CHAPTER 10
APPROACH TREATMENTS
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LIST OF EXHIBITS

10.0 APPROACH TREATMENTS

Approaches are critical signalized intersection components. Intersections and traffic control devices should be obvious to approaching motorists, bicyclist, and pedestrians. Adequate signing and pavement marking must provide the driver with sufficient information to determine the appropriate lane and direction to travel. The pavement on the approaches should provide the needed degree of friction for a turning maneuver or stop and adequate drainage. The approaches ideally should meet at right angles and should be at grade and free of unnecessary clutter and obstacles. Sight distance for all approaches should be adequate for drivers proceeding through the intersection, particularly those making a permissive left turn.

This chapter will discuss various treatments related to signalized intersection approaches, as summarized in Exhibit 10-1.

Approach Treatment Type	Treatment
Traffic control	Mast arm and span wire mounts Advanced warning flashers Dilemma zone protection Operating speed Extended lane line markings
Pavement/cross section improvements	Skid resistance Rumble strips Improved cross section Removal of obstacles Reduce intersection skew
Visibility	Near-side traffic signal heads Larger traffic signal heads Increase number of signal heads Backplates Adequate sight distance for conflicting turning movements, pedestrian crossings

Exhibit 10-1. Summary of approach treatments.

10.1 SIGNAL HEAD PLACEMENT AND VISIBILITY

Traffic signals should be placed so the signal heads are visible at a distance upstream of the intersection and from all lanes on the approach. Approaches with poorly placed traffic signals are likely to experience an increase of conflicts and collisions. At intersections with a higher proportion of heavy trucks, drivers in adjacent lanes or following a heavy vehicle may not be able to see the signal indication, which may lead to inadvertent red-light running. Some red-light runners claim they did not see the traffic signal, and one reason could be suboptimal placement of traffic signal heads or a failure to make the traffic signal head visually prominent.

Approach treatments that improve signal visibility help drivers make decisions at the intersection and alert them to the presence of a signalized intersection. Subsequently, the probability of driver error, such as inadvertently running a red light and being involved in a collision, is lower.

The following sections identify traffic control treatments that can be applied to improve the visibility of signal heads.

10.1.1 Convert to Over-the-Road Signal Heads

Description

Three major types of signal head placement are in popular use today: pedestal, span wire, or mast arm mounted. Chapter 5 discussed the merits and drawbacks of each. For a signalized intersection experiencing safety problems related to the placement or visibility of a pedestal-mounted signal head, the traffic engineer should consider either replacing signal heads or supplementing signal heads. Replacing or supplementing signal heads should be considered when:

- An approach where a pedestal-mounted traffic signal head is located against a backdrop with a considerable amount of visual clutter.
- An approach where heavy truck traffic habitually prevents adjacent and following drivers from viewing a pedestal-mounted traffic signal head.

Both mast arms and span wire mounted traffic signals improve the signal head's prominence upstream of the intersection.

Application

This treatment should be considered:

- At intersections where a high number of angle collisions occur that may be attributable to unintentional red-light runners.

Safety Performance

The safety impact of mast arm mounted signal heads relates to the conspicuity of the signal indications, especially in areas where there are competing visual distractions like on-site signing and lighting near the pedestal-mounted heads. Safety effects of signal upgrades from pedestal to mast arm are shown in Exhibit 10-2.

Treatment	Finding
Replace pedestals with mast arms, (155)	36 percent reduction for all crash types and severities. 47 percent reduction for severe injuries (all crash types) 13 percent reduction for minor injuries (all crash types) 72 percent reduction for right angle crashes (all severities) 20 percent increase in rear-end crashes (all severities) 2 percent increase in left turn crashes (all severities)

Exhibit 10-2. Safety benefits associated with using mast arms: selected findings.

Operational Performance

Signal head placement has a negligible effect on intersection capacity. However, centering signal heads over lanes can help drivers chose the proper lane to navigate through the intersection.

Multimodal Impacts

The placement of traffic signal heads on span wires or mast arms will be particularly advantageous for heavy vehicles, giving them additional time to decelerate and come to a full stop.

Physical Impacts

Span wire mounted signal heads have a constructability advantage over mast arm mounted signal heads. At larger intersections, the length of the mast arm may limit its use.

Socioeconomic Impacts

Span wire installations are generally considered less esthetically pleasing than mast arms because of overhead wires.

Enforcement, Education, and Maintenance

Span wire installations generally have higher ongoing maintenance costs than mast arms. Both types may need additional reinforcements if installed in a location known for strong winds.

Summary

Exhibit 10-3 summarizes the issues associated with using mast arm or span wire mounts for signal heads.

Characteristic	Potential Benefits	Potential Concerns
Safety	Increases signal visibility. Decreases collisions.	None identified.
Operations	Negligible effect.	None identified.
Multimodal	Heavy vehicles have more time to stop.	None identified.
Physical	Greater flexibility in placement of span wire poles.	Less flexibility in placement of mast arm poles.
Socioeconomic	None identified.	Span wires not aesthetically pleasing.
Enforcement, Education, and Maintenance	None identified.	Span wires typically require more maintenance than mast arms.

Exhibit 10-3. Summary of issues for using mast arm/span wire-mounted signal heads.

10.1.2 Add Supplemental Signal Heads

Description

Supplemental traffic signals may also be placed on the near side of the intersection, far-left, far-right, or very high. This may be particularly useful if:

- Sight distance is an issue, such as on approaches to intersections on horizontal and vertical curves.
- The intersection is particularly wide, so that a far-side signal cannot be placed within MUTCD sight distance requirements for approaching drivers.(1)
- Auxiliary turn lanes are present.

Applicability

Supplemental head placements may be considered where there may be limited sight distance or at a particularly wide intersection where visibility of the signal indications could be a problem. Refer to the MUTCD for guidance on the location of signal heads.(1)

Safety Performance

Supplemental traffic signal heads appear to reduce the number of fatal and injury collisions at an intersection, according to the limited research that has been done on their effectiveness at preventing collisions.

Operational Performance

When placed on the near side of an intersection, additional signal poles have a negligible effect on intersection capacity.

Multimodal Impacts

Near-side traffic signal placement on a median benefits heavy trucks by giving them additional warning.

The placement of the traffic signal should not interfere with the movement of pedestrians across the intersection or along the sidewalk.

Physical Impacts

As a pedestal traffic signal is mounted on the near side of an intersection, a median must be present in that location. This will likely incur additional costs to provide electricity and conduit to connect to the traffic controller. In other cases (far-left, far-right, or very high-mounted), the signal head can often be placed on an existing pole with access to conduit and power.

Summary

Exhibit 10-4 summarizes the issues associated with supplemental near-side traffic signal poles.

