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PERFORMANCE BENEFITS OF CONNECTED VEHICLES FOR IMPLEMENTING SPEED HARMONIZATION

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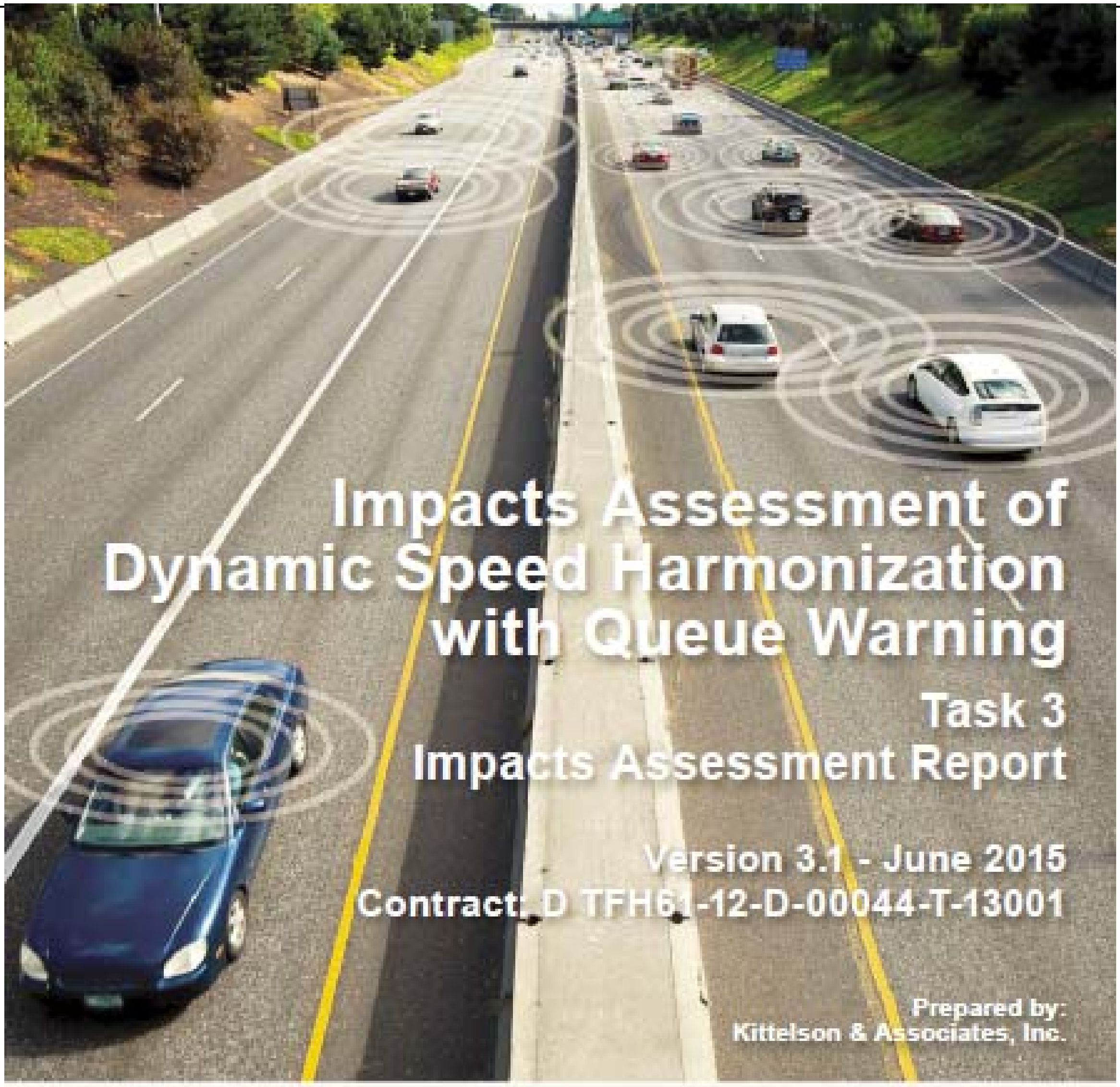


Purpose

- To estimate what the freeway performance benefits would be of employing speed harmonization with connected vehicles.

