An Integrated Intelligent Intersection Control System (III-CS) for Safety Improvement

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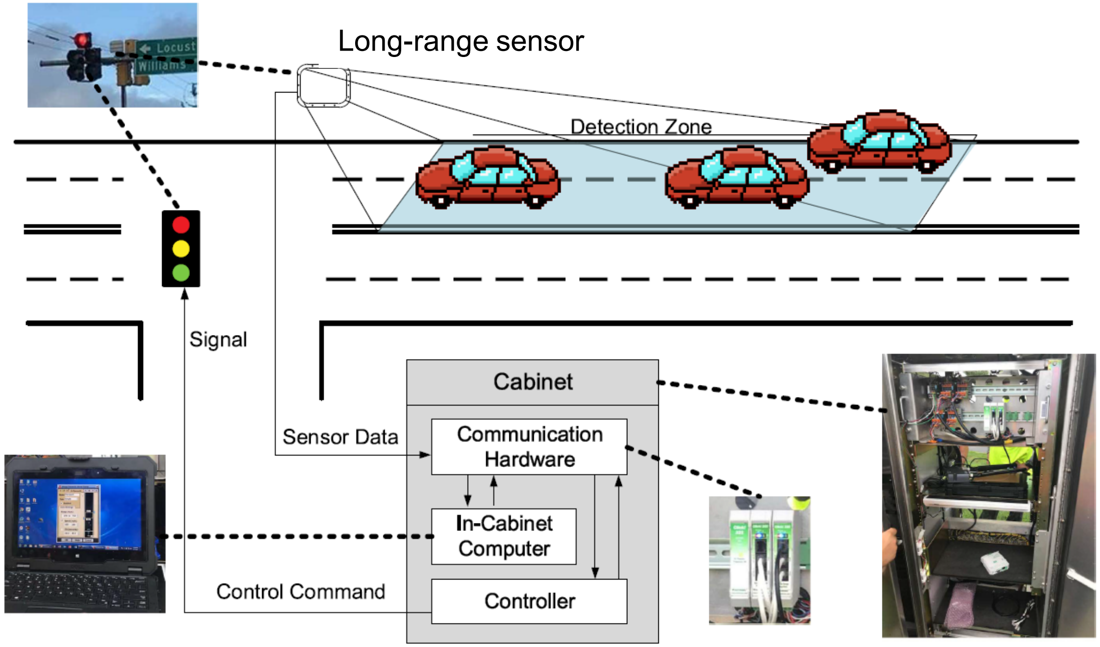
Introduction

- High-speed intersections often plagued by
  - Angle crashes & rear-end crashes

- An ***Integrated intelligent intersection control system (III-CS)*** has been developed to minimize the likelihood of having such crashes with **safety-based** control strategies

- Key system components:
  - Long-range sensors
  - Controller
  - In-cabinet computer
  - Communication hardware
- Control strategies
  - Dynamic all-red extension (DARE)
  - Dynamic green extension (DGE)



