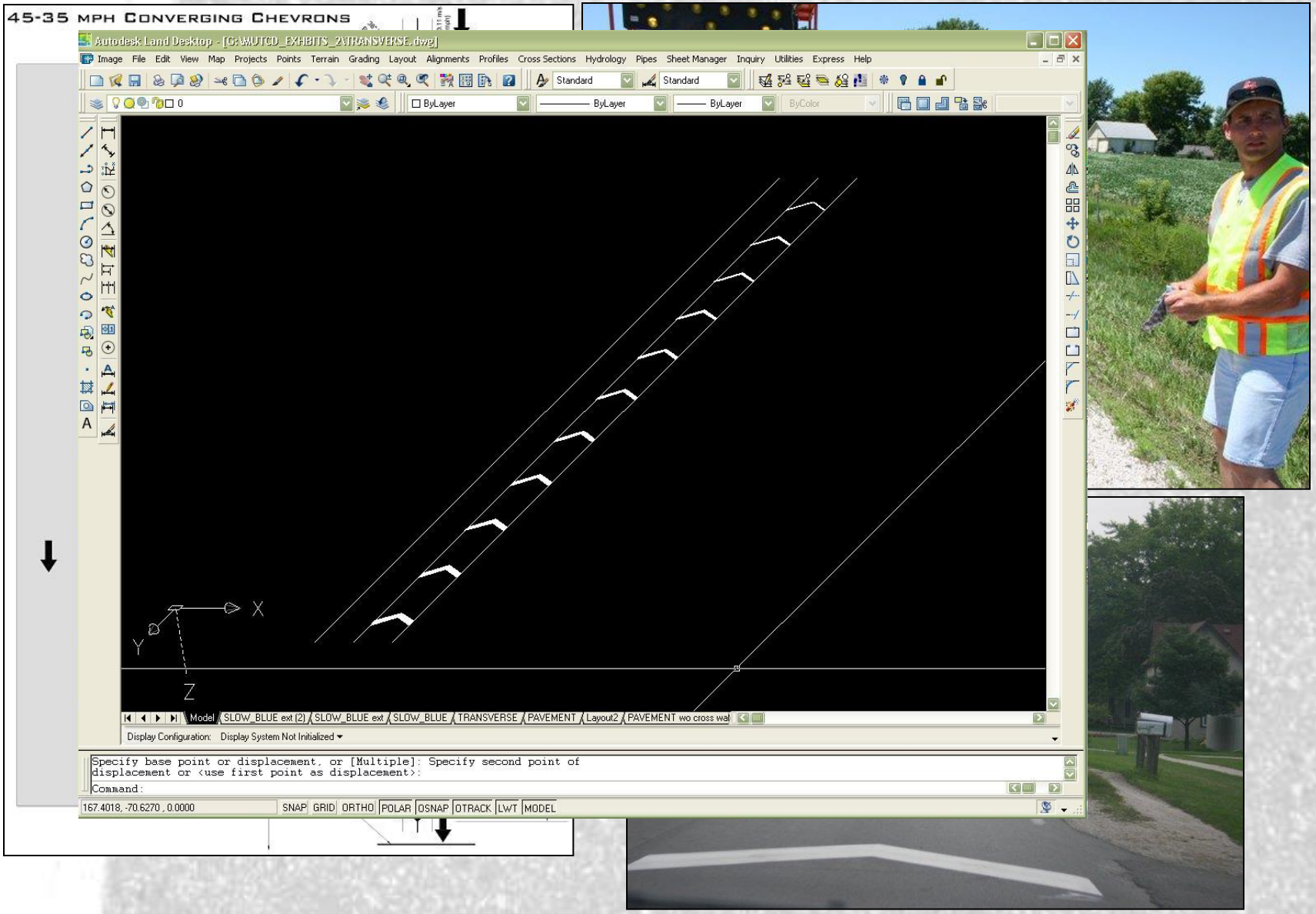
Calculations (Converging Spacing / Thickness)

- Given: Length = 293.75 ft → 89.53 m
  Vo = 20.1173 m/s
  Vf = 15.6468 m/s
  Total time (t) = 5.0 sec.
  Deceleration braking (a) = -1m/s2
  # Chevrons = 11
  Rate = 2.2 Chevrons per sec.