- Resources:
  - Microsimulation model
  - Limited field testing of devices in 7 vehicles
    - Proof of concept for DSRC technology
  - No human behavior testing, no safety testing

Speed Harmonization

- **Speed harmonization is the use of recommended speeds upstream of a vehicle queue to reduce the speed differential between the vehicles in queue and vehicles joining the queue.**

- **The objective is to reduce the occurrence of vehicle rear end collisions at the tail end of the queue caused by inattentive drivers.**

Conventional Speed Harmonization Installation in United States

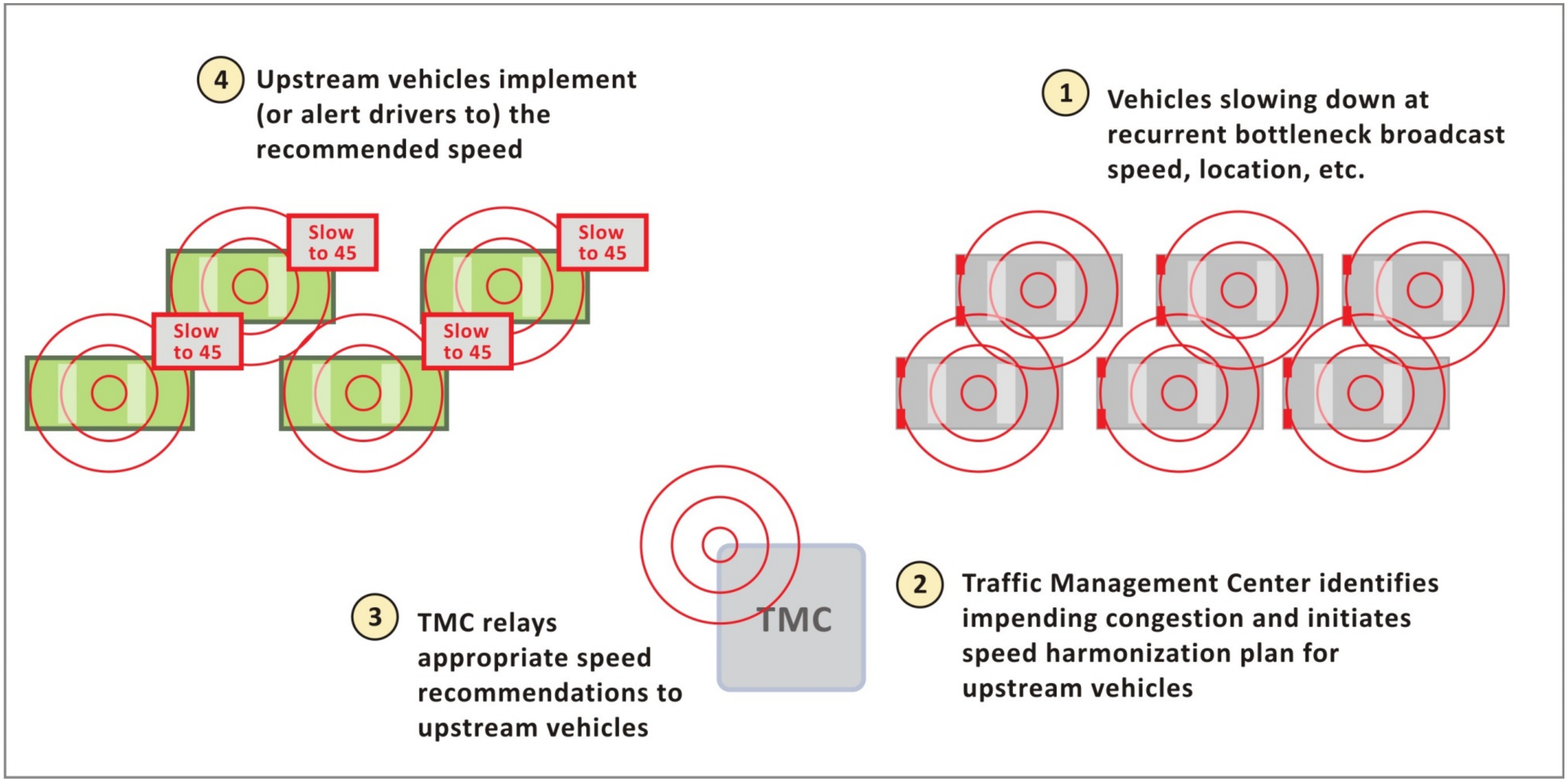
Detroit, MI, 1960

Seattle, WA, Now

Why Connected Vehicles

- Conventional Speed Harmonization employs roadside detectors to spot queues, and overhead electronic signs to display recommended speeds upstream of queue.
- Problem:
  - Detectors and overhead signs are expensive and hard to place more densely than one km apart.
- Solution:
  - Employ connected vehicles.
  - Can obtain speeds every 200m
  - Can communicate recommended speeds to drivers every 15 secs.
  - Don’t need 100% connected vehicles for success.