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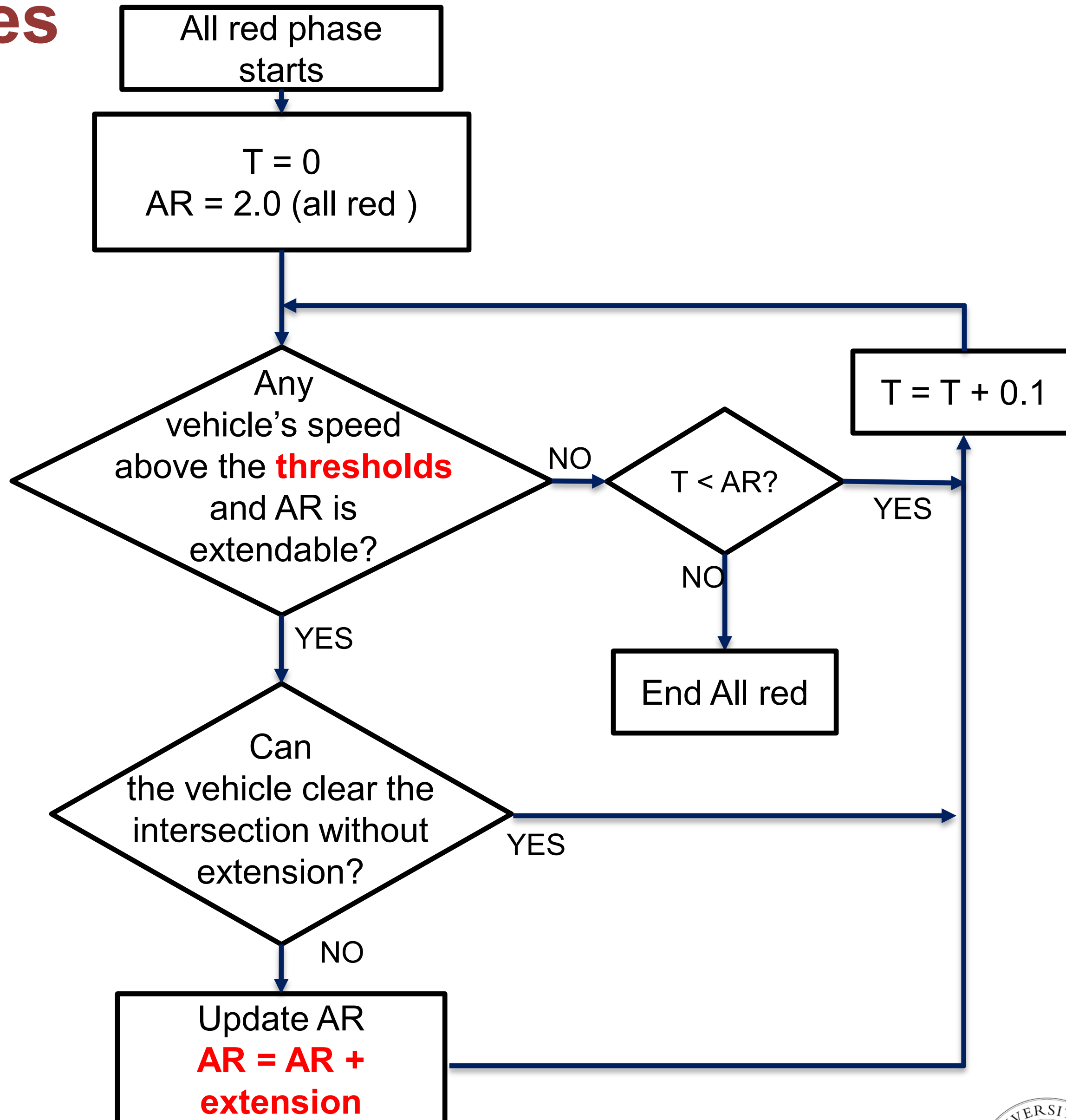
Control Strategies

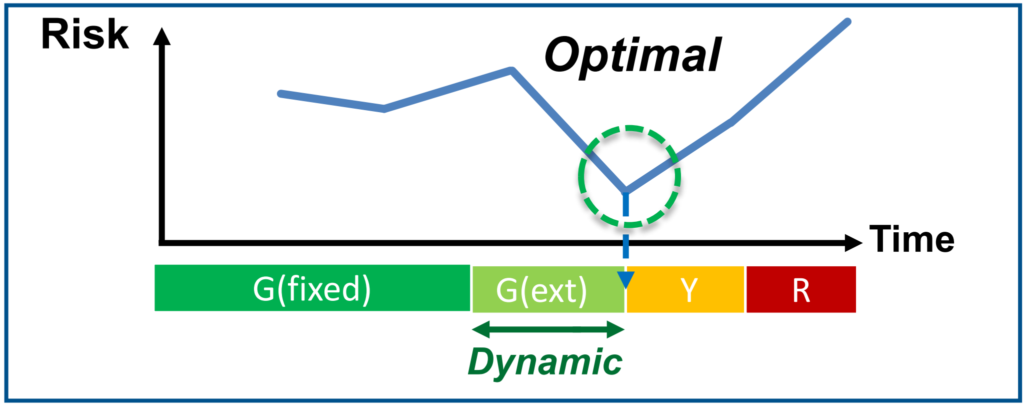
Dynamic all-red extension (DARE)

- Preventing angle crashes by detecting red-light running (RLR) vehicles
- Has been implemented since the previous phase (Park et al., 2018)



Control Strategies (Cont'd)

- **Dynamic green extension (DGE)**
  - **Purpose**: Minimizing the probability of incurring ***rear-end crashes***
  - DGE extends the green phase up to the duration of having the ***minimal risk*** of rear-end collisions.