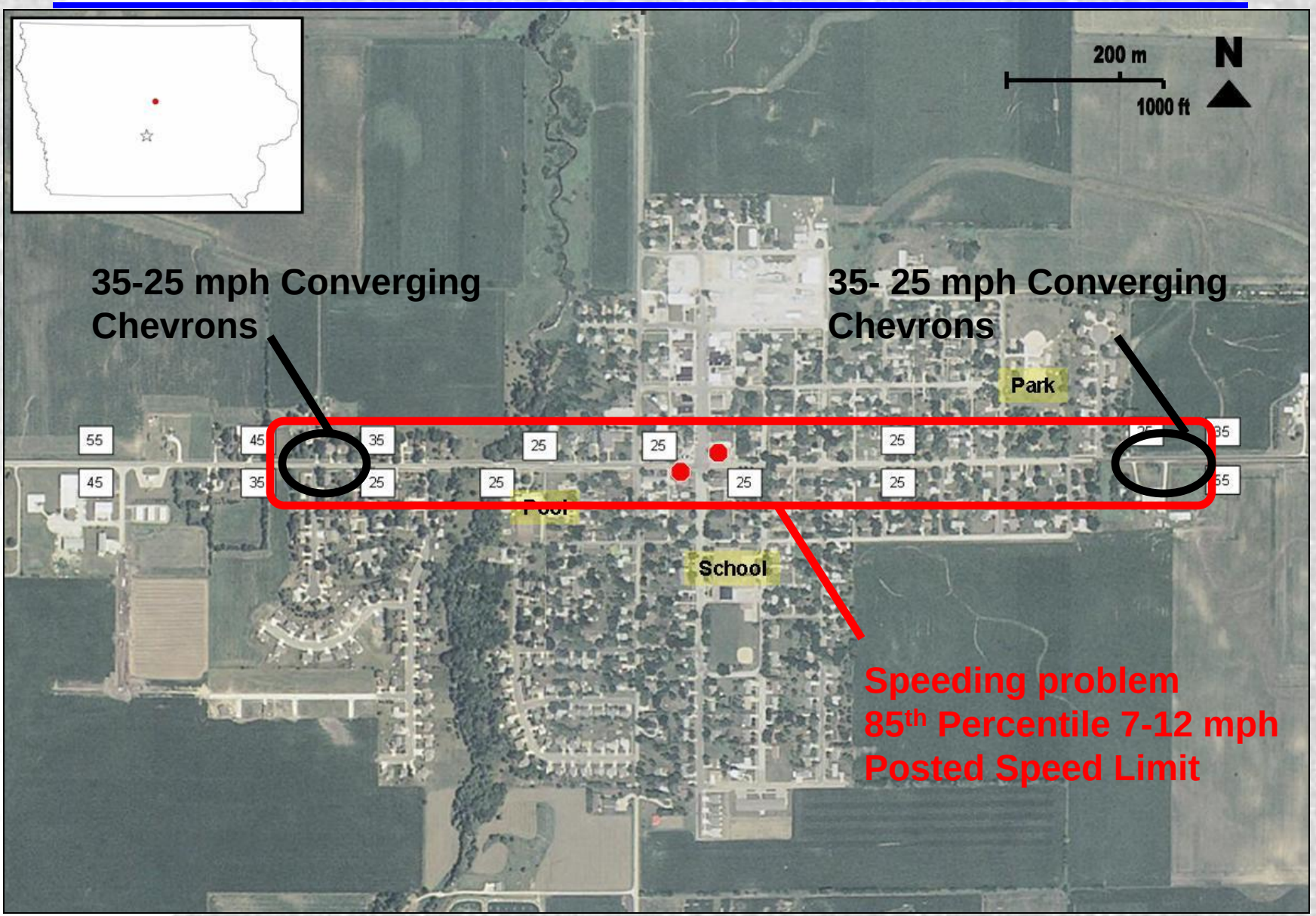
- Time spacing between spacing (constant): $\frac{5.0\,\text{sec}}{10\,\text{spaces}}$ = **0.5 sec. / space**
- Velocity Equation: V1=Vo+at
- Spacing Equation: $2aS1=V_1^2-V_o^2 \rightarrow \mathbf{S_1 = \frac{(V_1^2 - V_o^2)}{2(a)}}$

