AASHTO
AASHTO INNOVATION INITIATIVE

AASHTO Innovation Initiative

[Proposed] Nomination of Innovation Ready for Implementation

Sponsor

Nominations must be submitted by an AASHTO member DOT willing to help promote the innovation. If selected, the sponsoring DOT will be asked to promote the innovation to other states by participating on a Lead States Team supported by the AASHTO Innovation Initiative.

1. Sponsoring DOT (State): Arizona Department of Transportation

2. Name and Title: Steven Cheshko, Transportation Engineer Associate

Organization: Arizona Department of Transportation

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State: AZ

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Phone: 602-712-2239

Fax: N/A

Innovation Description (10 points)

The term “innovation” may include processes, products, techniques, procedures, and practices.

3. Name of the innovation:

MaxFlow Adaptive Ramp Metering

4. Please describe the innovation.

ADOT uses ramp metering at most of the freeway on-ramps in the Phoenix area to ease merging, increase mobility, and improve safety over free-flow ramps. ADOT has upgraded to Q-Free® 2070© controllers for ramp meter operations. Within the ramp metering software on these controllers, there is a "User Program" capability that allows for specialized and customizable operations. ADOT engineers used this platform to create an algorithm that allows a ramp meter to use inputs from both the local ramp meter and a downstream neighbor in a decision tree to adjust a virtual "detector" by comparing local flow with downstream excess demand (realistic metering rates for queuing and compliance versus the ideal rate for traffic flow balance). The built-in traffic-responsive metering strategy then uses this "detector" to set metering rates.

5. What is the existing baseline practice that the innovation intends to replace/improve?

Prior ramp metering was either done at a fixed rate or through a local-traffic responsive strategy. While responsive could make decisions on turning on and which metering rates to use, it could not turn itself off.

6. What problems associated with the baseline practice does the innovation propose to solve?

Baseline practice only looked at the detectors locally hardwired into the controller. Balancing traffic flow was difficult because meters either had to be constantly trying to adjust for possible downstream congestion or wait until the congestion had backed up to the local meter. While other options for adaptive are available, they often require third-party software.
Once a ramp began to meter, it would not go dark until the allowable hours were over.

7. Briefly describe the history of its development.

Original meters operated at fixed rates. ADOT then expanded to the use of local-traffic responsive metering. In 2019, the adaptive algorithm (MaxFlow) was developed in-house and piloted on southbound State Route 51 in Phoenix. Starting in 2021, it was rolled out to different areas of the system depending on hardware and traffic congestion. The same year saw their first use in off-peak hours for construction-detour metering. Finally, starting at the end of 2022, more speed-based thresholds were tested for less-congested areas.

8. What resources—such as technical specifications, training materials, and user guides—have you developed to assist with the deployment effort? If appropriate, please attach or provide weblinks to reports, videos, photographs, diagrams, or other images illustrating the appearance or functionality of the innovation (if electronic, please provide a separate file). Please list your attachments or weblinks here.

i. A Tableau© dashboard was created to identify capacity, a needed requirement, for each individualized location.

ii. The University of Arizona developed an analytics tool to upload data from loop detectors, controller cabinets, and INRIX to evaluate the before-and-after operation and performance of the system. (Refer to attached report.)

iii. The Ramp Metering Design Guide was updated to remove warrant criteria in the Phoenix region to better utilize adaptive metering.
https://azdot.gov/sites/default/files/2019/07/Ramp-Metering-Design-Guide-Errata.pdf

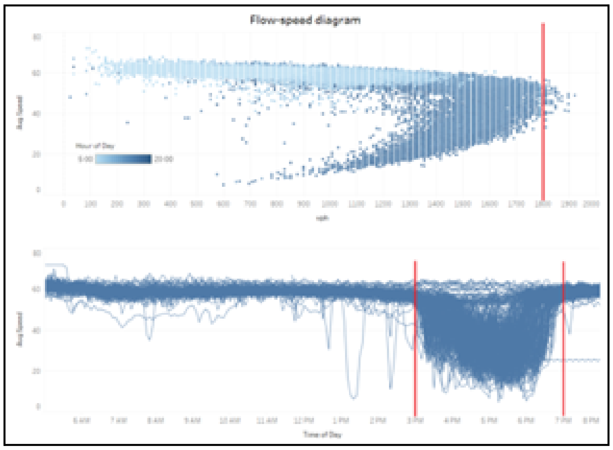
iv. Decision diagrams and example coding have been shared with different DOTs and organizations. (Refer to attached spreadsheet.)

v. A rollout plan, standard work, and ramp settings spreadsheet were written for in-house planning and setup.