  - Risks of rear-end collision: can be measured by ***"the estimated number of vehicles trapped in the dilemma zone"***

Dilemma zone (type-II)
- the spatial distribution in which these drivers are observed to have the probability of **10%–90%** to take the **stop decision** during the yellow phase

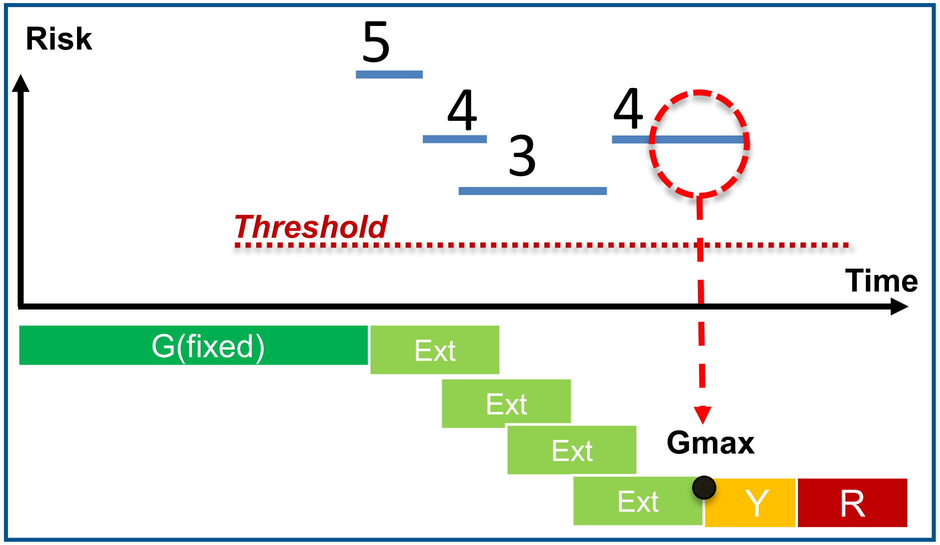
Parsonson, P. S., R. W. Roseveare, and J. R. Thomas Jr. 1974. "Small-area detection at intersection approaches." Traffic Eng. 44 (N5): 8–17.

Threshold and Comparison-based Logic

The key feature of the III-CS:
Comparison-based logic to making decisions by ***comparing current and future risks***

Threshold-based decisions (conventional)

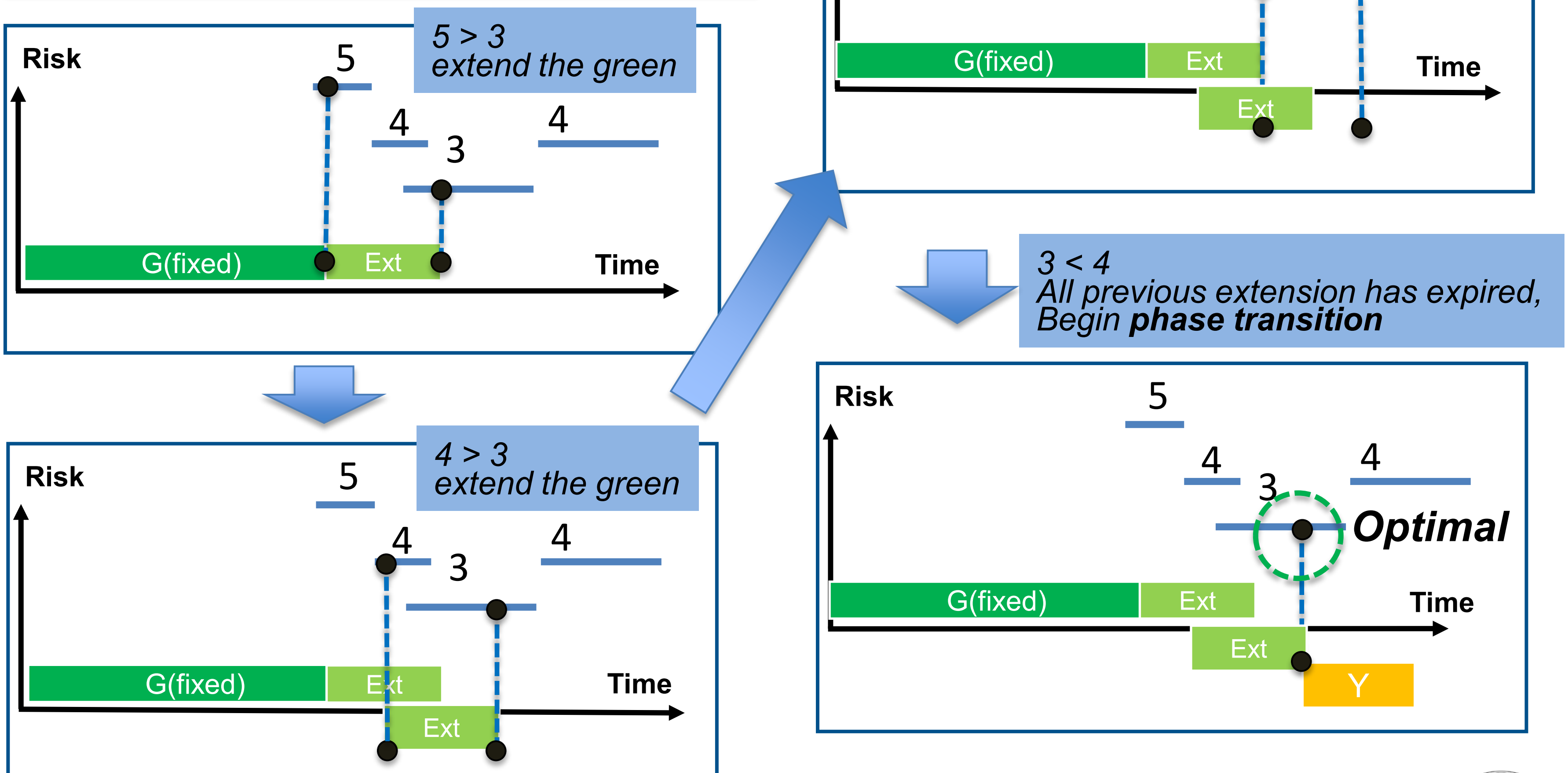
- Set a threshold to extend the green phase (e.g., 1 vehicle in DZ or 2 vehicles in DZ
- Works well in low-volume conditions
- However, will always extend to green when with high volumes (Zegeer, & Deen, 1978) or with multiple approaching lanes



