Comment on intersection control warrants

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FHWA proposes changes to intersection control standards based on the NCHRP report *Potential MUTCD Criteria for Selecting the Type of Control for Unsignalized Intersections* (Fitzpatrick et al. (2015)). The data in the report show that all way stop signs are very rarely justified, but FHWA proposes to greatly increase the number of such signs. What used to be secondary factors are elevated to primary factors. The crash warrants have been effectively halved. The cost-benefit analysis has been ignored.

Who am I? Why am I here?

FHWA needs to think about the proliferation of stop signs. The all way stop sign did not exist 60 years ago but now it is ubiquitous. Two way stop signs have also proliferated. I agree with the comment by Montgomery County Department of Transportation (FHWA-2020-0001-0269):

> The overuse of STOP signs as compared to YIELD signs seems to have eroded the efficacy of STOP signs. This MUTCD should take a more stringent stance that emphasizes YIELD signs as the default intersection control, with STOP signs being reserved for more limited circumstances necessitating a full and complete stop.

In the Northeast many stop lines are so far back that the true intersection operates as if it had yield control. Drivers learn that there is no point in stopping at the stop line because they can not see cross traffic from so far back. Even if they stop at the edge of the road they are legally considered to have run the stop sign. The combination of poor traffic control devices and properly behaving drivers makes happy hunting for police out for a pretext stop.

The survey of existing practice was incomplete. Massachusetts MUTCD section 10A-4 reads

> 10A-4 Stop Signs
>
> The purpose of the Stop Sign is to designate right-of-way to vehicles making conflicting movements. It is not intended, nor shall it be used for

> the control of speed, traffic calming or to forestall pedestrian, rear-end or turning movement accidents.

This language is present because the most common request for stop signs is for traffic calming. The question asked at traffic committee meetings is not "*should* we post stop signs?" but "*can* we post stop signs?" Meaning, "we want to post stop signs and we need our engineer to find an excuse." It doesn't matter if there are no crashes, because the signs are not being posted to reduce crashes. It doesn't matter if there is no traffic delay, because the signs are not being posted to manage delay. The city council wants stop signs because a resident asked for stop signs. To slow traffic. For pedestrians. For the children. To deter commuters. Because it's an accident waiting to happen. Because all intersections are supposed to have stop signs.

I remember driving off the main roads near Thornbury, Pennsylvania. Every intersection was a three or four-way stop. Outside of commuting hours there was not even a need to tap the brakes. With one exception. A stop sign at the junction of Route 926, a busy, high speed, two lane road, looks like the rest. Being familiar with the area I knew that was a legitimate stop sign despite the others being nuisance stop signs. How many drivers would not?

Engineers, under pressure to give stop signs as favors, will approve them based on vague fears that are belied by actual crash data. In order to achieve uniformity and maintain respect for stop signs, the need to meet quantitative warrants should be emphasized and the warrants should not be relaxed so much that every intersection "needs" stop signs.

Specific changes proposed by FHWA

Speed control

The new prohibition on use of stop signs for speed control (formerly guidance) is welcome. FHWA should adopt more of Massachusetts' language quoted above.

All-way stop warrants

The proposed rewriting of all way stop warrants will encourage an extreme change from prior standards not supported by the data in Fitzpatrick et al. (2015).

Under the 2009 MUTCD it is commonly understood that the numeric warrants are the main factors and the options influence decision at the margin.[1] The literature refers to safety effects of *warranted* stop signs, meaning signs that meet the numeric warrants, with unwarranted stop signs sometimes increasing crash rates[2]. FHWA proposes that

[1] For example, the Massachustts MUTCD states "Multi-way Stop Signs must meet the warrant criteria as outlined in Section 2B.07"

[2] E.g. Ewing (1999, p. 120), Fitzpatrick et al. (2015, p. 30)

the formerly secondary options be elevated to primary warrants. The new warrants are subjective, not objective. Anywhere somebody is not satisfied with sight distance, all way stop warrants A and B will be satisfied. Anywhere a pedestrian or bicycle might be found, all way stop warrant E will be satisfied.

Pedestrian and bicycle movements

In the proposed 11^{th} edition warrant E makes all the others irrelevant.

All way stop signs may be posted "where pedestrian and/or bicycle movements justify the installation of all-way stop control." This is the same as writing "All way stop signs may be posted at any intersection where pedestrians or bicycles are allowed." There is not an intersection in the country where you can not find an engineer willing to sign off on a concern that some day, somehow, a pedestrian or bicycle might wander by and get hit.

No guidance is given as to what sort of pedestrian or bicycle movements might justify all way stop control. No explanation is offered for why including pedestrians and bicycles in volume and injury counts is inadequate. At low volumes, why are pedestrian and bicycle movements called out for special treatment when low volume motor vehicle movements are not? At high volumes, additional treatments are provided elsewhere in the MUTCD.

