



STUDY SESSION MEMORANDUM

TO: Mayor and Members of City Council

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DATE: December 12, 2024

SUBJECT: Study Session for December 12, 2024
Vision Zero Action Plan: Traffic Signal Practices Update

EXECUTIVE SUMMARY

The purpose of the Council Study Session is to:

- Describe the city's current traffic signal practices and the results of implementation
- Identify opportunities for change and highlight constraints
- Receive feedback on the scope of work prior to staff initiating work

In 2018, city staff prepared a traffic signal practices manual to guide the planning, design, construction, maintenance, and operations of the traffic signal system. The manual was prepared based on review of national standards, peer agency and industry research, as well as documentation of city practices. The manual is a technical document that Transportation Operations staff use to efficiently and consistently make decisions about traffic signal installation and operation based on established engineering principles and in alignment with [Transportation Master Plan](#) and Vision Zero goals.

Subsequently, the [Boulder Vision Zero Action Plan, May 2023](#) includes actions that recommend certain sections of the traffic signal practices manual related to left turn phasing, right turn on red restrictions, and leading pedestrian intervals (LPI) be updated. The sections on accessible pedestrian signals (APS) and signal coordination with respect to pedestrian signals are also planned to be updated in response to recent Transportation Advisory Board (TAB) and community working group feedback received on the *Pedestrian Crossing Treatment Guidelines* update. The action plan specifies that once the practices are updated, any changes recommended as a result should first be implemented across the High Risk Network, then at other signals. The action plan also acknowledges

that the city will likely need to pursue and secure grant funding to fully fund the anticipated signal system enhancements.

KEY ISSUES IDENTIFIED

The key issues identified include:

- Signal practices manual overview
 - Clarify the sections on which the update will focus
- Vision Zero context
 - Describe the crash patterns occurring at signals and potential for crash reduction
- Results of implementing current signal practices
 - Highlight crash reduction attributed to implementing current practices
- Existing signal system context
 - Identify opportunities and constraints to implementing left turn phasing changes
- Scope of work considerations
 - Understand the various levers that can be adjusted and the technical considerations, costs, and impacts of doing so

These issues are described in more detail within the memo and are expected to be the focus of the staff presentation to and discussion with Council.

Questions for Council

1. Does council have any questions about the current state of the signal system and practices to date?
2. Does council have any questions about the overall intent of the signal practices update as a *Vision Zero Action Plan* action item?
3. Does council have any feedback on the proposed scope of work outlined in this memo?

BACKGROUND

The traffic signal practices manual was first developed in 2018. The manual is divided into five sections that cover many aspects related to the installation and operation of traffic signals, such as: planning and warrants; design; construction; maintenance; and operations. The *Vision Zero Action Plan* directs the city to complete an update to the operations section. This section details how the city determines such things as left turn phasing, location of right turn on red restrictions, and location of leading pedestrian intervals.

The *Vision Zero Action Plan* includes actions focused on updating the operations section of the signal practices manual because left turn crashes and right turn on

red crashes are two of the top seven common crash types that account for 62% of fatal and serious injury crashes across the High Risk Network. These crash types can be mitigated, in part, through signal timing or phasing changes expected to be informed by an update to the traffic signal practices manual.

Since the late 1970s, cities in the United States have typically practiced allowing right turns on red (RTOR). This widespread practice was based on assumptions that allowing RTOR would reduce emissions from idling vehicles. However, in recent years, some cities have reconsidered this practice, trending toward restricting RTOR at high-pedestrian volume locations or locations with other conflicts, or banning RTOR outright. Cities in the United States that currently have a ban on right turns on red include: New York City; Ann Arbor, MI; Cambridge, MA; and Washington, D.C. (upcoming). Several other cities like Atlanta, San Francisco, Seattle and Los Angeles are also considering widespread bans on right turns on red lights.