Characteristic	Potential Benefits	Potential Concerns
Safety	Increases signal visibility. Decreases angle collisions.	None identified.
Operations	Negligible.	None identified.
Multimodal	Heavy trucks have more time to stop.	May interfere with movement of crossing pedestrians.
Physical	None identified.	None identified.
Socioeconomic	None identified.	Moderate costs.
Enforcement, Education, and Maintenance	None identified.	None identified.

Exhibit 10-4. Summary of issues for supplemental near-side traffic signal heads.

10.1.3 Increase Size of Signal Heads

Description

Two diameter sizes are currently used for signal lenses: 8 inches and 12 inches. Of these, 12-inch signal faces for red, amber, and green indications are commonly used at medium- and high-volume intersections. Many jurisdictions are working to limit the use of 8-inch signal heads to only low-speed locations without confusing/complex backgrounds. The MUTCD indicates 12-inch signal faces shall be used for all signal sections in all new signal faces, with the following exceptions:[(1)]

Eight-inch circular signal indications may be used in new signal faces only for:

A. The green or flashing yellow signal indications in an emergency-vehicle traffic control signal;

B. The circular indications in signal faces controlling the approach to the downstream location where two adjacent signalized locations are close to each other and it is not practical because of factors such as high approach speeds, horizontal or vertical curves, or other geometric factors to install visibility-limited signal faces for the downstream approach;

C. The circular indications in a signal face located less than 120 feet from the stop line on a roadway with a posted or statutory speed limit of 30 mph or less;

D. The circular indications in a supplemental near-side signal face;

E. The circular indications in a supplemental signal face installed for the sole purpose of controlling pedestrian movements rather than vehicular movements; and

F. The circular indications in a signal face installed for the sole purpose of controlling a bikeway or a bicycle movement.

Existing 8-inch circular signal indications not included in items A through F may be retained for the remainder of their useful service life.

Application

Using 12-inch lenses should improve visibility for the driver, and as such may reduce red-light running and associated angle collisions.

Safety Performance

Srinivasan et al. (2008) conducted a before-after evaluation for four types of treatments at signalized intersections using data from Winston-Salem, NC. The result was an estimated 42 percent reduction in right-angle collisions and a 3 percent reduction in total collisions.[156] Another before-and-after study was undertaken to assess the effectiveness of larger (12 inches) and brighter signal head displays in British Columbia. Results from an EB analysis showed the frequency of total crashes was reduced by approximately 24 percent with the proposed signal displays. The results were found to be consistent with previous studies and laboratory tests that showed increased signal visibility results in shorter reaction times by drivers and leads to improved safety.[157]

References regarding the safety benefits of installing 12-inch signal lenses are shown in Exhibit 10-5.

Treatment	Finding
Install 12-inch signal lenses, use higher wattage bulbs.[157]	24 percent estimated reduction in all collisions.
Install 12-inch signal lenses.[156]	42 percent estimated reduction in right angle collisions. 3 percent estimated reduction in all collisions.

Exhibit 10-5. Safety benefits associated with using 12-inch signal lenses: selected findings.

Operational Performance

None identified.

Socioeconomic Impacts

Using 12-inch lenses costs nominally more than using 8-inch lenses.

Summary

Exhibit 10-6 summarizes the issues associated with increasing the size of signal heads.

Characteristic	Potential Benefits	Potential Concerns
Safety	Reduction in collisions – particularly angle collisions.	None identified.
Operations	None identified.	None identified.
Multimodal	None identified.	None identified.
Physical	None identified.	None identified.
Socioeconomic	None identified.	Larger signal heads cost nominally more than smaller signal heads.
Enforcement, Education, and Maintenance	None identified.	None identified.

Exhibit 10-6. Summary of issues for increasing the size of signal heads.

10.1.4 Increase Number of Signal Heads

Description

The number of signal heads may be increased so one signal head is over each lane of traffic on an approach. Current MUTCD requirements for signal head placement state "a minimum of two signal faces shall be provided for the major movement on the approach, even if the major movement is a turning movement."[1] In addition, at least one signal head must be not less than 40 ft beyond the stop line and not more than 180 ft beyond the stop line unless a supplemental near-side signal face is provided. Finally, at least one and preferably both of the signal faces must be within the 20-degree cone of vision.

Traffic signal heads on a mast arm typically located above each. Exhibit 10-7 shows an example of an approach with dual left-turn lanes, two through lanes, and a right-turn lane with lane-aligned signal heads.

Exhibit 10-7. Lane-aligned signal heads.

Application

Consider this treatment in situations where unusually high numbers of angle collisions occur because a vehicle runs a red light. Also, consider it at high speed intersections with fewer signal heads than approach lanes. This application may be a local or spot treatment, or may be part of a systematic improvement plan.

Safety Performance

A Canadian study evaluated the crash effects associated with additional primary signal heads and found a 28 percent decrease in all collisions, a 28 percent decrease in rear-end collisions, and a 35 percent reduction in angle collisions. (158)

Exhibit 10-8 summarizes selected findings relating to the safety benefits of adding a signal head.

Treatment	Finding
Add a primary signal head. (158)	28 percent estimated reduction in all collisions. 28 percent estimated reduction in rear-end collisions. 35 percent estimated reduction in angle collisions.

Exhibit 10-8. Safety benefits associated with addition of a signal head: selected findings.

Operational Performance

None identified.

Socioeconomic Impacts

The capital cost of adding an extra signal head is minimal if the existing mounting and pole can be used. If a new mast arm and/or pole is required, for instance, the costs could be significant. Additional maintenance and electricity costs are incurred over time.

Summary

Exhibit 10-9 summarizes the issues associated with adding a signal head.

Characteristic	Potential Benefits	Potential Concerns
Safety	Reduction in collisions.	None identified
Operations	None identified.	None identified.
Multimodal	None identified.	None identified.
Physical	None identified.	May require new signal pole and foundation.
Socioeconomic	None identified.	Costs may be high if a new mast arm and pole is required.
Enforcement, Education, and Maintenance	None identified.	None identified.

Exhibit 10-9. Summary of issues for adding a signal head.

10.1.5 Provide Backplates

Description

Backplates are a common treatment for enhancing the signal head visibility. Backplates have a dull black finish to enhance the contrast between the signal head and its surroundings, and can include a strip of yellow retroreflective tape around the perimeter of the backplate.

Applicability

The MUTCD contains guidance pertaining to the use of backplates in Section 4D.12, Visibility, Aiming, and Shielding of Signal Faces. Backplates should be provided for the following situations

- Intersections with approach speeds 45 mph or higher.
- Sun glare, bright sky, and/or complex or confusing backgrounds indicate a need for enhanced signal face target value.

