MaineDOT

TRAFFIC ANALYSIS GUIDELINES

Traffic Signal Design and Operation

Index

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Attachments:

- MaineDOT Traffic Signal System Engineering Worksheet

Purpose and Need:

Consistency in the design of traffic control devices is vital to providing a clear message to the traveling public so that they can easily comprehend traffic control devices, understand potential conflicts, and safely navigate through intersections. The following describes the guidelines and procedures provided by MaineDOT related to the design and operation of signalized intersections.

Note that this document is intended to help provide engineers with guidance and communicate MaineDOT's expectations when designing a signalized intersection. Not all of these guidelines will apply to the unique needs of each intersection, and it will be expected that engineers will use engineering judgement in applying the information within this document.

Required Information and References:

Manual on Uniform Traffic Control Devices (MUTCD):
Federal Highway Administration, ISBN:978-1598049848. The Manual on Uniform Traffic Control Devices for Streets and Highways—the MUTCD—defines the standards used by road managers nationwide to install and maintain traffic control devices on all streets, highways, pedestrian and bicycle facilities, and site roadways open to public travel. The MUTCD is published by the Federal Highway Administration (FHWA) under 23 Code of Federal Regulations (CFR), Part 655, Subpart F.

NCHRP Report 812, Signal Timing Manual Second Edition:
Transportation Research Board, National Cooperative Highway Research Program, ISBN:978-0-309-30888-5. TRB's National Cooperative Highway Research Program (NCHRP) Report 812: Signal Timing Manual - Second Edition, covers fundamentals and advanced concepts related to signal timing. The report addresses ways to develop a signal timing program based on the operating environment, users, user priorities by movement, and local operational objectives. Advanced concepts covered in the report include the systems engineering process, adaptive signal control, preferential vehicle treatments, and timing strategies for over-saturated conditions, special events, and inclement weather.

NCHRP Report 731, Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections:
Transportation Research Board, National Cooperative Highway Research Program, ISBN:978-0-309-25859-3. This report provides comprehensive and uniform guidelines for safe and efficient yellow change and all-red clearance intervals at signalized intersections. The project (1) reviewed and compared the definitions of yellow change and all-red clearance intervals,(2) conducted a critical review of relevant available literature, (3) conducted a survey of yellow and all-red timing practices at public agencies, and (4) reviewed past studies and agency operational experiences in relating change interval timing to red-light running and crashes. This information was synthesized to identify key stakeholder groups, point out knowledge gaps encountered in the research, and produce a draft outline of the guidelines. The project conducted field studies on critical factors including reaction time, deceleration rates, and the impact of the other factors identified as important in the design of change intervals. This information was analyzed to develop yellow change and all-red clearance interval guidelines, which provide a framework that can be easily applied by state and local transportation agencies.

MaineDOT Standard Specifications:
Maine Department of Transportation, "https://www.maine.gov/mdot/contractors/publications /standardspec/". Collection of MaineDOT specifications that apply to all projects unless otherwise overridden by contract specific special provisions. In particular, SECTION 643 – TRAFFIC SIGNALS and SECTION 718 – TRAFFIC SIGNALS MATERIAL are relevant to this document.

MaineDOT Standard Details:
Maine Department of Transportation, "https://www.maine.gov/mdot/contractors/publications/ standarddetail/". Collection of MaineDOT details that apply to all projects unless otherwise overridden by contract specific details. In particular, TRAFFIC SIGNALS 643(01) to 643(13) are relevant to this document.

MaineDOT Data Collection Guidelines:
Maine Department of Transportation, "https://www.maine.gov/mdot/traffic/". Guidelines for the accurate and consistent collection of transportation data for the use of transportation plans, feasibility studies, engineering studies, projects, and traffic movement permits.

MaineDOT Data Vehicle Detection Guidlines:
Maine Department of Transportation, "https://www.maine.gov/mdot/traffic/". Guidelines for the configuration and requirements of vehicle detection systems including stop bar and advance detection systems.

MaineDOT Minimum ADA Requirements for Pedestrian Facilities:
Maine Department of Transportation, "https://www.maine.gov/mdot/engineering/highway/". This document is intended to provide guidance on what makes each individual element of a pedestrian facility ADA compliant. It should be the basis for determining if an existing pedestrian facility is ADA compliant and for designing and constructing new or improved pedestrian facilities.