The Connected Vehicle, Speed Harmonization Concept (CV-SPD-HRM)

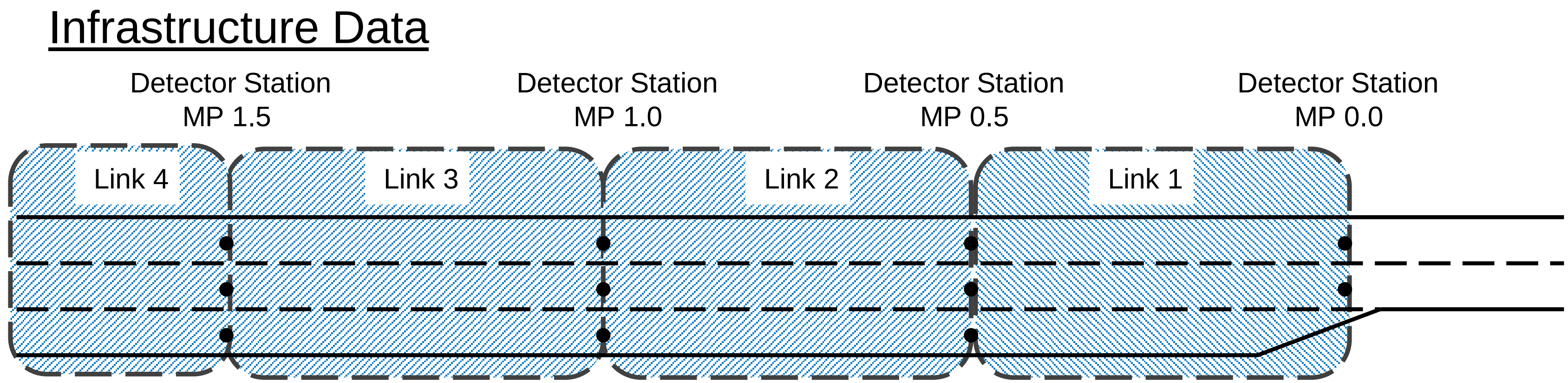


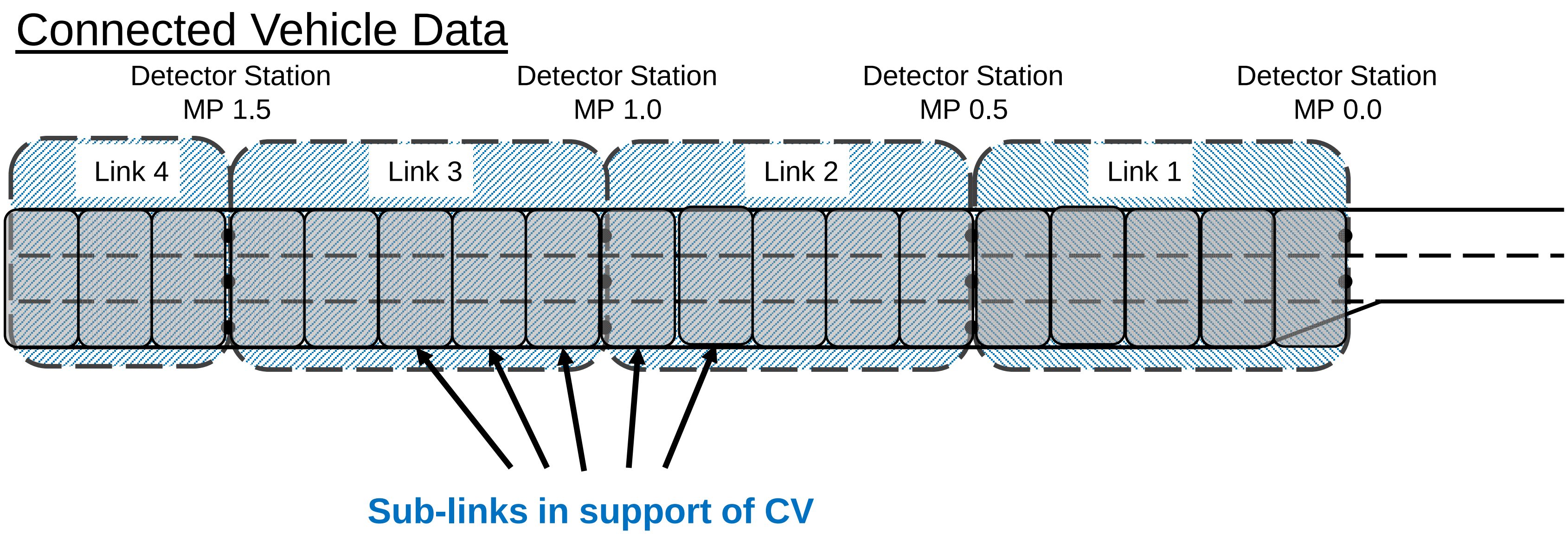
Source: FHWA-JPO-13-013 -- Concept Development and Needs Identification for Intelligent Network Flow Optimization (INFLO)