Will always extend to maximum green, hence green phase termination is ***irrelevant to the risk level*** and may terminate at higher risks

Comparison-based decisions (proposed)

- Make decisions by ***comparing current and future risks***
- Even with heavy volumes, will select the optimal timing for phase transition, which has lowest risks



The Proposed Algorithm – DGT

Major steps of DGT

Step 1 Begin the green phase of high-speed approaches

Step 2 Retrieve the real-time data from the sensors

Step 3 Compare the current and future risks in real-time

Step 4 Determine if the window of dynamic green has begun

Step 5 Determine whether to change from green to yellow phase

Step 6 End DGT module, begin DARE module

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- Long-range wide sensors can update the following information at the interval of every 0.13(s) and cover the range of 500 - 1000(ft):
  - time-varying **speed** **[MPH]** of each vehicle
  - time-varying **position** **[ft]** of each vehicle
  - **Time-to-stop-line** (TSSL) **[s]** of each vehicle

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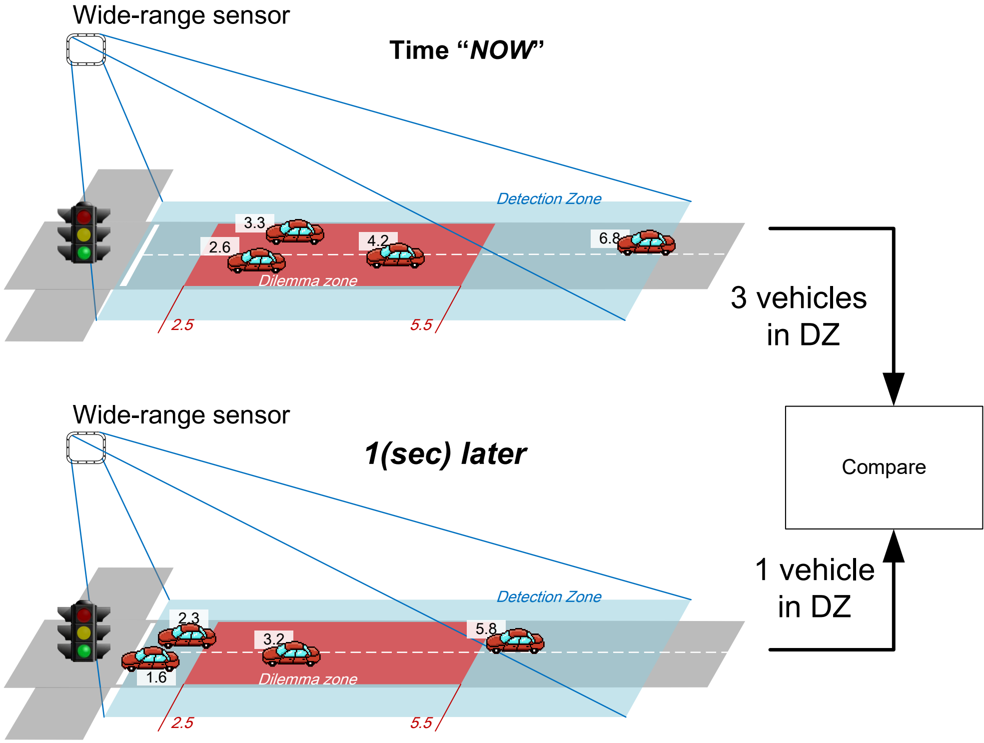
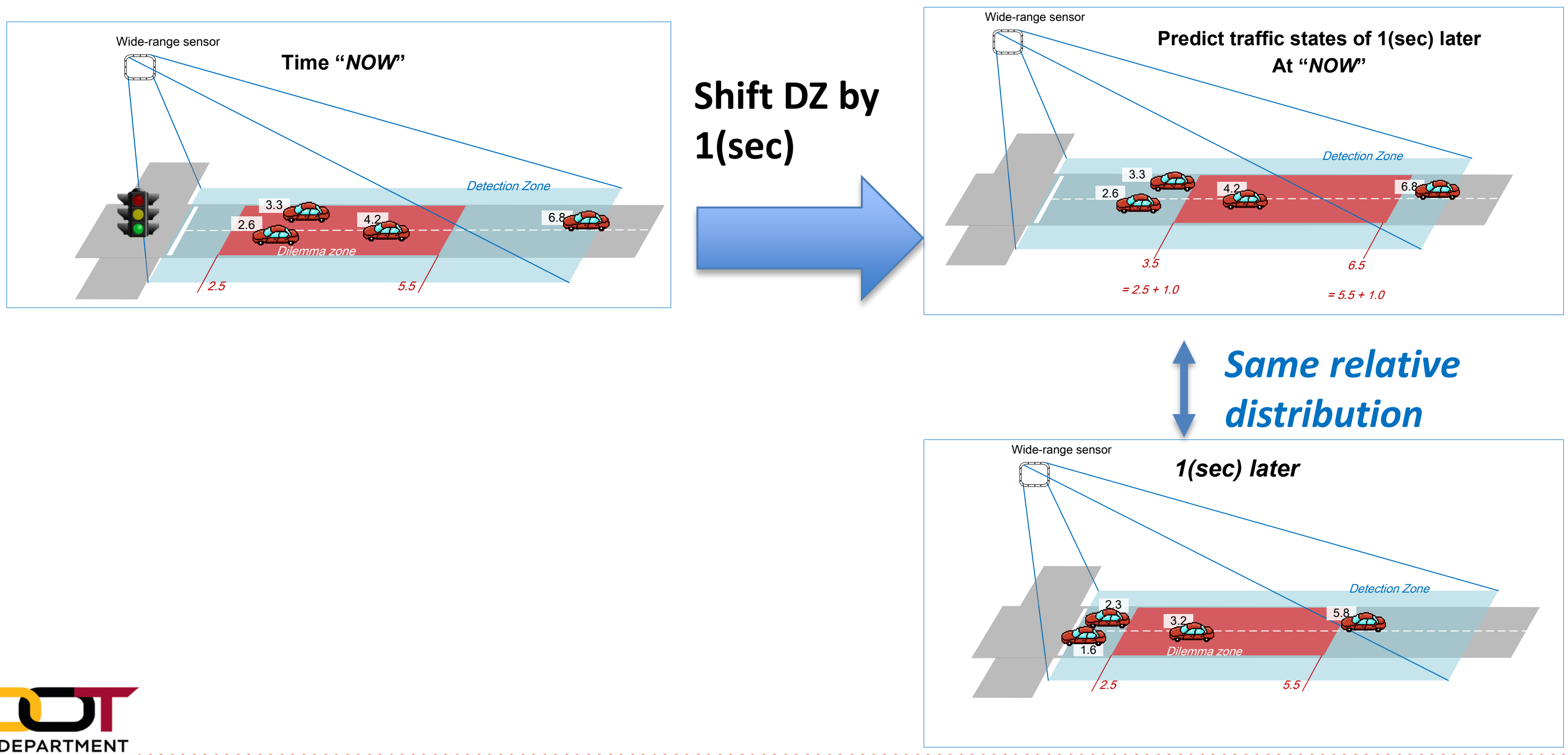


How to Predict Vehicles in DZ 1(sec) later?