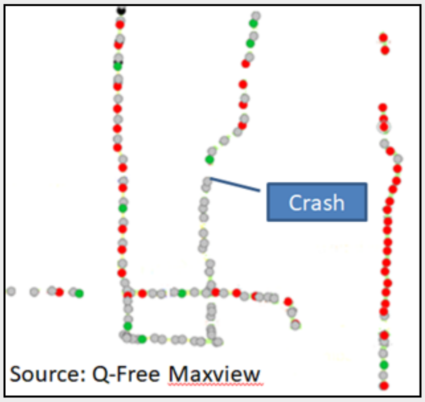
vi. Presentations have been shared with peer exchange groups, professional conferences, and the Operations Academy management program for traffic operations.

Attach photographs, diagrams, or other images here. If images are of larger resolution size, please provide as separate files.

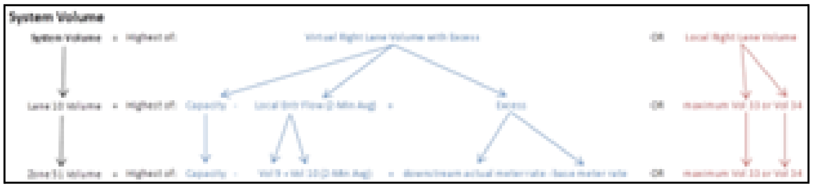
Tableau for Capacity and Metering Hours



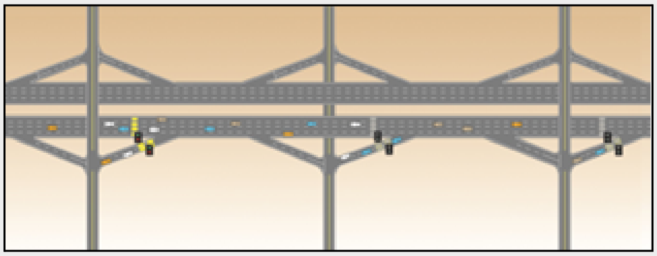
Adaptive Going Dark Downstream of a Large Crash