It is significantly more challenging from a policy perspective for cities to allow left turns at traffic signals to occur only on green arrows (protected only phasing). This is due either to constraints with signal system infrastructure (signal mast arm not long or strong enough, outdated controller software, constrained conduits to run additional wiring) or intersection lane geometry. Boulder also faces these constraints. National research, and Boulder's own before/after evaluation studies, shows that protected only left turn phasing is most beneficial in locations with high multimodal and vehicle volumes or where there is a left turn crash pattern, attributable to site conditions, such as number of lanes turned across, speed or visibility of oncoming traffic, and the number of gaps in opposing traffic and number of left turns. Cities, including Boulder, have begun to implement left turn phasing changes both reactively in response to crash patterns or proactively in areas with high multimodal volumes and have seen positive results in crash reduction. The city began implementing left turn phasing changes proactively as early as 2004, with flashing yellow arrow signal indications installed at a total of six intersection approaches that year.

In Boulder, Transportation Operations staff has been strategically implementing the current signal practices across the city to address the most problematic locations and proactively make changes where conditions met criteria to do so. Many of the locations where changes have been made were identified through prior crash data analyses done for *Safe Streets Boulder Reports*. Since 2018, Flashing Yellow Arrow (FYA) signal heads have been installed at 149 intersection approaches and left turn phasing changes have been made at 54 approaches. The progress made is significant and has resulted in a 68 percent reduction in all left turn crashes (property damage only plus severe) (76 crashes/year reduced to 25 crashes/year). This finding is based on a review of before/after crash data at intersections where left turn phasing changes have been made, in accordance with the current practices.

The strategic approach to implementing the current practices has served the community well and been successful. In addition, because of the current practices, Transportation & Mobility has been able to successfully pursue grants to assist with funding enhancements

to the signal system because of the way in which the left turn phasing evaluation process justifies the project against various grant scoring criteria, such as those for Highway Safety Improvement Program (HSIP) or Safer Signals.

Types of Left Turn Signal Phasing

Signalized left-turn movements can be operated in three primary ways – permitted only, protected only, and protected-permitted. The way in which left turns are operated on an intersection approach is currently programmed, in many cases across the city, to vary by time-of-day. The left turn phasing for a particular time period is guided by the current signal timing practices and selected depending on evaluation of specific conditions, such as the vehicle and multimodal volumes, that vary throughout the day.

Permitted only left turns are indicated with either a solid green ball or FYA signal indication. A vehicle may turn left on one of these indications but must yield to conflicting vehicular traffic, as well as bicyclists or pedestrians in a bicycle lane or crosswalk.



Protected only left turns are indicated with a green arrow indication when vehicles are allowed to turn and a red arrow display when vehicles are not allowed to turn. During a protected left turn phase, a vehicle may turn left while opposing traffic, and any other conflicting road users, including bicyclists and pedestrians, are stopped. To implement protected left turn phasing, an intersection approach must have an exclusive left turn lane and the necessary signal head(s) positioned over the center or aligning with the left turn lane marking. This requires the mast arm to be both long enough to extend to/over the left turn lane and strong enough to support the left turn signal head(s) at the end of the mast arm.



In some cases, the city uses a combination of *protected and permitted* operations at the same signal. The protected left turn phase may either be served first (leading) or last (lagging). The use of FYA signal indications allows for greater flexibility in how the phases operate and the sequences in which they can be shown throughout the signal cycle.

Council Prioritization

Boulder City Council elevated implementation of Actions 1.B.ii., 1.C.i., and 5 of the *Vision Zero Action Plan*, to update the signal practices manual, as an area of strategic focus at the April 2024 council retreat.