The TTI/Battelle Prototype

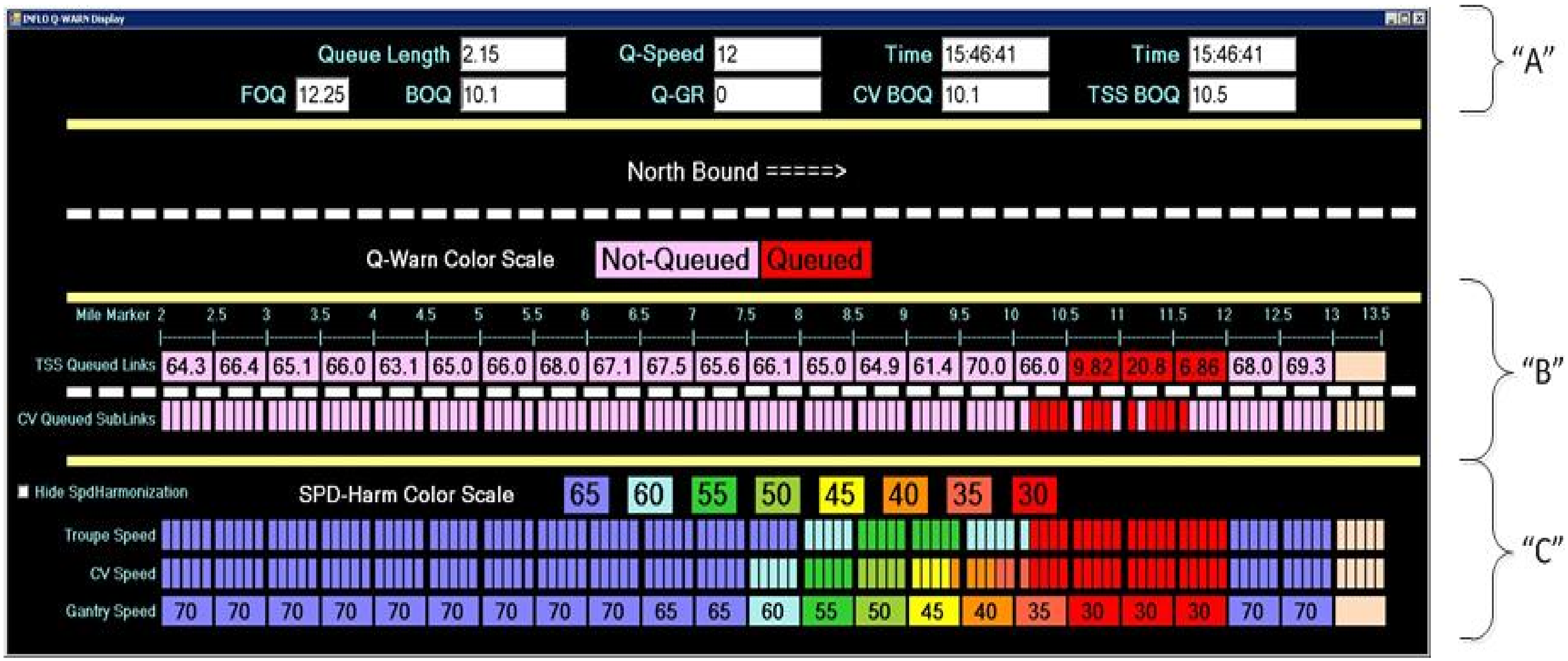
- Does not predict breakdowns, reacts to them.
- Method
  - Divides freeway into 160m long segments
  - Obtains speeds from road detectors and connected vehicles.
  - Averages speed for segment.
  - Groups adjacent segments with similar mean speeds into “super-segments”.
- Recommends speed (to nearest 10 km/h) for segment.
  - Cannot be > 10 km/h different from adjacent segment
  - Cannot be > Speed Limit
  - Cannot be < 50 km/h
  - Cannot be changed more than once per 15 seconds.