- **Critical issue**: how to predict vehicles in DZ 1(sec) later?
  - In order to execute comparison-based logic
- **Proposed Method**: By shifting the dilemma zone, 1 second in terms of time-to-stop-line,
  - Because the relative distribution between vehicles and the dilemma zone will be the same



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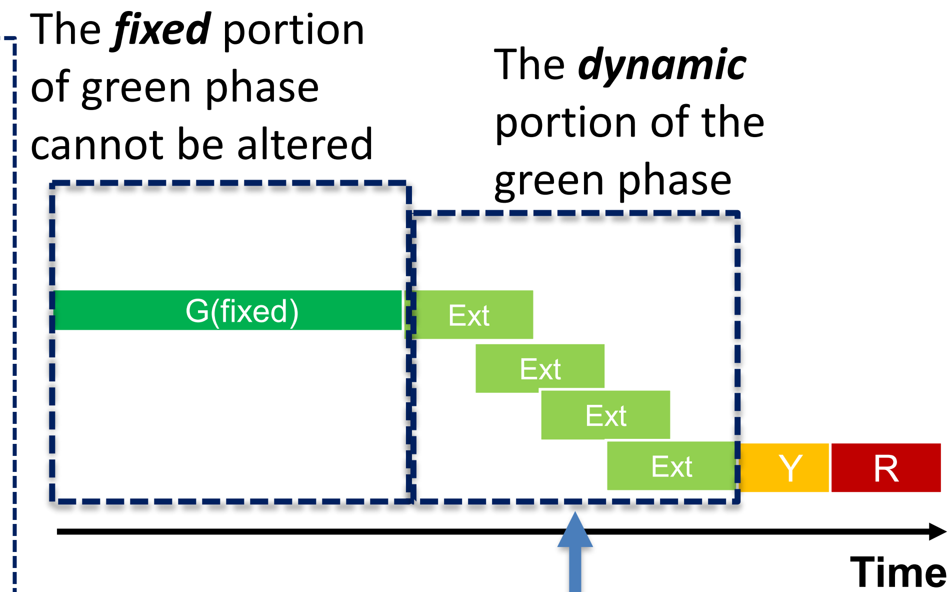

If the within the time window of the dynamic green:

- Go to step 5

Else: go back to step 2

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If current risk is lowest

- ***Compare with past-*** The green extension one second earlier has expired (current risk lower than 1 sec earlier)
- ***Compare with projected future-*** And no further extension has been called (current risk no higher than 1 sec later)
- **Then** change to yellow phase

Else If the maximum green has reached

- **Then** change to yellow phase

- Maximum green:
  - gMax for isolated intersections
  - “Yield Point” in coordinated intersections