MaineDOT Intersections and Interchanges Design Guidance:
Maine Department of Transportation, "https://www.maine.gov/mdot/engineering/highway/". This guidance contains information about intersection alignments and profiles, intersection sight distances, turning radii, roadways, auxiliary lanes, continuous two-way left turn lanes, median openings, islands, entrance design, roundabouts, interchanges, and ramp design.

Traffic Signal Warrants:

The MUTCD provides requirements and guidelines for an engineering study to evaluate if the installation of a traffic signal is justified based on the characteristics of the intersection. At the time of this guide, the MUTCD provides nine different Warrants to be used to for the engineering study; Warrant 1: Eight-Hour Vehicular Volume, Warrant 2: Four-Hour Vehicular Volume, Warrant 3: Peak Hour, Warrant 4: Pedestrian Volume, Warrant 5: School Crossing, Warrant 6: Coordinated Signal System, Warrant 7: Crash Experience, Warrant 8: Roadway Network, and Warrant 9: Intersection Near a Grade Crossing. The following details MaineDOT's guidelines when preparing the engineering study.

1. A traffic signal shall only be installed if it meets at least one traffic signal Warrant. The only exception will be if the engineering study shows that the installation of a traffic signal is the only reasonable option with a notable benefit to the safety of the public. These exceptions will only be considered on a case-by-case basis and require approval from the State Traffic Engineer or their representative.
2. The installation of a traffic signal shall be determined based on the results of an engineering study showing a notable benefit to the safety of the public. Meeting one or more of the MUTCD Warrants does not necessarily mandate the installation of a traffic signal.
3. A 24-hour count shall be collected consistent with the requirements in "MaineDOT Data Collection Guidelines". The count shall be seasonally adjusted to the average day by distributing the AADT reported by the MaineDOT for each approach to the hourly turning movement volume distribution collected by the 24-hour count.
4. The approaches with the higher nonconflicting ingress volumes shall be defined as the major approaches (up to two approaches) and the approaches with the highest conflicting volumes with the major approaches (up to two approaches) shall be defined as the minor approaches. The major and minor approaches shall be consistent for all time periods.
    - Note that it is acceptable to use the left turn movement on one of the major approaches as the minor approach; when doing so only the opposing major approach shall be considered the major approach and only the left turn movement shall be the minor approach.
5. The right turning volumes of a shared lane shall be reduced using an approved methodology. Engineering judgement shall be used to determine if the right turning volume in a dedicated lane is reduced or considered based on the delay and queueing caused by excessive main line volumes and the geometry of the intersection; in such a case that right turn volume in a dedicated lane appears to be the contributing factor to meeting Warrant 1: Eight-Hour Vehicular Volume, only "Condition B The Interruption of Continuous Traffic" shall be considered in the engineering study.
6. Warrant 3: Peak Hour shall only be considered at locations adjacent to land uses with a documented peak hour discrepancy in the side road/entrance traffic, such as but not limited to: factories, schools, and other land uses with scheduled releases or shift changes.
7. When evaluating Warrant 7 Crash Experience: Only the crashes of types susceptible to correction by a traffic control signal and only the crashes in a One-Year period (Table 4C-2 or Table 4C-4) shall be considered in the evaluation.

8. A 50% reduction in the required "Total of all Pedestrians Crossing Major street per Hour" when considering Warrant 4: Pedestrian Volume can be taken if the engineering study demonstrates that the pedestrian frequency at the intersection has a documented history of causing safety issues between pedestrians and vehicles or vehicles and other vehicles yielding to pedestrians. Other alternatives need to be considered and attempted at the location, such as a rapid rectangular flashing beacon or pedestrian hybrid beacon, before the 50% reduction can be considered.

Traffic Signal Design, TMP Requirements, and General Guidance:

The following covers the planning of traffic signals and other miscellaneous guidance.