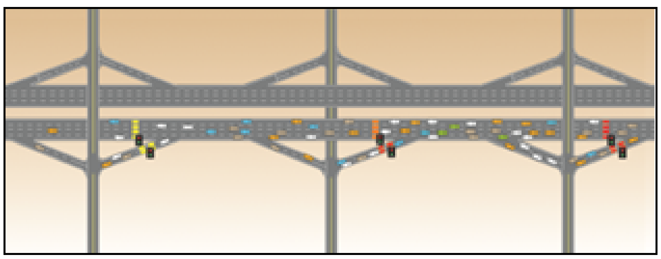
Decision Tree



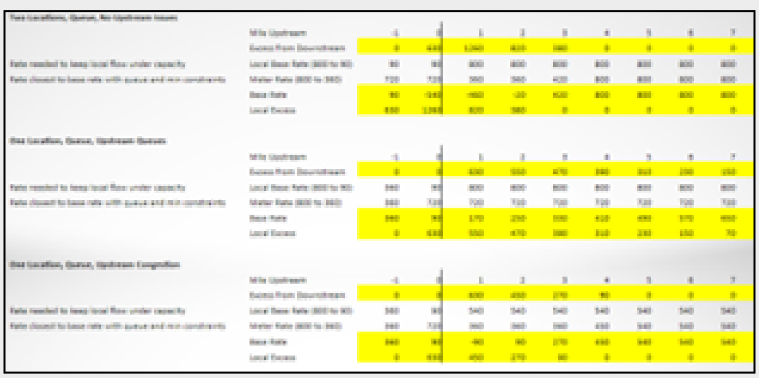
Adaptive Function at Low Flows



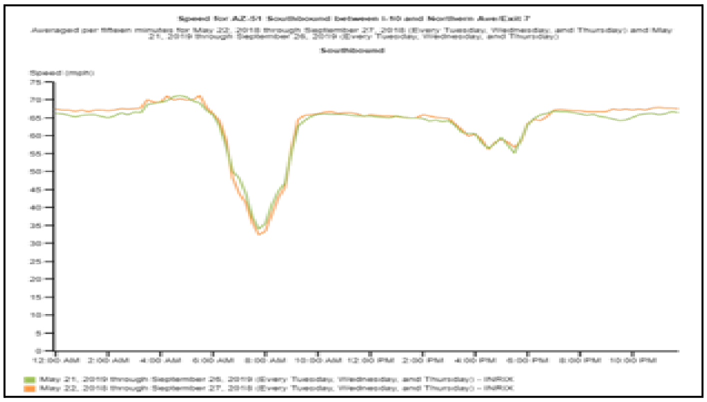
Adaptive Function With Excess Flows



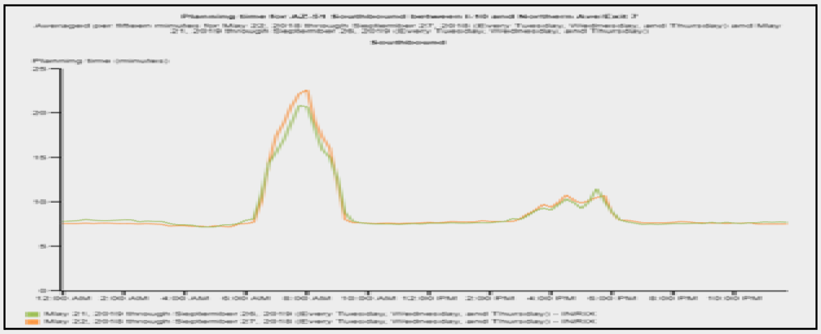
Example of Adaptive Rates and Propagation



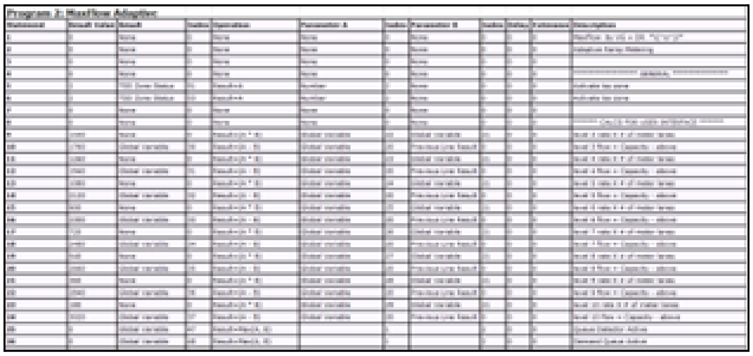
Before-and-After Speeds From Pilot Test



Before-and-After Planning Time Index (PTI) From Pilot Test



Snippet of MaxFlow Code



State of Development (40 points)

Innovations must be successfully deployed in at least one State DOT. The AII selection process will favor innovations that have advanced beyond the research stage, at least to the pilot deployment stage, and preferably into routine use.

9. How ready is this innovation for implementation in an operational environment? Please select from the following options. Please describe.

☐ Prototype is fully functional and yet to be piloted

☐ Prototype has been piloted successfully in an operational environment

☐ Technology has been deployed multiple times in an operational environment

☒ Technology is ready for full-scale implementation

ADOT has implemented this technology on over 75% of its 250+ ramp meters. Different use cases and threshold methodologies have also been tested.

10. What additional development is necessary to enable implementation of the innovation for routine use?

The main development is done and the innovation is used routinely. Special-use cases—such as navigating system interchanges to understand where metering ramps on one corridor may affect traffic on another corridor, as well as more speed-dependent thresholds—have also been tried, the latter more so.

11. Are other organizations using, currently developing, or have they shown interest in this innovation or of similar technology?? ☒ Yes ☐ No

If so, please list organization names and contacts. Please identify the source of this information.

Organization	Name	Phone	Email
Utah Department of Transportation	Scott Stevenson	801-824-0314	scottstevenson@utah.gov
Washington Department of Transportation	Lian E. Roberts	509-324-6560	RobertsL@wsdot.wa.gov
RTC of Southern Nevada	Joanna Wadsworth	702-901-8466	wadsworthjo@rtcsnv.com

Potential Payoff (30 points)

Payoff is defined as the combination of broad applicability and significant benefit or advantage over baseline practice.

12. How does the innovation meet customer or stakeholder needs in your State DOT or other organizations that have used it?