This change was not based on any evidence in Fitzpatrick et al. (2015) and was not called out as an intentional change in that report. It seems to be an accidental result of reformatting.

Warrants should be quantitative. I have proposed language below making pedestrian and bicycle conflicts a factor to consider after warrants are met. When pedestrians and bicyclists are actually injured, as opposed to suffering ill-defined "conflicts", their injuries will count towards the safety warrant.

Elevation of sight distance

Sight distance has also been promoted to a primary factor in warrants A and B (redundantly). It is not appropriate to have anything as vague as "sight distance…is not adequate" as a warrant. Warrants should be quantitative.

The only mention of sight distance for multi-way stops in Fitzpatrick et al. (2015) is a box in Table 2–10, copied from a 1988 ITE publication, reading "highly restricted visibility on opposing approaches." This would appear to mean something more than simply "not adequate."

There is hardly an intersection in my area where you can not find an engineer willing to put in writing that sight distance is inadequate despite a documented history of safe operation. Since the MUTCD provides no guidance on what sight distance is required the criteria are up to the local government.

Some look to the "Green Book" for figures. The AASHTO intersection design goals should not be considered warrants. Design speed is not a speed limit warrant[3]. Passing zone design goals are not used for passing zone marking warrants. And AASHTO's many intersection-related distances should not be used to determine intersection control.

The only formal agency policy I have seen for sight distance and stop control is the UK Department for Transport's standards for minor road stop control(DfT, p. 18). The sight distances to consider stop control are approximately half of stopping sight distance under AASHTO design guidlines. All way stop control is not used in the UK but obviously the rules would need to be even stricter than for minor road stop control.

Most intersections where all way stops are being considered are old enough to have crash history. If there are no crashes, there is no need for more stop signs to prevent them. Remember, "an accident waiting to happen" is the highest praise that can be given to any road.

To provide an objective measure I propose using the DfT sight distance warrants for minor road stop control only. For all way stops, sight distance should be relegated to to support. I propose specific language below.

Elimination of delay requirement

In the 2009 MUTCD the purpose of the volume warrant for all way stop signs is to manage minor street delay. The minor road warrant is a combination of volume and delay ("with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle").

The delay requirement has been removed from the proposed 11^{th} edition volume warrant (section 2B.16) without explanation. It would be allowed to stop major street traffic regardless of benefit to minor street traffic.

Fitzpatrick et al. (2015) acknowledged the important of the 30 second threshold. On page 12 they say after 30 seconds road users become impatient and engage in more risky behavior. On page 93 they write "Delays in excess of 35 sec/veh on the minor-road approach have been suggested as a tipping point." NCUTCD recommendation 15B-RW-02 also retains the delay warrant.

Removal may be a mistake, or perhaps it was thought that a simulation was good enough to predict delay. But simulations would need to cover the entire possible range of turning and truck percentages. As they acknowledge, "Another ITE paper from 2004 found that turning percentages have a major impact on the performance of stop-controlled intersections." Facts are more important than models.

The requirement to measure 30 seconds of delay should be restored.

[3]See Fitzpatrick et al. (2003) Table 42: "Arbitrarily setting lower speed limits at point locations due to a lower inferred design speed is neither effective nor good engineering practice."

Reduction in crash warrant

The new standard for 36-month crash experience will substantially increase the number of intersections eligible for stop signs and should be reconsidered. I agree with comment FHWA-2020-0001-0168 that "36 month criteria is an unreasonably low threshold to meet and could result in a multitude of new all-way stops causing a decrease in vehicle mobility and an increase in vehicle emissions."

The addition of 36-month values was said to be based on "the proposed signal crash experience warrant developed in NCHRP Project 07-18" (Bonneson et al. (2014)). I gather from that document that engineers wanted to use longer intervals to smooth out year-to-year variation. While that is a legitimate concern the practical effect of the change is to make many more intersections "need" stop signs.

While not explicitly stated, it appears the minor road stop conditions were derived by assuming accidents are described by a Poisson distribution.[4] At least, the minor road stop control values are roughly consistent with a Poisson distribution. By that I mean, the chances of having 3 accidents in any of three consecutive years is similar to the chance of having 5 or 6 accidents in the whole three year period.

It also appears that the 36-month figures were copied from minor road stop control to all-way stop control, meaning an intersection that qualified for minor road stop control would also qualify for all way stop control. That is a mistake. The figures should be much higher.

The consequences of the change

Below I list the chances that an intersection will meet warrants looking at the past three years of data, taking the single year warrant three times or the three year warrant once. I assume a Poisson distribution. The first row shows the true expected rate of accidents per year over the long term, the parameter of the Poisson distribution. The first row of percentages is the chance that the intersection will meet the old 5 per year warrant in a single year. The next row is the chance that the intersection will meet that warrant in any of the past three years. The last row shows the chances of meeting the 6 per 3 year warrants over the same period.