1. **Existing and Proposed Traffic Signal Timing Plan** – Any and all modifications to the configuration of the traffic signal controller that affect traffic operations or may have an impact to the public shall be approved by the State Traffic Engineer, their representative, or a licensed Professional Engineer responsible for the traffic operations at the intersection. The only exception is if the existing configuration or a malfunction in the cabinet causes a situation that negatively impacts the safety of the public. In this situation a certified technician or equivalent can make changes to remove the potential hazard; after which the technician shall notify the State Traffic Engineer, their representative, or the licensed Professional Engineer responsible for the traffic operations at the intersection as soon as possible.
2. **ADA Requirements** - Any new or modified signal project shall check to determine which ADA issues need to be addressed.
    - All projects with proposed improvements involving earthwork or other below surface work at a signalized intersection shall be required to ensure that all pedestrian facilities at that intersection meet the latest ADA requirements in the MUTCD, the "MaineDOT" Standard Details", and "MaineDOT Standard Specifications".
    - All proposed signal equipment shall meet the latest ADA requirements in the MUTCD, the "MaineDOT Standard Details", and "MaineDOT Standard Specifications".
    - All improvements to pedestrian facilities shall follow the "Minimum ADA Requirements for Pedestrian Facilities" Design Guidance.
3. **Intersection Design** – For new intersections with two or more lanes on the egress approach, the extra lanes shall be carried beyond the intersection based on engineering judgement to ensure as close to balanced lane utilization on the ingress lanes. Intersections with two through lanes shall have a minimum receiving lane length of 12 times the maximum green time of the through phase. All pavement marking and other relevant highway related design shall follow the requirements in the "MaineDOT Intersections and Interchanges Design Guidance".
4. **Traffic Signal Plans** – The layout and design of traffic signal plans shall follow the guidelines below:
    - The Engineer of Record shall minimize or remove redundant information on the signal plans that are also located within the "MaineDOT Standard Details", "MaineDOT Standard Specifications", or the Special Provisions for the project.
    - The Engineer of Record will be responsible for addressing any errors or omissions from the traffic signal plans that are discovered or identified in construction unless otherwise directed by the State Traffic Engineer or their representative. The contractor shall not be tasked with determining existing timings or making design changes.

- The Traffic Signal Plans shall at a minimum have the following details and information:
  - *General Notes* - Specific to the Project
  - *General Details* - Specific to the Project
  - *List of Work Items* - with relevant bid items identified.
  - *List of Structures* - with relevant structure information.
  - *Preferential Phase Sequence* - including a visual representation of the sequence of all possible states of the signal indications.
  - *System Design Volumes* - including at least the AM and PM peak hours.
  - *Existing Indications to Remain* - including a visual representation of the signal indication arrangements.
  - *Proposed Indications* - including a visual representation of the signal indication arrangements.
  - *Detector Schedule* - including the detector channel in the controller, phases for presence-based detection, phases for extension-based detection, and any relevant parameters.
  - *Signal Timing Schedule* – including the relevant NEMA timing plan parameters.
  - *Preemption and Priority Operation* – detail the design and relevant parameters of the preemption and priority systems.
  - *Existing Signs to Remain* – including visual representation of the signs, the MUTCD sign designation, and the size of the sign.
  - *Proposed Signs* – including visual representation of the signs, the MUTCD sign designation, and the size of the sign.
- The traffic signal plans shall clearly detail the approximate location of each item listed in the List of Work Items
- The traffic signal plans shall include topographic information and pavement markings.

5. **Traffic Movement Permit** - Traffic signals required through the Traffic Movement Permit process or Developer Review process shall follow the guidelines below:
   - A traffic signal may be required through the Traffic Movement Permit process based on information presented to MaineDOT by the applicant. The signal can be fully operational for up to a 6-week window once the development is occupied, starting at the discretion of the developer unless otherwise instructed by the Municipality or MaineDOT. In the 6-week window, the applicant will complete an engineering study to justify the traffic signal using counts from the vehicle detection system. Only if the engineering study shows that the traffic signal is justified then the signal will remain fully operational; If the engineering study shows that the traffic signal is not justified then the signal will be placed into flashing operations and all pedestrian related equipment will be covered or removed. A future engineering study evaluating if a traffic signal is justified will only be considered by the MaineDOT 12 months after the initial engineering study or other follow up studies unless otherwise approved by the State Traffic Engineer or their representative.

- When a Traffic Movement Permit requires an engineering study to justify the traffic signal at a certain percentage of the full build out of the permitted facility (this is usually done when the numbers or reliability of those numbers come into question) the applicant will perform the engineering study at the designated time and shall install a traffic signal at the intersection within 12 months if the traffic signal was justified.

Design of Traffic Signal Operations:

The following details the functional requirements for all new or retrofitted traffic signals.