Infrastructure vs. Connected Vehicles



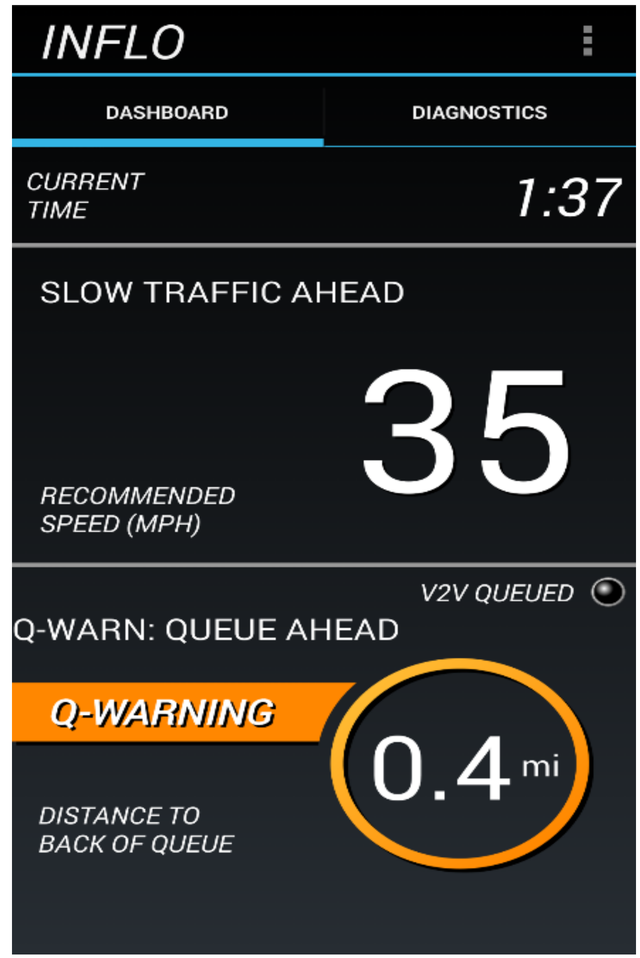


TMC Display



INFLO Q-WARN Display
Queue Length 2.15
Q-Speed 12
Time 15:46:41
Time 15:46:41
FOQ 12.25
BOQ 10.1
Q-GR 0
CV BOQ 10.1
TSS BOQ 10.5
North Bound =====>
Q-Warn Color Scale
Not-Queued
Queued
Mile Marker 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5
TSS Queued Links 64.3 66.4 65.1 66.0 63.1 65.0 66.0 68.0 67.1 67.5 65.6 66.1 65.0 64.9 61.4 70.0 66.0 9.82 20.8 6.86 68.0 69.3
CV Queued SubLinks
Hide SpdHarmonization
SPD-Harm Color Scale 65 60 55 50 45 40 35 30
Troupe Speed
CV Speed
Gantry Speed 70 70 70 70 70 70 70 70 70 65 65 60 55 50 45 40 35 30 30 30 70 70
"A"
"B"
"C"