Backplates serve to increase the contrast between the signal head and its surroundings, drawing the attention of approaching drivers and therefore increasing the likelihood that they will stop on a red indication. They should be considered in situations where a high number of angle collisions occur.

Operational Features

Backplates with a yellow retroreflective strip around the outside edge highlight the presence of the traffic signal. This is an advantage particularly during power outages, and provides an additional benefit to drivers with a color vision deficiency (the shape of the signal is clear, helping a color deficient driver identify red-yellow-green by placement rather than color).

Safety Performance

A British Columbia study evaluated crash effects of installing yellow micro-prismatic retroreflective sheeting along the outer edge of backplates in an attempt to frame the signal heads and make them more visible to motorists.(159) The study found an estimated 15 percent reduction in all crashes.

Operational Performance

The use of backplates enhances the contrast between the traffic signal indications and their surroundings for both day and night conditions, which is also helpful to older drivers (MUTCD Section 4D.12).(1)

Socioeconomic Impacts

The cost of installing signal backplates on a signal head is minimal. In addition, extra wind loading caused by backplates may necessitate larger (more costly) support poles for both span wires and mast arms.

Education, Enforcement, and Maintenance

Due to their larger size, signal heads with backplates may be more prone to movement during high winds. This may pose a problem if they are mounted on a span wire, leading to maintenance issues; however, there are designs available (e.g., vented backplates) to mitigate potential problems.

Summary

Exhibit 10-10 summarizes the issues associated with using signal head backplates.

Characteristic	Potential Benefits	Potential Concerns
Safety	Reduction in angle collisions.	None identified.
Operations	Benefit to Older Drivers	None identified.
Multimodal	None identified.	None identified.
Physical	None identified.	None identified.
Socioeconomic	None identified.	Minor cost for backplates and reflective tape. Possible increased pole cost for increased wind loads.
Enforcement, Education, and Maintenance	None identified.	None identified.

Exhibit 10-10. Summary of issues for using signal head backplates.

10.1.6 Provide Advance Warning

Description

These two treatments provide advance warning to motorists:

1. Provide a general warning of a signalized intersection ahead.
2. Provide a specific advance warning of an impending traffic signal change (from green to red) ahead.

Treatments that provide a general warning include static signs (SIGNAL AHEAD) and continuous advance-warning flashers. These flashers consist of a sign mounted on a pole with a yellow flashing light. The sign may read BE PREPARED TO STOP or show a schematic of a traffic signal. This type of flasher flashes regardless of what is occurring at the signal. Both treatments are placed upstream of the traffic signal at a distance sufficient to allow drivers time to react to the signal.

The second type of treatment provides a specific warning of an impending traffic signal change ahead. These advance-warning flashers inform drivers of the status of a downstream signal. This type is activated showing yellow flashing lights or illuminating an otherwise blank changeable message such as “Red Signal Ahead.”

The sign and the flashers are placed a certain distance from the stop line as determined by the speed limit on the approach.

Applicability

A SIGNAL AHEAD sign (possibly with an optional warning flasher) is required by the MUTCD in cases were the primary traffic control is not visible from a sufficient distance to permit the driver to respond to the signal. Warning flashers may be an effective countermeasure for:

- Rear-end collisions where a driver appears to have stopped suddenly to avoid running a red light and was struck from behind.
- Angle collisions caused by inadvertent red-light running.
- Queues from a red signal occurring at a location where approaching traffic cannot see it due to a vertical or horizontal curve.

Advance-warning flashers are appropriate for higher-speed, isolated intersections where the signalized intersection may be unexpected or where there may be sight distance issues. They appear to be most beneficial in situations where the minor approach volumes exceed 13,000 AADT or greater.(160)

Operational Features

A key factor in operating an advance-warning flasher is determining an appropriate time for coordinating the onset of flash with the onset of the yellow interval at the traffic signal. The recommended practice is to time the onset of flash as a function of posted speed for the distance from the flasher to the stop line. Timing the onset of flash for speeds greater than the posted speed encourages speeding to clear the intersection before the onset of the red interval.

Safety Performance

The introduction of advance-warning flashers on the approaches to a signalized intersection appears to be associated with a reduction in right-angle collisions.

Angle collisions were reduced by 35 percent at 11 signalized intersections where a SIGNAL AHEAD sign was installed on one or more approaches.(161)

A study conducted in Minnesota involving the installation of an advance-warning flasher on one approach found a 29 percent reduction in the number of red-light running events, in particular those involving trucks (63 percent). The study did not use a control or comparison group of intersection approaches.(162)

Results from a study of 106 signalized intersections in British Columbia showed that intersections with advance-warning flashers have a lower frequency of crashes than similar locations without flashers. The results were not statistically significant at the 95th percentile confidence level. Benefits were found primarily for moderate-to-high traffic volumes on the minor approach.(160)

Exhibit 10-11 shows selected references to safety benefits of advance-warning devices.

Treatment	Finding
Post SIGNAL AHEAD signs.(161)	35 percent estimated decrease in angle collisions.
Advance-warning flasher (163)	8 percent estimated decrease in all crash types, all severities.
	11 percent estimated decrease in injury crashes (all crash types)
	43 percent estimated decrease in right angle crashes (all severities)
	1 percent estimated decrease in rear-end crashes (all severities)

Exhibit 10-11. Safety benefits associated with advance warning signs and flashers: selected findings.

Operational Performance

Advance-warning flashers have no documented effect on intersection capacity.

Multimodal Impacts

Flashers may be particularly useful for larger commercial vehicles, which need a greater distance to stop on intersection approaches.

Socioeconomic Impacts

Advance-warning flashers that activate before the onset of the yellow phase may be costly to install.

Enforcement, Education, and Maintenance

Another study investigated the effect of advance flashing amber signs at two intersection approaches. Results showed that only a few drivers responded to the start of flashing by slowing down. The majority of vehicles increased their speed; many significantly exceeded the speed limit. Fifty percent of drivers who saw the flashing amber within the first 3 seconds it was displayed continued through the stop line. Driver education and police enforcement should be applied to ensure that drivers respond appropriately to signal-activated advance warning flashers.[164]

Summary

Exhibit 10-12 summarizes the issues associated with advance warning treatments.

Characteristics	Potential Benefits	Potential Concerns
Safety	Decreases angle collisions.	May induce some drivers to try to beat the light.
Operations	Negligible effect.	None identified.
Multimodal	Heavy vehicles given more time to stop.	None identified.
Physical	None identified.	Activated advance-warning flashers require link to traffic controller at intersection.
Socioeconomic	Signing and continuous advance-warning flashers have low cost.	Activated advance-warning flashers have moderate costs.
Enforcement, Education, and Maintenance	None identified.	Enforcement may be needed to ensure compliance with the signal indications.