Transportation Advisory Board Feedback

The Transportation Advisory Board (TAB) provided feedback on the traffic signal practices manual update at its September 2024 meeting. High-level themes of the feedback are summarized as follows:

- Interest in the advisability and feasibility of banning right turns on red.
- Interest in the use of technology, such as blank-out signs, or other signal operational changes, such as LPI, to mitigate right turn on green crashes.
- Ability to analyze all crash types, even those that are property damage only, to inform decisions about traffic signal operations.
- Feasibility of using near-miss technology or analyzing close call reports to inform decisions about traffic signal operations.
- Options to mitigate concerns about the Broadway/Regent Dr/20th St intersection.
 - Note: A Transportation & Mobility grant-funded project will be completed at the intersection in the winter/spring 2025 timeline to add left turn phasing on the Regent Dr and 20th St approaches to mitigate conflicts between left turning vehicles and pedestrians and bicyclists crossing Broadway.
- Feasibility of adjusting signal timing and phasing on a time-of-day or seasonal basis (e.g. no right on red or protected left turn phasing only during certain times of day or seasons of the year [when school is in session]).
 - Note: Many left and right turn operations are already programmed to operate differently during certain times of day based on site conditions.

ANALYSIS

Council is asked to consider the scope of work for the update to the traffic signal practices manual, specifically with respect to the content, expected crash reduction potential, and existing signal system constraints relative to the anticipated cost and time required to implement phasing changes or other movement restrictions.

Each of the key issues identified will now be described in more detail to illustrate staff's perspectives and experiences as the subject matter experts most familiar with the traffic signal practices manual.

Traffic Signal Practices Manual Overview

As noted, the manual is divided into five sections that cover many aspects related to the installation and operation of traffic signals. The operations section is intended to be the focus of the update. It is the section that covers topic areas that can most impactfully reduce the common crash types that occur at traffic signals and corresponds to *Vision Zero Action Plan* actions. Staff recommends keeping the update focused on topic areas within the operations section.

Vision Zero Context

The signal timing practices update is focused on addressing a subset of severe crashes that occur at signalized intersections, particularly crashes involving left turning vehicles and vehicles turning right on red. Review of the most recent four years (2020-2023) of severe crash data indicates that 37 percent of all severe crashes citywide occur at signalized intersections. This equates to approximately 18 severe crashes per year at signals and 30 severe crashes per year occurring at other locations.

Based on a review of 2020-2023 crash data, there are nine crash types occurring at signals that have led to severe crashes.

- An average of just over eight severe crashes per year are attributed to making left turns at signalized intersections, making it the most common crash type, representing about 46 percent of all severe crashes that occur each year at signals.
- An average of five severe crashes per year are attributed to red light running, making it the second most common crash type, representing about 28 percent of all severe crashes at signals.
- The remaining seven crash types at signalized intersections result in approximately five severe crashes per year, or 25 percent of all severe crashes at signals.
 - Note that all crashes involving right turn movements at signals, such as at right turn bypass lanes, right turn on red, and right turn hook collectively result in less than two severe crashes per year on average.

Common causes of left turn crashes at signals include:

- Failure to see oncoming traffic.
- Assuming oncoming traffic will stop (at phase change).
- Misinterpreting the traffic signal indication or phasing sequence.
- Choosing an inadequate gap.
- Failure to see bicyclists, pedestrians and motorcyclists.

With respect to the crash data, the key takeaways are that left turn crashes are the crash type at signalized intersections that most frequently results in severe crashes (average of eight total per year across the entire signal system) while severe crashes involving right turns result in far fewer severe crashes (less than one per year for right on red crashes).

Thus, staff's recommendation is to keep the focus of the signal practices manual update more focused on changes to left turn phasing than restriction of right turns on red.

Results of Implementing Current Signal Practices

As mentioned previously, staff have been working diligently to strategically make changes, both proactively and reactively, to left turn signal phasing using the current signal timing practices. In many cases, staff has been able to leverage grant dollars to maximize the ability to make changes more quickly. Since 2018, FYA signal indications have been installed at 149 intersection approaches, left turn phasing changes have been

made at 54 approaches, LPI have been installed at 77 approaches, and RTOR restrictions have been installed at seven approaches. As noted, the changes to left turn phasing have resulted in a 68 percent reduction in all left turn crashes at signalized intersections.