Chevron	Projected Velocity, m/s	Spacing, m	Spacing, ft.	Chevron Thickness,
1	20.11			36"
2	19.6173	33	10	33"
3	19.1173	32	9.75	30"
4	18.6173	31	9.45	27"
5	18.1173	30	9.15	24"
6	17.6173	29	8.84	21"
7	17.1173	28	8.68	18"
8	16.6173	28	8.53	15"
9	16.1173	27	8.23	12"
10	15.6173	26	7.92	9"
11	15.1173	25	7.62	6"
*Taken from Minnesota 45-30 Chevron Study				

Design


45-35 MPH CONVERGING CHEVRONS
Autodesk Land Desktop - [G:\MUTCD_EXHIBITS_2\TRANSVERSE.dwg]
Image File Edit View Map Projects Points Terrain Grading Layout Alignments Profiles Cross Sections Hydrology Pipes Sheet Manager Inquiry Utilities Express Help
Standard
Standard
ByLayer
ByLayer
ByLayer
ByColor
X
Y
Z
Model SLOW_BLUE ext (2) SLOW_BLUE ext SLOW_BLUE TRANSVERSE PAVEMENT Layout2 PAVEMENT wo cross wal
Display Configuration: Display System Not Initialized
Specify base point or displacement, or [Multiple]: Specify second point of
displacement or <use first point as displacement>:
Command:
167.4018, -70.6270 , 0.0000
SNAP GRID ORTHO POLAR OSNAP OTRACK LWT MODEL

Roland, Iowa


200 m
1000 ft
N
35-25 mph Converging Chevrons
35- 25 mph Converging Chevrons
Park
School
55
45
35
25
Speeding problem
85th Percentile 7-12 mph
Posted Speed Limit

Roland, Iowa

	Eastbound All (mph)		
	Before	1 Month	Difference
Sample	4,216	4,135	
Mean	30.8	29.7	1.1
Std		4.9	
Min	7	8	
Max	49	56	
85th Percentile	35	34	1
% >= 5 mph over	63.4%	51.8%	11.6%[C]
% >= 10 mph over	20.7%	14.2%	6.5%[C]
% >= 15 mph over	3.1%	2.6%	0.5%[D]
% >= 20 mph over	0.4%	0.3%	0.1%
% >= 25 mph over	0%	0.1%	-0.1%

*statistically significant at 95% CI using t-test





Images: Neal Hawkins

Westbound All (mph)		
Before	1 Month	Difference
2,397	2,062	
29.6	29.2	0.4[A]
6.4	6.0	
11	11	
60	54	
36	35	1
51.4%	47.7%	3.7%[C]
19.7%	16.6%	3.1%[C]
5.3%	4.0%	1.3%[C]
1.5%	0.9%	0.6%[C]
0.3%	0.3%	0%

- No change in 85th Percentile after 1 month
- Modest decrease in speeds over posted

Conclusions

- Peripheral Pavement Markings as a Traffic Calming Device
  - Excellent low cost treatment to install and maintain
  - Speed limit zones could have an affect on results
  - More positive results found in the literature on multi-lane highways and ramps
  - Many assumptions (*i.e. equations, dimensions, placement)*

Questions