Exhibit 10-12. Summary of issues related to advance warning treatments.

10.2 SIGNING AND SPEED CONTROL TREATMENTS

10.2.1 Improve Lane Use and Street Name Signing

Description

For some intersections, the use of signs beyond the minimum required by the MUTCD may improve safety and/or operations.[1]

Application

Signing treatments to consider at signalized intersections include:

- Increase the size of signs. Signs located on wide streets are more difficult to read from the far lane, and signs located overhead appear smaller to drivers and therefore need to be substantially larger than ground-mounted signs to have the same visibility.[69]
- Use overhead lane-use signs. These provide improved visibility and may help correct a problem with sideswipe crashes on approach due to last-minute lane changes. These are especially important for treatments involving indirect turning movements that may violate driver expectation. In addition, ground-mounted signs may be less visible in a typical urban environment due to visual clutter.
- Use large street name signs on mast arms. These signs, either retroreflective or internally illuminated, are visible from a greater distance.

- Use advance street name signs.

Safety Performance

Advance lane-use signs may improve safety by reducing last-minute lane changes and better preparing drivers to watch for potential conflicts. One study in Winston Salem, NC based on limited data reported that advance signing reduced angle collisions by 35 percent.[161] An evaluation of advance street name signs estimated these devices were associated with a 10 percent reduction in sideswipe crashes.[165]

Selected findings of safety benefits of other types of improved signing at signalized intersections are shown in Exhibit 10-13.

Treatment	Finding
Install larger signs.[101]	15 percent decrease in all collisions.
Overhead lane-use signs.[166]	10 percent decrease in rear-end collisions. 20 percent decrease in sideswipe collisions.
Install advance warning signs. [161]	35 percent estimated reduction in angle crashes.
Install advance street name signs. [165]	10 percent estimated reduction in sideswipe crashes.

Exhibit 10-13. Safety benefits associated with advance lane-use signs: selected findings.

Operational Performance

Advance lane-use signing may improve lane utilization at the intersection and therefore improve capacity if the affected movement is critical.

Physical Impacts

Sign supports are obstacles that could injure bicyclists, motorcyclists, pedestrians, and vehicle occupants.[69] Therefore, each sign should be carefully located to minimize the potential hazard. In addition, large advance signs can be difficult to locate in areas with tight right-of-way or where a sidewalk would be adversely affected by the sign or its support.

Socioeconomic Impacts

Low to moderate cost.

Summary

Exhibit 10-14 summarizes the issues associated with improving signing.

Characteristic	Potential Benefits	Potential Concerns
Safety	Various types of improved informational signing can reduce crashes.	None identified.
Operations	Advance signing may improve lane utilization and capacity of the intersection.	None identified.
Multimodal	None identified.	None identified.
Physical	None identified.	Sign supports must be designed to minimize potential hazard.
Socioeconomic	None identified.	Low to moderate cost.
Enforcement, Education, and Maintenance	None identified.	Added sign inventory to manage/maintain.

Exhibit 10-14. Summary of issues for improving signing.

10.2.2 Reduce Operating Speed

Excessive speed on an approach may lead to drivers' running a red light, braking suddenly to avoid a signal change, or losing control of the vehicle while attempting a left or right turn. Reducing the operating speed on an intersection approach cannot be accomplished through simply lowering the posted speed limit. Research suggests that drivers use the road and the surrounding road environment in choosing the operating speed of their vehicle, as opposed to a posted speed limit.

Possible countermeasures to reduce vehicles' operating speed include landscaping, rumble strips, medians, narrow travel lanes, bike lanes, on-street parking, curb radii reductions, and automated speed enforcement. Several of these treatments are discussed elsewhere in the guide; the reader is encouraged to refer to those sections for more information.

10.3 ROADWAY SURFACE IMPROVEMENTS

10.3.1 Improve Pavement Surface

Description

An important objective of highway design objective is ensuring that pavement provides sufficient friction and provides for adequate drainage. A polished pavement surface, a surface with drainage problems, or a poorly maintained road surface can contribute to crashes at or within intersections. Within an intersection, the potential for vehicles on adjacent approaches to be involved in crashes contributes to the likelihood of severe (angle) crashes, particularly in crashes where the driver is unable to stop in time.

Water can accumulate on pavement surfaces due to rutted wheel paths, inadequate crowns, and poor shoulder maintenance. These problems can also cause skidding crashes and should be treated when present. While there is only limited research on such site-specific programs, the results provide confidence that pavement improvements are effective in decreasing crashes related to wet pavement. The effectiveness will vary with respect to location, traffic volume, rainfall intensity, road geometry, temperature, pavement structure, and other factors

Vehicles often experience difficulties in coming to a safe stop at intersections because of reduced friction on wet or slippery pavement. A vehicle will skid during braking and maneuvering when frictional demand exceeds the friction force that can be developed between the tire and the road surface; friction is greatly reduced on a wet and slippery surface, which has 20 to 30 percent less friction than a dry road surface.[167]

Water pooling on or flowing across the roadway can prevent smooth operation of an intersection if vehicles are forced to decelerate or swerve in order to proceed safely through the intersection. It is necessary to intercept concentrated storm water at all intersection locations before it reaches the highway and to remove over-the-curb flow and surface water without interrupting traffic flow or causing a problem for vehicle occupants, pedestrians, or bicyclists. Improvements to storm drainage may be needed to improve intersection operations and safety. Potholes, if present on an approach, increase the likelihood of drivers' swerving or braking to avoid damage to their vehicles. A rough surface may also allow water to pool, and in colder environments, can cause ice to form on an intersection approach.

Proper drainage and a high-quality surface will prevent problems related to pooled water and lack of skid resistance. Skid resistance is an important consideration in pavement design, and polished pavement surfaces should be addressed to reduce the potential for skidding. Both vehicle speeds and pavement condition affect the surface's skid resistance. Improving the pavement condition, especially for wet weather conditions, can be accomplished by providing adequate drainage, grooving existing pavement, or overlaying existing pavement.

Improvements to pavement condition should have high initial skid resistance, ability to retain skid resistance with time and traffic, and minimum decrease in skid resistance with increasing speed.

Applicability

Improvements related to skid resistance, drainage problems, and pavement surface should be considered when:

- A high number of wet road surface collisions occur.
- Angle collisions occur and many involve one or more vehicles' skidding into the intersection and striking another vehicle.
- Single vehicle collisions occur where the driver lost control due to skidding.
- Rear-end or sideswipe collisions occur when drivers swerve or brake to avoid potholes or puddles.
- Change in type of control.