1. All traffic signals shall be fully actuated and shall be responsive to vehicular traffic using vehicle detection systems.
    - Scheduled flashing operation shall only be considered on a case-by-case basis and only if there is a notable safety benefit to the public. Scheduled flashing operation shall not be allowed at any intersection with pedestrian facilities.
    - All movements within the limits of the signalized intersection shall be controlled by the traffic signal, including but not limited to driveways and entrances.
2. A systems engineering approach shall be used to evaluate alternative control strategies such as coordination, demand-based coordination, traffic responsive, peer to peer, or adaptive. A "MaineDOT Traffic Signal System Engineering Worksheet" is attached that summarizes the guidance provided in the "NTCRP 812, Signal Timing Manual Second Edition".
3. The Engineer of Record should be retained after a new signal installation or modification to monitor the performance of the intersection for at least six months and shall be responsible for adjusting the controller configuration as necessary to calibrate the implemented timings to field conditions.
4. Where feasible, NEMA compliant phasing shall be required at all new or retrofitted traffic signals. Phase 2 shall either be the mainline through movement on the northbound or eastbound approach and Phase 4 shall either be the respective eastbound or southbound through movement on the minor street approach.
5. The design of left turn phasing shall consider the following:
    - Protected left turn movements from a shared left and through lane shall not be allowed unless the entire approach utilizes the same phase and all the signal indications on that approach sequence in sync.
    - Permitted left turn phases shall not be allowed when there are two opposing through lanes. Exceptions will be considered on a case-by-case scenario with approval by the State Traffic Engineer or their representative.
    - Great care shall be taken to prevent yellow trap scenarios, particularly when using leading/lagging protected and permissive left turn phasing for opposing movements. The traffic signal controller shall be configured to eliminate scenarios where yellow traps can occur such as providing flashing yellow arrows where appropriate or forcing an all-red clearance before reservicing a protected left turn phase.
    - Flashing yellow arrow indications shall be provided at all new traffic signals for any approach with a dedicated left turn lane and permissive phasing.
    - Permissive only left turn movements with a three-section flashing yellow indication display shall have a 4 second delay before the start of the flashing yellow indication.

6. Steady straight-through green arrows should be used in all applicable scenarios following the guidance in the MUTCD, except for where there may be traffic making permissive movements on other approaches conflicting with the through movement.
7. Depending on the capabilities of the vehicle detection system, the traffic signal controller shall be configured to optimally respond to vehicle demand and minimize delays to the traveling public during all hours of the day.
    - Advance detectors shall be used on approaches with speed limits equal to or greater than 35 MPH, or as needed based on site conditions.
    - All vehicle detection systems shall be configured consistent with the "MaineDOT Vehicle Detector Guidelines".
    - The use of "Dynamic Red Extension" shall only be used on a case-by-case basis with the approval of the State Traffic Engineer or their representative.
8. Vehicular and Pedestrian Clearance Intervals shall be determined based on the guidance provided by the MUTCD, "NCHRP 812, Signal Timing Manual Second Edition", and "NTCRP 731, Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections".
    - Yellow and Red clearance intervals shall be rounded up to the nearest half second. Consideration should be given to signal equipment delay when rounding up numbers by only 1/10 of a second.
    - All pedestrian clearance interval calculations shall use a crossing speed of 3.0 feet per second or less appropriate to the unique needs of each signalized intersection.
    - Pedestrian Clearance intervals shall be rounded up to the nearest second.
    - Where reasonably practicable, the clearance intervals of phases terminating at the same time should be consistent so that the traffic signal operates in a predictable manner for opposing or adjacent traffic movements.
9. Concurrent pedestrian phasing is preferred. However, engineering judgement should be used when selecting the appropriate pedestrian phasing type considering the likely number of pedestrians, vehicular volume, crosswalk visibility and the benefits of utilizing a pedestrian scramble.
    - At locations with proposed concurrent pedestrian phasing, R10-15 "Turning Vehicles Yield to Pedestrian" signs should be used for the permissive movements that cross the crosswalk when the pedestrian may have a "walk" or "flashing don't walk" indication.
    - Dynamic blank out signs using "No Turn on Red" and/ or "Turning Traffic Yield to Pedestrian" messages shall be used instead of R10-15 signs at locations with right turn movements that cross a crosswalk. The signs shall be coordinated with pedestrian timings for both crosswalks parallel and perpendicular to the approach with a right turn movement.
    - At locations with proposed concurrent pedestrian phasing, a leading pedestrian interval shall be considered unless it can be shown that the inclusion of a leading pedestrian interval results in little benefit to the pedestrian or causes notable disruption to the operations of the traffic signal.

Traffic Signal Equipment:

The following details the expectations for all new or retrofitted proposed traffic signal related equipment.