The pilot project saw an increase of speed and reliability (planning time index, or "PTI") in a year-to-year comparison. (Note that subsequent rollouts have had varying success, although post-pandemic traffic is harder to compare.)

The strategy also allows for more flexible metering as ramps can go dark when they are no longer needed. This means more effective stopping for the public during less predictable traffic patterns.

Finally, having an in-house algorithm that works within the ramp meter software saved the cost of having to purchase and integrate third-party adaptive software.

13. Identify the top three benefit types your DOT has realized from using this innovation. Describe the type and scale of benefits of using this innovation over baseline practice. Provide additional information, if available, using quantitative metrics, to describe the benefits.

Benefit Types	Please describe:
Improved Operation Performance	Speeds during morning rush hour increased an average of 3% (1.3 mph) with a max of 9% (4 mph)*
Improved Operation Performance	PTI during morning rush hour increased an average of 6% (0.9 min) with a max of 10% (1.9 min)*
Improved Operation Performance	Flexibility to use metering in different scenarios with less fear of over-metering if conditions do not degrade as expected

Provide any additional description, if necessary:

*This was for the more congested southern portion of the corridor. The time period was mostly June through September for 2018 and 2019 to correspond to the beginning of the pilot but avoided influence from the new service patrol and Covid-19. The parallel fixed rate corridor nearby had no significant change in speed.

14. How broadly might this innovation be deployed for other applications in the transportation industry (including other disciplines of a DOT, other transportation modes, and private industry)?

The basic methodology of getting upstream signals to help balance high demand downstream may work for different types of signals that are working along a corridor. However, it would depend on whether or how that information could be shared. The coding part is also likely unique to this controller and manufacturer.

Market Readiness (20 points)

The AII selection process will favor innovations that can be adopted with a reasonable amount of effort and cost, commensurate with the payoff potential.

15. What specific actions would another organization need to take along each of the following dimensions to adopt this innovation?

Check boxes that apply	Dimensions	Please describe:
☐	Gaining executive leadership support	Changing what travelers expect (i.e., time of day) should be cleared with leadership.
☒	Communicating benefits	The public understands the platooning but not the flow benefits of ramp metering.
☐	Overcoming funding constraints	The algorithm is free and only requires some programming time (assuming the right hardware is already installed).
☐	Acquiring in-house capabilities	The algorithm is already available and is relatively simple to input with instruction.
☐	Addressing legal issues (if applicable) (e.g., liability and intellectual property)	There could be some liability issues around changing traveler expectations.
☒	Resolving conflicts with existing national/state regulations and standards	Depends on what exists. Guidelines were updated for ramp-metering warrants.
☒	Other challenges	Need to work with internal staff (maintenance, operators, etc.) to discern if reported abnormalities are actual issues or artifacts of the algorithm.

16. Please provide details of cost, effort, and length of time expended to deploy the innovation in your organization.

Cost: (Keep in mind that this runs on the Q-Free ramp meter system. ADOT's hardware and license fees through Q-Free, at scale, are currently at a one-time cost between $5–6K per location.)

The algorithm was written in-house, so the initial cost was staff hours. For subsequent deployments, the algorithm itself is free, so the main cost would be staff hours for individual setup.

Level of Effort: Initial involvement effort was high since it required creating the methodology, learning the programming language, and developing the algorithm. Adjusting the algorithm, especially for particular use cases, is a medium effort. Deploying to new locations will only take a template and some basic information, so it is low effort.

Time: Initial development of and adjustments to the algorithm took a few months. With a template and capacity information, staff time can be around 15 minutes per location. It is also recommended that staff monitor corridors for a couple of peak periods after deployment to make sure things are functioning as expected.

17. To what extent might implementation of this innovation require the involvement of third parties, including vendors, contractors, and consultants? If so, please describe. List the type of expertise required for implementation.

ADOT worked with the vendor (Q-Free) to learn how to use the User Program function and the virtual detector option. The ADOT staff were all civil engineers.

The data side (capacity, congestion hours, mobility measures) has been a mix of in-house, OZ Engineering, the University of Arizona, and INRIX. However, most DOTs likely already have their own processes in place for most of this.

Assuming that any given DOT is already using Q-Free ramp metering, the template can be set up in-house either by engineers, operators, or maintenance (depending on who normally sets up the meters).