Safety Performance

Several pavement treatments appear to reduce collisions, although the study locations for the following findings of effectiveness were not necessarily signalized intersections. A 2010 California study reported that resurfacing with grooved pavement reduced wet road crashes by 50 percent, but results were not significant due to the lack of sufficient data.[168] Grooves carry off water from the road surface and increase the coefficient of friction between tires and pavement. The same study found that resurfacing with open-graded asphalt concrete significantly decreased the number of wet-related collisions by 42 percent. Another paper describes a non-carbonate surface treatment used at a wide range of sites as part of a comprehensive Skid Accident Reduction Program. Wet pavement collisions dropped by 61 to 82 percent; fatal and injury wet pavement collisions dropped by 73 to 84 percent.[169] Apart from addressing wet road surface collisions, resurfacing the approaches to an intersection will likely reduce the number of rear-end or sideswipe collisions caused when vehicles swerve or slow to avoid potholes. It may, however, lead to a higher operating speed and an overall shift in the collision profile toward collisions of greater severity.

Exhibit 10-15 shows the safety benefits associated with nonskid treatments, drainage improvements or resurfacing.

Treatment	Finding
Groove pavement.[168]	50 percent estimated reduction in wet pavement collisions.
Resurface with open-graded asphalt concrete.[168]	42 percent estimated reduction in wet pavement collisions.
Overlay pavement.[170]	27 percent estimated reduction in all collisions. 29 percent estimated reduction in fatal collisions. 16 percent estimated reduction in injury collisions. 32 percent estimated reduction in PDO collisions.
Resurface.[171]	5 percent estimated reduction in fatal/serious injury collisions. 1 percent estimated increase in all collisions.
Improve pavement friction (increase skid resistance).	40 to 78 percent estimated reduction in wet road crashes
Improve pavement texture.[172]	5 percent estimated reduction in all collisions.
Noncarbonate surface treatment.[169]	61 to 82 percent estimated reduction in wet pavement collisions. 73 to 82 percent estimated reduction in fatal/injury collisions on wet pavement.
Drainage improvement.[101]	20 percent estimated reduction in all collisions.

Exhibit 10-15. Safety benefits associated with nonskid treatments, drainage improvements, or resurfacing: selected findings.

Operational Performance

A pavement in poor condition can result in lower saturation flow rates and, consequently, reduce the capacity of the intersection. If vehicles need to proceed at slow speeds through an intersection or deviate from the travel path to avoid potholes, pooled water, or ice, operations likely will degrade.

Pavement resurfacing and drainage improvements usually improve intersection operations, although no known research conclusively indicates the expected capacity benefit of these treatments.

Multimodal Impacts

If road improvements are being carried out, sidewalks and bike paths adjacent to the intersection should be considered for skid-resistant treatments, checked for adequate drainage, and repaired if uneven surfaces exist due to cracking, frost heaves, etc. This will reduce pedestrian tripping hazards and the likelihood of bicyclists' swerving into traffic to avoid potential roadside hazards.

Enforcement, Education, and Maintenance

Pavement improvements (particularly resurfacing) may convey the message to drivers that they can now travel at higher speeds. Speeds on the approaches to the intersection should be monitored to ensure that the speed profile has not increased significantly in the post-implementation period. If speed has increased significantly and this is leading to degradation in safety, speed enforcement should be considered.

Summary

Exhibit 10-16 summarizes the issues associated with pavement treatments.

Characteristic	Potential Benefits	Potential Concerns
Safety	Wet-weather collisions reduced. Angle collisions due to skidding reduced. Rear-end/sideswipe collisions due to swerving/braking reduced.	Higher speed profile is a possible byproduct.
Operations	Improved traffic flow, less swerving.	None identified.
Multimodal	None identified.	None identified.
Physical	No additional requirements.	None identified.
Socioeconomic	None identified	Moderate to high costs associated with improvements.
Enforcement, Education, and Maintenance	None identified.	Enforcement may be needed to control speeds.

Exhibit 10-16. Summary of issues for pavement treatments.

10.3.2 Improve Cross Section

Description

Roadways should intersect on as flat a grade as possible to prevent difficulty in vehicle handling, especially when vehicles will likely need to wait for their turn to enter the intersection (as with left-turn lanes). However, it is not always feasible to design a level intersection, so consideration should be given to the profiles of the roadways as they intersect. Practitioners should examine roadway profiles and crowns to determine whether the intersection of these slopes contributes to vehicle handling difficulties. Generally, the pavement of the minor road is warped so that the crown is tilted to the same plane as the major road profile. Another option is to flatten the cross sections of both roadways so that they are each inclined to intersect with the profile of the other road. This method can create a large, flat roadway area, which in turn can lead to drainage problems; therefore, this design should only be used on smaller intersections or where the drainage problem can be solved. A third option involves maintaining constant cross sections on both roadways, and altering the centerline profiles to provide smooth pavement. This is a less desirable option than the previous two discussed, given that drivers from both directions must pass over three grade breaks at the intersection.[(3)]

In addition to the benefits to vehicles, pedestrians and bicyclists benefit from improvements to the cross section of an intersection. Severe grades and cross slopes can be difficult for bicyclists and pedestrians to negotiate. For example, flatter uphill grades allow bicyclists to more easily accelerate from a complete stop. Low cross slopes of no more than 2 percent are essential for pedestrians with mobility impairments per ADAAG, as severe cross slopes can make a roadway inaccessible.[(36)]

Application

This treatment may be applicable at intersections where the grades of intersecting roads are greater than 3 percent and one or both of the following is true:

- A high number of rear-end collisions are occurring due to driver hesitation on the approaches and while making left or right turns.
- A high number of left-turn collisions are occurring due to poor sight distance.

Safety Performance

The cross section improvements discussed above will improve sight distance, and therefore should decrease left-turn conflicts with through vehicles. It will also allow a more uniform operating speed through the intersection on the major road approaches, reducing rear-end conflicts.

Operational Performance

The cross section improvements discussed above may reduce the time headway between vehicles and increase the capacity of the intersection.

Multimodal Impacts

Larger commercial vehicles and transit buses will particularly benefit from cross section improvements to the intersection. During any intersection reconstructing, the engineer should consider improvements to the adjacent sidewalks if pedestrian facilities exist and are being used.

Socioeconomic impacts

Cross section improvements may have moderate costs. They may be difficult to implement in areas where there is little or no right-of-way. Coordination with adjacent landowners may be needed.