In 2024, staff implemented left turn phasing changes at six intersection approaches. The changes implemented protected only left turn phasing during additional times throughout the day. Two grant projects are planned to be constructed next year that will result in signal infrastructure enhancements to support left turn phasing changes at a total of 22 additional intersection approaches.

Existing Signal System Context

The existing signal system context with respect to the current type of left turn phasing or lane geometry present on intersection approaches will now be described.

Number of locations: Across the city, there are a total of 146 traffic signals that control vehicular movements, and there are 494 approaches where the signal controls left turn movements. **Nearly half of the existing signal system does not support quick or easy implementation of left turn phasing changes** – be it to protected only all the time or another type of left turn phasing. There are 164 intersection approaches that currently operate with permitted only left turn phasing, representing about 33 percent of all approaches. There are an additional 76 intersection approaches that do not have an exclusive left turn lane, representing 15 percent of all approaches. This [map](#) shows the status of operations across the signal system with respect to left turn phasing, LPI, and no right turn on red.

Implementation considerations: To implement left turn phasing changes at intersections currently operating with permitted only phasing or with shared lanes, signal heads would need to be installed, controllers and conduit may also need to be upgraded, and exclusive left turn lanes would need to be constructed where they are not present. This would also, in some cases, mean that the signal pole and mast arm would need to be reconstructed to either be made long enough or strong enough to support the additional signal head(s) needed to display and operate the left turn phasing.

Estimated costs: Work to modify signals or construct exclusive left turn lanes is quite costly and time consuming. For every intersection approach in the city to be capable of operating with protected only left turn phasing, modifications would need to be made to approximately 240 intersection approaches. As a recent example of the costs to do this type of work, the Safer Signals grant project referenced earlier that is going to upgrade 14 intersection approaches to add flashing yellow arrow left turn signal heads and phasing will cost approximately \$720,000. Extrapolating this cost per approach across the 240 intersection approaches, and assuming no locations need significant modifications such as a new signal pole and mast arm, equates to a minimum estimate of at least \$12.5 million in today's dollars in investment needed. However, the costs to complete the necessary upgrades across the signal system are likely substantially higher as only one of the 14 intersections included in the Safer Signals grant requires a new pole and mast arm.

Other considerations: As noted, one of the infrastructure considerations relative to having the ability to more broadly and more restrictively control left turns is the need for an exclusive left turn lane to be present on the intersection approach to the signal. While in some cases a shared lane condition could be alleviated through lane repurposing, in many more cases, it would require the intersection approach to be reconstructed and widened, which has its own considerations and drawbacks relative to TMP and Vision Zero goals. The main drawback being a wider intersection with more lanes and distance for pedestrians and bicyclists to cross.

The other interesting thing to note is that currently only 35 signalized intersection approaches (seven percent) across the system always operate with protected only left turn phasing. Despite this, there are very few intersections remaining across the system that have developed a crash pattern (3 or more crashes in 3 years) that would be correctable by a change to protected only left turn phasing. Again, across the entire signal system (all 494 approaches where the signal controls left turn movements) there are an average of eight severe crashes per year attributed to left turn movements. The strategic approach has had success so far, and updates to the practices are anticipated to further minimize conflicts and risks associated with left turn movements.

Scope of Work Considerations

As noted, while there has been focused and strategic implementation of the current signal practices that has led to crash reduction, crashes involving left turns at signals continue to represent approximately 15-20 percent of severe crashes citywide. Staff currently envisions that the scope of work for the signal practices update will consider key topic areas within the operations section, particularly with respect to left turn phasing, LPI, right turn on red restrictions, APS, and coordination of pedestrian signals. Updates to the sections on APS and coordination of pedestrian signals are being done in response to feedback received on the update to the *Pedestrian Crossing Treatment Guidelines* and to ensure these topics align with the latest requirements of the *Public Right-of-Way Accessibility Guidelines (PROWAG)*, and so that implementation can be considered in the update to the city's ADA Transition Plan. The update will strive to understand the various thresholds that can be adjusted and the technical considerations, costs, and anticipated crash or risk reduction impacts of doing so. The scope of work is expected to consider whether any new practices related to left or right turn operation should be added, such as with respect to right turn operation across a two-way, vertically separated bicycle lane.