Else Repeat step 2

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Sites

US 40 @ Western Maryland Pkwy., Hagerstown

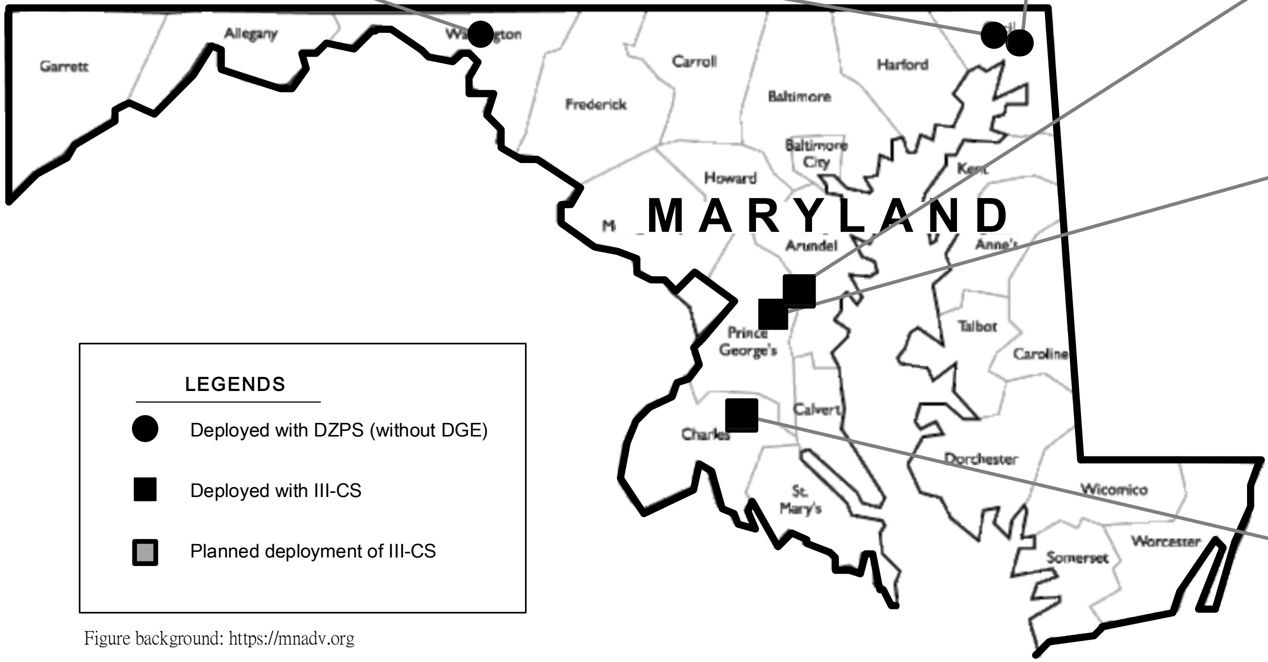
US 40 @ Red Toad Rd., North East

MD 213 @ Locus Point Rd. Williams St., Elkton

US 301 @ Governor Bridge Rd./ Harbour Way, Bowie

MD 4 @ Forestville Rd., Forestville

US 301 @Billingsley Rd., St. Charles



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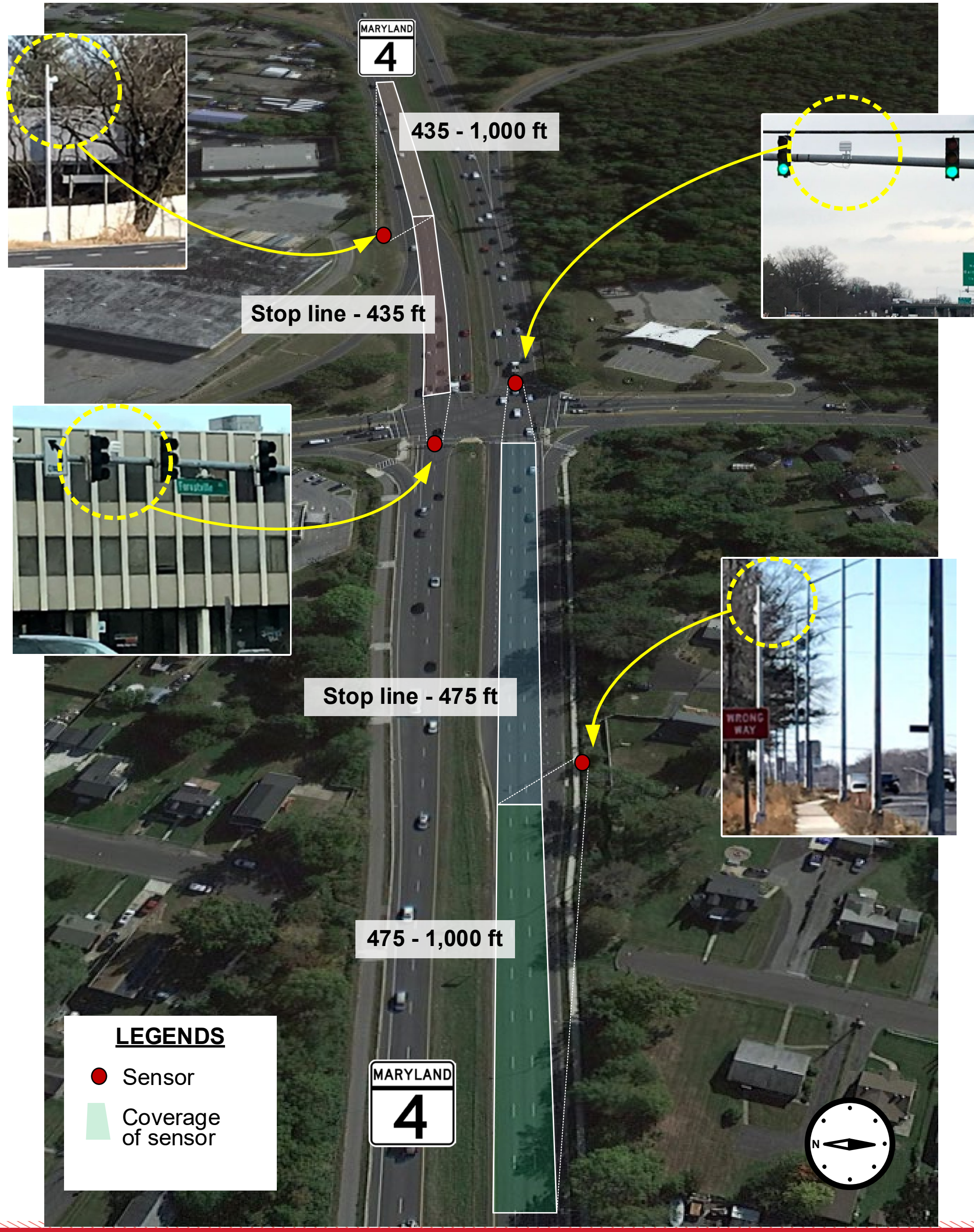