Education, Enforcement, and Maintenance

Cross section improvements may convey the message that drivers can now travel at higher speeds. Speeds on the approaches to the intersection should be monitored to ensure that the speed profile has not increased significantly in the post-implementation period. If speed has increased significantly and this leads to safety problems, consider police speed enforcement. Note that cross section improvements on hilly roadways may actually result in reduced speeds.

The effectiveness of this treatment will likely be enhanced if performed in conjunction with a comprehensive and timely winter road maintenance program in colder climates.

Summary

Exhibit 10-17 summarizes the issues associated with cross section improvements.

Characteristic	Potential Benefits	Potential Concerns
Safety	Decrease in rear-end collisions due to driver braking. Decrease in left-and right-turning collisions involving inadequate sight distance.	Higher speed profile.
Operations	Better traffic flow.	None identified.
Multimodal	Improved driver handling of large trucks and transit. Sidewalks and curb ramps will be made more accessible by retrofitting to new cross section.	None identified.
Physical	None identified.	Significant right-of-way requirements.
Socioeconomic	None identified.	Moderate costs.
Enforcement, Education, and Maintenance	None identified.	Speed enforcement may be necessary. Winter maintenance may be needed.

Exhibit 10-17. Summary of issues for cross section improvements.

10.3.3 Remove Obstacles from Clear Zone

Description

Roadside objects can be a particular hazard to motorists on high-speed approaches. Utility poles, luminaires, traffic signal poles, bus shelters, signs, and other street furniture should be moved back from the edge of the road if possible. In general, a signalized intersection and the entire area within the right-of-way should be kept free of visual clutter, particularly illegally placed commercial signs.

Application

For high speed approaches at rural intersections, obstacles should be routinely removed from the clear zone on intersection approaches. Removing objects should be considered an immediate priority when:

- An unusually high number of run-off-the-road injury and fatal collisions involving roadside obstacles occurs.
- There is evidence in the collision police report that drivers claim distraction by unnecessary or illegally placed signing or other visual clutter.

Poles and other hardware that cannot be removed could be shielded from impact by errant vehicles.

For urban, low-speed environments, the right-of-way is often limited. It may not be practical to establish a full-width clear zone. Types of obstructions that may be located near signals could be fire hydrants, signs, utility poles, transit facilities, and luminaire supports. Obstacles should be located far enough away from the shoulder and curb to accomplish the following:

- Avoid adverse impacts on vehicle lane position and encroachments into other lanes.
- Improve sight distance for all users at the signal.
- Reduce the travel lane encroachments from occasional parked and disabled vehicles.
- Minimize contact between obstacles and vehicles.

The practitioner should relocate objects a minimum of 4 feet and at least 6 feet where feasible under these conditions. Other considerations can be found in the Roadside Design Guide.[62]

Safety Performance

This treatment should decrease the frequency and severity of run-off-the-road collisions involving roadside obstacles. An Ohio study on roadside safety treatments estimated that removing or relocating fixed objects outside of the clear zone was associated with a 38 percent reduction in fatal and injury crashes.[173] This study was not limited to intersections.

Physical Impacts

Moving objects further away from the roadside may be difficult to implement in built-up areas where right-of-way is limited. Studies have shown under urban conditions that a minimum offset from curbs of 4 ft and, if possible, a distance of 6 ft can reduce fixed object crashes. For buffer areas between sidewalks and curbs, the practitioner should only allow posts with frangible bases.[174]

Enforcement, Education, and Maintenance

Traffic engineers should coordinate with their equivalents in the planning department and maintenance staff to ensure that the entire right-of-way surrounding the intersection and its approaches stays free of obstacles and extraneous signing.

Summary

Exhibit 10-18 summarizes the issues associated with removing obstacles from the clear zone.

Characteristic	Potential Benefits	Potential Concerns
Safety	Reduction in the number and severity of single-vehicle collisions.	None identified.
Operations	None identified.	None identified.
Multimodal	None identified.	None identified.
Physical	--	Obstacle removal may be difficult in built-up areas with limited right-of-way.
Socioeconomic	None identified.	None identified.
Enforcement, Education, and Maintenance	--	Ongoing maintenance will be needed to ensure that the clear zone remains free of obstacles.

Exhibit 10-18. Summary of issues for removing obstacles from the clear zone.

10.4 SIGHT DISTANCE TREATMENTS

10.4.1 Improve Sight Lines

Description

Adequate sight distance for drivers contributes to the safety of the intersection. In general, left-turning vehicles need sight distance to see opposing through vehicles approaching the intersection in situations where a permissive left-turn signal is being used. Also, where right turns on red are permitted, right-turning vehicles need adequate sight distance to view vehicles approaching from the left on the cross street, as well as opposing vehicles turning left onto the cross street. AASHTO's *A Policy on Geometric Design of Highways and Streets* recommends providing adequate sight distance for all movements at signalized intersections where the signal operates on flash at times.(3)

Sight distance at signalized intersections should:

- Provide drivers making permissive left-turning movements need enough sight distance to judge on-coming traffic.
- Provide clear sight lines to all signal faces.
- Provide clear sight lines at pedestrian crosswalks.
- Provide clear sight lines at bike lanes and other bicycle facilities or treatments.
- Have sight distance at or above the above the minimums used in the AASHTO Green Book when placed on flash for emergencies.

Carefully consider landscaping at signalized intersections; it could prevent motorists from making left and right turns safely due to inadequate sight distances. Practitioners should ensure that traffic signs, pedestrian crossings, and nearby railroad crossing and school zones are not obstructed. Median planting of trees or shrubs greater than 2 ft in height should be well away from the intersection (more than 50 ft). No plantings having foliage between 2 ft and 8 ft in height should be present within sight triangles. Low shrubs or plants not exceeding a height of 2 ft are appropriate on the approaches to a signalized intersection, either on the median, or along the edge of the roadway. The 1990 FHWA Guide, *Vegetation Control for Safety: A Guide for Street and Highway Maintenance Personnel,* provides additional guidelines and insight on vegetation control with regard to sight distance issues.[87]

Application

Visibility improvements at signalized intersections should be considered when:

- Inadequate sight distance exists between vehicles and/or pedestrian. Any obstructions that limit sight distance of any types of users should be removed or relocated. A high number of left- and right-turn collisions are occurring.