In-Vehicle Smart Phone Display

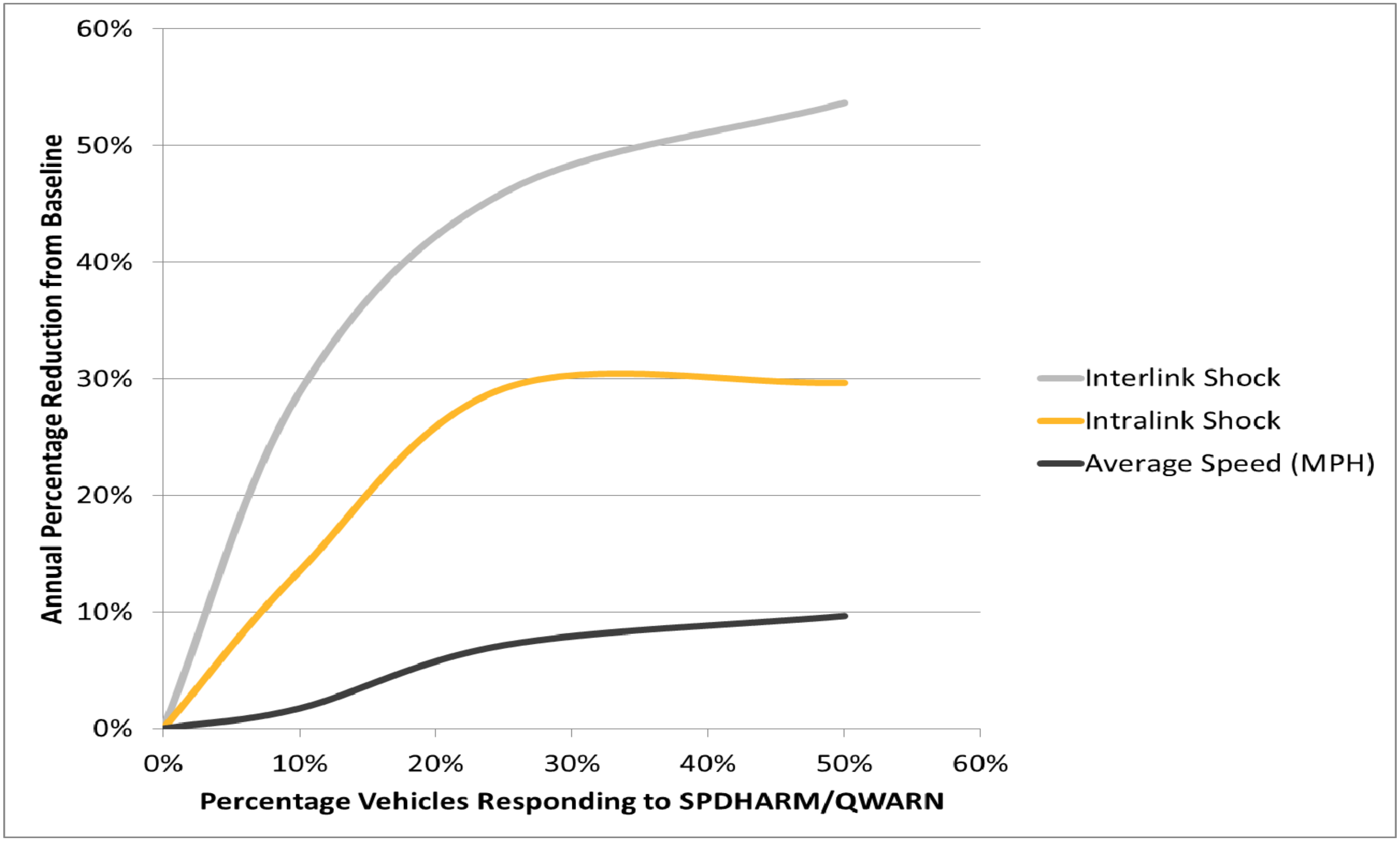


Evaluation Plan

- Test potential performance benefits using a microsimulation model for various crash and weather scenarios.
  - This enabled testing the effects of different connected vehicle market penetration rates.
    - Is there a minimum required penetration rate for success?

- Evaluate technical feasibility of connected vehicle communication with the TMC in the field.
  - Determine the relative feasibility of DSRC (dedicated short range communications) versus cell phone communication.

Microsimulation Results



Conclusions-Simulation

- Significant reduction in shockwaves between vehicles, even at the 10% response level.*
- Significant increase in lane changing by unconnected vehicles.
- Tradeoff for reduced shockwaves is 10% reduction in freeway speeds.
- The shockwave reduction benefits of CV-SPD-HARM increase rapidly even at low (under 10%) connected vehicle response levels

* Response Level = (% connected vehicles) x (% drivers complying with recommendations)

Conclusions – Field Test

- **Communication losses (lost messages) and delays (latency) for cell phone communication did not impair operation of the prototype.**
  - **Latency (time between vehicle slowing, detection, transmission, receipt by TMC, retransmission, and receipt by vehicle) was under 10 secs.**
- **Connected vehicles:**
  - **Detected queues 3 minutes sooner than the in-road detectors.**
  - **Pinpointed the back of queue 1 to 2 km farther upstream than road detectors.**