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Results- DARE

RLR: Red-light runner
AR: All-red interval

	Before Apri-10-2019	**After** Jan-28-2021	**After** Mar-22-2021
Red-Light Running			
No. of cycles	92	123	196
No. of RLRs	11	8	24
RLR/cycle	0.119	0.065	0.116
No. of RLRs not cleared after 2-sec default AR	**2**	**3**	**7**
DARE Activations			
# AR-Extension actions	N/A	12	30
# False alarm	N/A	9	23
# Missed call	N/A	0	0
Missed call rate (%)	N/A	**0% (0/3)**	**0% (0/7)**
Detection rate (%)	N/A	**100% (3/3)**	**100% (7/7)**
False alarm rate (%)	N/A	**7.3% (9/123)**	**11.7% (23/196)**

Results-DGE

Samples from the DGE's actions:

- ***Optimal activation***: the decisions by the DGE indeed resulted in a **lower collision risk** over the subsequent intervals based on the traffic conditions and the number of vehicles in the dilemma zone.
- ***Non-optimal activation***: the DGE's decisions did not result in a reduction in the collision risk over the subsequent intervals
- ***Incorrect call***: the DGE failed to extend the green time

	After Jan-28-2021	**After** Mar-22-2021
Rate of optimal DGE activation (Number of optimal activations/ Number of activations)	**66.7%** (72/108)	**81.3%** (87/107)
Rate of non-optimal activation (Number of non-optimal activations/ Number of activations)	30.6% (33/108)	18.7% (20/107)
Incorrect call rate (Number of incorrect activations/Number of activations)	2.7% (3/108)	0.0% (0/107)

Summary

- Using the hardware for the previously-developed **dynamic all-red extension (DARE)** for dilemma zone protection system (DZPS), III-CS further is further embodied with a **dynamic green extension (DGE)** to prevent rear-end collisions

- III-CS has identified potential risks.
  - Risk of angle crashes reduced by DARE
  - Risk of rear-end crashes reduced by DGE

- III-CS has proved to effectively reduce the risk of collisions during the field deployment, which can be observed from
  - High **red-light runner detection rate** of DARE (100%)
  - High **optimal activation** of DGE (66.7%, 81.3%)

Extensions

- Integrate pedestrian protection function to the current system
  - Delay the pedestrian phase or alert pedestrians when there is a red-light runner
- Implement the system to an arterial to further improve its effectiveness

References

- Park, S. Y., Lan, C. L., Rao, R. S., & Chang, G. L. (2018). Field evaluation of the dilemma zone protection system at suburban intersections. *Transportation research record*, *2672*(21), 51-62.
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- Zegeer, C. V., and R. C. Deen. 1978. Green-extension systems at highspeed intersections. Research Rep. No. 503. Frankfort, KY: Dept. of Transportation, Commonwealth of Kentucky

THANK YOU!

For additional Questions, please contact

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