Safety Performance

Crashes related to inadequate sight distance (specifically, angle- and turning-related) would be reduced if sight distance problems were improved. Intersections with sight distance problems will experience higher collision rates.[157] Older drivers are likely to have problems at intersections with limited sight distances, as they may need more time to perceive and react to hazards. Exhibit 10-19 shows the expected reduction in number of collisions per intersection per year, based on an FHWA report.[175]

AADT* (1000s)	Increased Sight Distance		
	20 ft–49 ft	50 ft–99 ft	> 100 ft
< 5	0.18	0.20	0.30
5-10	1.00	1.30	1.40
10-15	0.87	2.26	3.46
> 15	5.25	7.41	11.26

* Annual average daily traffic entering the intersection

Exhibit 10-19. Expected reduction in number of crashes per intersection per year by increased sight distance.[175]

A report by FHWA cites sight distance improvements as being one of the most cost-effective treatments (see Exhibit 10-20). Fatal collisions were reduced by 56 percent and nonfatal injury collisions were reduced by 37 percent at intersections having sight distance improvements.[176] The Handbook of Road Safety measures estimates that increasing triangle sight distance is associated with a 48 percent reduction in injury crashes, and an 11 percent reduction in property damage crashes.[145] However, these results include both signalized and unsignalized intersections.

Treatment	Implication
Sight distance improvements.[176]	56 percent estimated reduction in fatal collisions. 37 percent estimated reduction in injury collisions.
Sight distance improvements.[145]	48 percent estimated reduction in injury crashes. 11 percent estimated reduction in property damage crashes.

* Note: these crash results include both signalized and unsignalized intersections

Exhibit 10-20. Safety benefits associated with sight distance improvements: selected findings.

Socioeconomic Impacts

Sight distance improvements can often be achieved at relatively low cost by clearing sight triangles of vegetation or roadside appurtenances.

The most difficult aspect of this strategy is the removal of sight restrictions located on private property. The legal authority of highway agencies to deal with such sight obstructions varies widely, and the time (and possibly the cost) to implement sight distance improvements by clearing obstructions may be longer if those obstructions are located on private property than if they are on public property. If the object is mature trees or plantings, then environmental issues may arise. Larger constructed objects (i.e., bus shelters, buildings) may not be feasibly removed. Consider other alternatives in these situations.

Multimodal Impacts

The appropriate use of landscaping can visually enhance a road and its surroundings. Landscaping may act as a buffer between pedestrians and motorists and reduce the visual width of a roadway, serving to reduce traffic speeds while providing a more pleasant environment. However, landscaping should not interfere with the movement of pedestrians along sidewalks, nor should it block the motorist's view of the pedestrian, or the pedestrian's view of the motorist.

Enforcement, Education, and Maintenance

All plantings should have an adequate watering and drainage system, or should be drought resistant. This will minimize the amount of maintenance required and reduce the exposure of maintenance staff to traffic. Plantings should not be allowed to obstruct pedestrians at eye height or overhang the curb onto the pavement.

Summary

Exhibit 10-21 summarizes the issues associated with visibility treatments.

Characteristics	Potential Benefits	Potential Concerns
Safety	Left- and right-turning collisions involving inadequate sight distance.	None identified.
Operations	Negligible.	None identified.
Multimodal	Provides additional warning for heavy vehicles making left and right turns. Appropriate landscaping will provide a more pleasant environment for pedestrians.	None identified.
Physical	None identified.	May be significant right-of-way requirements.
Socioeconomic	Appropriate landscaping will visually enhance intersection and surroundings.	None identified.
Enforcement, Education, and Maintenance	None identified.	Landscaping may require extensive maintenance.

Exhibit 10-21. Summary of issues for visibility improvements.

10.5 DILEMMA ZONE DETECTION

Description

On a high-speed approach to a signalized intersection there is a length of roadway in advance of the intersection, commonly referred to as the "dilemma zone," wherein drivers may be indecisive and respond differently to the onset of the yellow signal. When in the dilemma zone at the onset of yellow, some drivers may stop abruptly, while others may decide not to stop and perhaps even accelerate through the intersection. Such variation in driver behavior is conducive to the occurrence of rear-end, right-angle, and left-turn collisions. A dilemma zone detection system uses pulse (or advanced) detectors placed at one or more locations on the intersection approach to extend the green and prevent the onset of yellow while approaching vehicles are in the dilemma zone (see Section 5.5.1).

The current state of the practice includes two typical installations:

1. Basic detection/actuation to increase the probability of gap-outs and reduce max-outs to improve both safety and operations.
2. Detection systems that take more dynamic control, extending all-red time if the system detects that a driver will likely run the red light.

As shown in Exhibit 10-22, some States use a rule of thumb of 5 seconds in advance of the stop line to provide dilemma zone protection. On very high speed routes, an additional set of detectors may be placed 8 seconds from the stop line. Exhibit 10-23 illustrates the distance traveled by vehicles at various speeds.

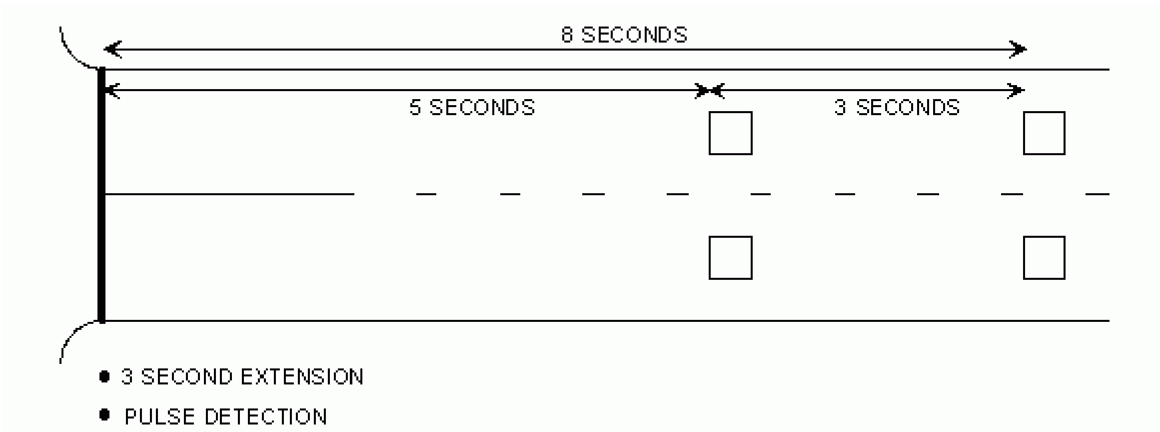

Exhibit 10-22. Dilemma Zone and detector placement.(63)

Exhibit 10-23. Vehicular distances traveled by speed.(Adapted from 63)

Speed (mph)		Time (s)	
		5	8
mph	fps	Distance Traveled (ft)	
5	7.3	37	59
10	14.7	73	117
15	22.0	110	176
20	29.3	147	235
25	36.7	183	293
30	44.0	220	352
35	51.3	257	411
40	58.7	293	469
45	66.0	330	528
50	73.3	367	587
55	80.7	403	645
60	88.0	440	704
65	95.3	477	763
70	102.7	513	821
75	110.0	550	880
80	117.3	587	939

Application

Dilemma zone detection systems apply to high-speed signalized intersections, often located in rural or suburban areas. This treatment (more specifically, a dynamic type control) is especially useful on high-speed approaches with heavy volumes of large trucks.