All way stop control crash warrants				
long term average / year	2.0	3.0	4.0	5.0
5+ in 1 year	5%	18%	37%	56%
5+ in any of 3 years	14%	45%	75%	91%
6+ total in 3 years	55%	88%	98%	100%

The new warrant is much easier to meet than the old one. Because the simulations by Fitzpatrick et al. (2015) said all way stops should be *less* common I believe the 36-month figures were accidentally copied from the minor road stop control warrants.

[4]The Poisson distribution models independent random events with a known long term average incidence rate. This is a reasonable approximation with well-understood statistical behavior, although Hauer (1997) observes that accident rates tend to vary more than a Poisson distribution would predict.

Count injury accidents

Comment FHWA-2020-0001-0890 observed "Exclusively relying on reported crashes is not an equitable metric." The fear is that disadvantaged residents will be afraid to report an accident to the police. While this effect is certainly real for minor accidents, I believe that severe accidents are likely to be reported, especially when a tow truck or ambulance is required. Blincoe et al. (2015, p. 2) write, "Unreported injury crashes tend to involve only minor or moderate injuries." They estimate (p. 13) that 75% of minor injuries are reported and essentially all injuries of severity MAIS3 or higher are reported.

To accomodate (1) the desire for a longer counting period, and (2) the fear that disadvantaged residents may not report minor accidents, I propose that the 36-month warrants count injury accidents with the same threshold as the 12-month warrants. The expected count of injury accidents in three years is about the same as the expected count of total accidents in one year. This change will slightly elevate the importance of injury prevention rather than property damage prevention, consistent with the observation by Fitzpatrick et al. (2015) that severe injuries and deaths may have been undervalued in the past.

Observations from NCHRP 213

Flashing beacons

Table 7 in Fitzpatrick et al. (2015) describes the benefit of flashing beacons when all way stop control is used. The crash rate is halved relative to the alternative of all way stop control without flashing beacons. If an intersection is dangerous enough to justify all way stop control, the crash reduction will be worth the cost.

Section 2B.12 should require that when all way stop is used to address a safety concern "beacons shall be provided as described in section 4S.05." This requirement is analagous to 2009 MUTCD Section 4E.03 which requires pedestrian signal heads when the pedestrian volume warrant is met. FHWA should also propose a specific compliance period for existing all way stop signs, for example "Within ten years of the effective date of this rule, existing all way stop signs shall be equipped with beacons as described in section 4S.05 unless the engineering study on file shows they were not installed based on safety concerns."

Volume ratio

The literature review and existing practice support all way stop control only when volumes are approximately equal (Fitzpatrick et al. (2015) pp. 12, 14, 15, 17, 54 and figure 3; Bonneson and Fontaine (2001) p. 15). This is a support statement in the 2009 MUTCD: "Multi-way stop control is used where the volume of traffic on the

intersecting roads is approximately equal." The support should be upgraded to guidance. I propose specific language below.

The cost of a stop

It is unclear how Fitzpatrick et al. (2015) count some costs related to stopping and starting. They may underestimate the cost of stop signs. Their Table 47 lists cost of delay based on free-flow fuel consumption. If traffic is moving at free-flow speeds it is by definition not delayed. Free-flow fuel consumption is irrelevant. Costs induced by intersection control are dominated by starting and stopping. No table is provided for those costs. For a big car the cost of acclerating from a stop to 45 miles per hour is comparable to the cost of one minute of cruising at that speed. In an urban grid with all way stops at every block fuel consumption could be several times as much as in free-flow traffic.

A simple cost-benefit calculation

Because I can not replicate the full model in the NCHRP report I offer a simplified analysis to show the the cost of an all way stop.

For residential streets in my area typical traffic speeds are around 30 miles per hour. The cost of stopping and starting from that speed is about 10 cents using US DOT figures for value of time (Blincoe et al., 2015, p. 103) and typical gas prices. (See calculations below.)

The average value of a property damage only accident is around $4,000, based on the same US DOT report. If more than 40,000 vehicles have to stop to prevent one accident, the stop signs do more damage than the accident. The average value of a minor injury is about $52,000. If more than half a million vehicles have to stop to prevent that injury, the stop signs do more damage than the accident.

The average cost of intersection accidents is about $25,000 (Blincoe et al. (2015) Table 13–7), dominated by the noneconomic cost of serious injuries and fatalies. You should not stop more than 250,000 vehicles to prevent an accident unless the intersection has an unusually high injury rate per accident. In other words, *an accident rate of less than four per million vehicles entering does not justify all-way stop signs*.