1. All traffic signal equipment and structures shall be placed in a way that the impacts to intersection sight distance for turning vehicles is minimized and the visibility of pedestrians is maximized.
2. The traffic signal cabinet shall have the capability to remotely access equipment within the traffic signal cabinet or auxiliary devices from a remote workstation utilizing Applied Information's MaineLINK.
    - Additional intersection to intersection interconnection may also be required between signalized intersections that are less than 2,600 feet apart or if interconnection is identified as a requirement in the systems engineering for a corridor. If feasible, fiber optic interconnection is the preferred connection between traffic signals. Spread spectrum radio can be considered for locations where there is a clear line of sight between the signalized intersections or if there are other limitations that make fiber optic interconnect infeasible.
3. The traffic signal cabinet shall have the capability to support the following types of preemption and priority:
    - The traffic signal cabinet and controller shall be able to respond to a railroad preemption system. A battery backup system shall be required at all signalized intersections that are within 200 feet of a railroad track, where the maximum queue length of an approach will conflict with a railroad crossing, or if railroad tracks are in a position that allowing certain phases will cause vehicular back-up into the intersection.
    - The traffic signal cabinet and controller shall be able to respond to a preemption request received through either an optical emitter on an emergency vehicle or through a NTCIP 1211 compliant request sent to the controller from a network device such as but not limited to either a field monitor unit or central management server.
        - The brand and type of optical preemption shall be consistent with the equipment present on the emergency vehicles of the local municipality or otherwise directed by the MaineDOT.
    - The traffic signal cabinet and controller shall be able to respond to a priority request received through either an optical emitter on a municipal or state-owned vehicle or through a NTCIP 1211 compliant request sent to the controller from a network device such as but not limited to either a field monitor unit or central management server. This may be extended to transit or freight-related vehicles at the discretion of MaineDOT. The time of service desired, maximum reduction, and maximum extension parameters shall be calibrated to field conditions to minimize the disruption to traffic operations while the priority request is being serviced.
4. The traffic signal cabinet shall have the capability to support connected vehicle operations through a Roadside Unit compatible with the MaineDOT's existing Applied Information based system, including Applied Information's "Travel Safely" cellular phone application.
5. All traffic signal cabinets shall be ground-mounted on a concrete foundation unless a ground mounted installation is determined to not be feasible.

6. Each traffic signal controller shall only control a single intersection unless engineering judgement shows that there is a notable benefit to operations and/or safety by using a single controller for multiple intersections.
7. Traffic signal controllers that can provide high resolution data to a user without a subscription fee or cost are preferred.
8. The horizontal, vertical, and longitudinal location and placement of traffic signal indications shall follow the requirements of the MUTCD without exception.
9. The preferred traffic signal structure type is span wire installations with guyed wooden poles. Mast arms, strain poles, or other steel structures with concrete foundations can be considered If wooden poles are not feasible or the traffic signal is located in a downtown or historic setting where there may be issues with the installation of span wires.
    - The Engineer of Record shall be responsible for providing a span wire design that can be constructed within the requirements of the "MaineDOT Standard Specifications".
    - Note that the location of structures with concrete foundations shall be located so that ADA standards are not violated.
    - When making modifications to a strain pole with span wire, great care shall be taken to take into consideration the intended design characteristics of the strain pole particularly the rake and rotation.
    - For guyed wooden poles with span wire, there shall be a guy for each span attached to the pole unless engineering judgement shows that multiple guys are not feasible.
10. LED pedestrian indications with countdown displays shall be used on all new installations or retrofits.
11. When feasible, separate structures should be provided for pedestrian equipment, including accessible pedestrian detection and pedestrian signals.
12. There shall be at least 1 junction box for each corner of the intersection that has traffic signal equipment or structures. The junction box shall be placed at least seven feet from the travel way and should be located in close proximity to the primary structure for that corner of the intersection.
13. Conduit should run as straight as feasible between each structure or junction box.
14. The use of R3-5, R3-6, and R3-8 overhead lane use signs should be used at all signalized intersections with multiple ingress lanes on an approach.
15. A R10-12 "Left Turn Yield on Green" or R10-12a (CUSTOM) "Left Turn Yield On Flashing Yellow" using a symbolic yellow arrow shall be used on approaches with a dedicated left turn lane and permissive left turn phasing with either a shared signal or flashing yellow arrow respectively.
16. Battery backup systems will be considered using engineering judgement based on the characteristics of the intersections such but not limited to: the location, traffic volumes, pedestrian volumes, frequency of power outages, variability in AC service line voltage, and priority of the intersection in an emergency event.