The scope is also expected to consider new evaluation criteria relative to each topic area being updated. Criteria to evaluate might include such things as: the number of anticipated conflicts between turning vehicles and multimodal users during each signal cycle; sight distance under varying conditions; crash data; and multimodal intersection operations. The scope will also clearly outline the tradeoff considerations of changes to operations in terms of: safety considerations; cycle lengths (which impact how long all users may have to wait at a signal); queue lengths (which can result in crashes of other types occurring if not managed properly); signal coordination (which can impact travel

times for all users); and potential for changes in travel patterns or other crash types to occur.

The scope will research and recommend whether certain advancements in traffic signal detection, programming, and data collection technology can be deployed and detail the considerations and criteria for doing so. Examples of technological advancements to consider include:

- **Pedestrian protect left turn phasing** – cycle-by-cycle protected lefts, as needed, when a pedestrian push button is activated.
- **Gap dependent flashing yellow arrow** – use of advanced detection to read gaps in oncoming traffic and display a red arrow until an adequate gap in traffic is detected.
- **Delayed display of flashing yellow arrow** – holding left turns with a red arrow indication until the WALK indication is off, then displaying the permitted FYA indication once pedestrians are more established and visible within the crosswalk.
- **Automated Traffic Signal Performance Measures (ATSPMs)** –transmission, storage, and analysis of real-time signal controller data to inform decision-making and more proactively troubleshoot detection or other timing/phasing issues.
- **Blank-out signs** – use of blank-out signs during certain portions of the signal cycle to restrict movements that might conflict with multimodal or other users.

The scope of work is also expected to consider a prioritization methodology for how improvements identified using the updated guidelines are programmed to be implemented or constructed. The prioritization methodology might consider such factors as: extent to which evaluation criteria are met; cost; staff time; ability to coordinate work with upcoming projects; ability to coordinate work with scheduled maintenance activities; equity-focused indicators; and grant program eligibility.

Another key aspect of the scope of work is the deliverables expected to be produced. Anticipated deliverables are envisioned to include:

- Documentation of current research/best practices related to relevant topic areas.
- Revised evaluation criteria.
- Revised decision-making flowcharts/matrices.
- Tabulation of intersection approaches where changes related to left turn phasing, LPIs, and no right turn on red are recommended.
- Development of a prioritization methodology.
- Cost estimates to understand implementation schedule/unfunded needs.

Takeaways

The takeaways from the key issues highlighted above are summarized as follows:

- Accurate and complete crash data is essential to understanding the underlying causes of crashes at signalized intersections.
- Engineering solutions can make the signal system more consistent and predictable.

- Many solutions can be implemented at a lower cost (changes to signal phasing where infrastructure already exists).
- Many solutions expected to be documented more thoroughly in the practices update can be win/win (improved safety with limited operational impacts).
- Continued strategic and targeted focus on left turn crashes can have a significant positive impact on achieving Vision Zero.

NEXT STEPS

Following the Study Session discussion with Council, staff will use the feedback received to finalize the scope of work. Staff will then initiate a process to select a consultant to assist with the work, which is expected to begin in early 2025 and be completed in the third quarter of 2025. Staff will provide council with an informational update on progress as the effort is underway. Once the update is completed, staff will review the outcomes and priorities identified and begin to plan for pursuing funding and implementation of changes, likely beginning at locations located along the High Risk Network and informed by the city's racial equity index and other equity-focused measures. Success will be measured through continual before/after evaluation of crash data.

ATTACHMENTS

None