Safety Performance

An evaluation of a dilemma zone detection system developed for the Texas Department of Transportation estimated that red light violations were reduced by 58 percent, heavy vehicle red light violations were reduced by 80 percent, and severe crash frequency was reduced by 39 percent.[177]

Operational Performance

The dilemma zone detection system developed for the Texas Department of Transportation was associated with a 14 percent reduction in approach delay and a 9 percent reduction in stop frequency. Other dynamic detection system designs for protection achieve similar operational improvements.

Multimodal Impacts

Large trucks and tour buses, which require longer stopping distances than passenger vehicles, especially benefit from the use of dilemma zone detection.

Socioeconomic impacts

Reductions in approach delay, heavy vehicle braking, and injury crashes provide economic benefits. Significant initial costs are associated with design and implementation of dilemma zone detection systems.

Education, Enforcement, and Maintenance

Traffic signal maintenance technicians may require additional training on technical aspects of dilemma zone detection systems.

Summary

Exhibit 10-24 summarizes the issues associated with the application of dilemma zone detection.

Characteristics	Potential Benefits	Potential Concerns
Safety	Reduced red-light running and injury crashes.	None identified.
Operations	Reduced approach delay and stop frequency.	None identified.
Multimodal	Especially useful for large trucks.	None identified.
Physical	None identified.	Possible disturbance to ROW and/or pavement surface.
Socioeconomic	Economic benefits from reductions in approach delay, heavy vehicle braking, and injury crashes.	Significant initial costs for design and implementation.
Enforcement, Education, and Maintenance	None identified.	Traffic signal technicians may require additional training for maintenance of installed equipment.

Exhibit 10-24. Summary of issues for dilemma zone detection

10.6 RED LIGHT CAMERA ENFORCEMENT

Description

Red light cameras automatically photograph vehicles whose drivers run red lights. The cameras are connected to the traffic signal and to sensors monitoring traffic flow just before the crosswalk or stop line. Vehicles that do not stop during the red phase are photographed. Depending on the particular technology, the system captures a series of photographs and/or a video clip showing the red light violator prior to entering the intersection on a red signal, as well as the vehicle's progression through the intersection. Cameras record the date, time of day, time elapsed since the beginning of the red signal, vehicle speed, and license plate. Tickets typically are mailed to owners of violating vehicles, based on a review of photographic evidence.

Application

Red light cameras are typically deployed at specific approaches to urban and suburban intersections with histories of red-light running crashes. Red light cameras may be especially useful on approaches where police officers have difficulty conducting traditional red light enforcement due to constrained environments and/or high traffic speeds.

It is vital to put public safety first in decisions regarding enforcement of traffic laws, including an emphasis on non-automated enforcement alternatives where applicable.(178) Note that other infrastructure treatments should be considered before automated red light enforcement, including the following:

- Updating signal timing to reflect current traffic conditions.
- Updating clearance timing per recommended practice.
    - Ensuring that clearance timing practice does not vary between State and local agencies in a region.
- Clearing sight lines to signal heads.
- Signing in advance of the intersection.
- Installing advance, signal-activated warning flashers.
- Installing reflectorized backplates.

Safety Performance

In NCHRP Report 729: *Automated Enforcement for Speeding and Red Light Running* three of the four case studies included information on safety performance:(179)

- The program in the city of Portland, Oregon, resulted in a 69 to 93 percent reduction in red-light running violations.
- The program in the city of Virginia Beach, Virginia, reduced red light violations more than 69 percent over a 13 month period since the activation of the red light cameras.
- An audit of the program in the city of San Diego, California, found an 8 percent reduction in crashes from red-light running and a 16 percent reduction in red-light running related crashes at the specific signals with cameras. The city has initiated many changes to the program since completion of the audit.

Some studies, including FHWA's Safety Evaluation of Red Light Cameras, (207) have reported reductions in angle crashes along with increases in rear end crashes, resulting in a net decrease in aggregate crash severity. The *Highway Safety Manual* (11) (Chapter 14) includes crash modification factors for red light cameras that indicate a 26 percent reduction in angle crashes and an 18 percent increase in rear-end crashes. However, NCHRP Report 729 concluded that the overall impact on violations and crashes related to a red light enforcement program needs further study.

Operational Performance

No operational performance measures have been reported for this treatment. However, changes to signal timing, detector settings, and other components of the intersection must be communicated to the division responsible for overseeing the red light program. As these adjustments are made, changes to the red light cameras can be made to ensure proper operation.

Multimodal Impacts

Pedestrians and bicyclists are vulnerable to impacts from motor vehicles that run red lights, and thus stand to benefit from reductions in red-light running behavior.

Socioeconomic impacts

A successful red light camera program will modify driver behavior in order to achieve a decrease in severe crashes associated with red-light running. The citations generated from red light cameras will result in fines and fees, which should be distributed in accordance with the state laws and/or local ordinances. In most cases, the citation fines and fees may be used to offset the cost of the red light camera program, with any excess monies used expressly for other road safety purposes.

The judiciary is critical to a successful red light camera program from the development of legislation to the choice of camera right down to the processing of violations. It is therefore important to get them involved as early on in the process as possible and for the judiciary to champion the effort. Another reason to involve them is to ensure that they are prepared to support the prosecution of the issued tickets when the red light camera system is activated.[180]

Education, Enforcement, and Maintenance

A key component in developing a new enforcement program is informing and educating the public about the program, especially the purpose, the camera locations, the process for adjudication of citations, the use of revenue, and results of program evaluation in terms of effect on violations and crashes. In addition to conducting a public information campaign, a jurisdiction should consider assessing public support prior to, and during, implementation of the program.

Summary

Exhibit 10-25 summarizes the issues associated with red light cameras

Characteristics	Potential Benefits	Potential Concerns
Safety	Reduced red-light running and angle crashes.	Increased rear-end crashes.
Operations	None identified.	Changes to signal timing must be addressed when an agency installs red light cameras.
Multimodal	Pedestrians and bicyclists benefit from reduced red-light running.	None identified.
Physical	None identified.	Additional equipment installed along the roadside.
Socioeconomic	Fines generated by citations typically cover the cost of camera installation and operation	Fine revenue in excess of program operating costs can be a source of controversy.
Enforcement, Education, and Maintenance	Enforcement should be accompanied by public information and education.	Maintenance of installed equipment.

Exhibit 10-25. Summary of issues for red light cameras.