On rural roads the relative fraction of injuries is greater, but so is the cost of stopping. At 50 miles per hour the cost is around 20 cents per stop. (Delay is proportional to speed, fuel consumption during acceleration to the square of speed.)

To be conservative, I propose language using two per million as the threshold.

At the end I include some case studies from my area showing how unwarranted stop signs were not beneficial and could not have been beneficial even if they had completely eliminated all accidents. It was obvious when the signs were posted that the subjective fears about confusion and sight lines were unjustified. The MUTCD needs to be written with this type of user in mind.

All way stop control is not justified

Consistent with my estimate, simulations by Fitzpatrick et al. (2015) found that all way stop control was never appropriate outside of high speed rural roads. See figures 17 to 24. (On those high speed roads the severity of accidents resulted in high costs.) They also acknowledge that under prior policies a only small range of traffic volume conditions was considered to warrant all way stop control. See figures 3 and 8.

So why are we seeing recommendations to make all way stop even more common instead of less common? The reason appears to be discomfort with the observation that traffic signal warrants are usually met before the implied all way stop warrants. All way stop signs should not be sacred. If the evidence says they are not appropriate, they should not be used. Other countries get by without them.

No intersection control

"Ultralow volume" roads in Iowa were found not to need intersection control even when sight distance was restricted by corn fields (Souleyrette et al. (2006), cited by Fitzpatrick et al. (2015) on page 29). As the intersections included unpaved roads it is likely that operating speeds were lower than on most rural two lane roads.

Below I propose guidance that very low volume intersections without high speed traffic have no control regardless of sight distance or intersection angle.

Explicitly recommending no control for ultralow-volume intersections will benefit owners of the large number of private roads that are to be governed by the MUTCD. For example, my driveway is shared with a few neighbors and the shared part is legally a private road. FHWA considers it a "site road open to public travel" because access is not restricted by gates or guards. There has never been an accident there despite some aging drivers. But if there ever is one a plaintiff's lawyer will point to the MUTCD to say homeowners were reckless for not posting enough signs. The fork in the driveway is an intersection where the angle might be less than 75 degrees. It is likely that sight distance of one movement does not meet Green Book standards. FHWA should not be telling us our driveway needs more signs. The ultralow-volume exception will accomodate property owners in similar situations.

I disagree with the NCUTCD's recommendation that "site roads" should be treated specially when choosing signs. The warrants should be crafted so that low volume roads, "site" or otherwise, are not burdened by excessive costs of compliance.

Traffic counts

In general pedestrians, motor vehicles, and bicycles should be counted separately and pedestrians not added to vehicle counts.

Pedestrian counts

The proposal to add pedestrians to vehicle counts is overly simplistic. Pedestrians do not queue with vehicles and they cross in groups rather than singly. They can also effectively assert the right of way when crossing in a continuous stream, unlike vehicles.[5]

In a cost-benefit analysis the value of time lost by pedestrians and vehicles should be calculated separately and then summed. Vehicles form a queue independent of the pedestrian count, with average delay related to queue length and gap interval. Pedestrians form a bunch independent of the vehicle count, with average delay half the major street gap interval.

Also, pedestrians should only be counted when they are crossing an approach where stop signs are under consideration. They should not be counted when crossing an approach that already has stop signs because they would not benefit from additional stop signs, and they should not be counted towards yield warrants.

Below I propose all-way stop warrant values that consider pedestrian delay without adding apples to oranges. I use the same 30 second delay threshold that applies to vehicles.

Bicycle counts

A comment points out the potential difficulty of measuring bicycles. The MUTCD should allow engineering judgment to determine whether there are enough bicycles to be worth counting manually. At most intersections the bicycle count is a small fraction of the motor vehicle count.

Queue bypass

Bicycles will often pass a line of stopped cars at an intersection. Where I live this is legal and common even without bike lanes. Bicycles should not be counted towards all-way stop volume warrants unless they wait in the queue or are subject to at least a 30 second delay.

Idaho stop

In many jurisdictions bicycles are not legally required to stop at stop signs (e.g. Idaho) or habitually do not stop (e.g. Massachusetts). If bicycles do not stop, converting yield to stop will not prevent crashes caused by bicycles entering the intersection. (The same principle argues against posting stop signs under circumstances when drivers are going to roll through them, which is one reason all way stop should not be used when approach volume is very unequal.)

[5] I agree with Fitzpatrick et al. (2015) that the first pedestrian is likely to wait for a gap regardless of crosswalk markings.

I suggest language like this:

> Guidance: When state or local law permits bicycles to treat stop signs like yield signs, or when engineering judgment determines that bicyclists are unlikely to stop for stop signs, crashes involving bicycles entering from a minor street currently under yield control should not be counted.

Other bicycle considerations

Bicycles conflict less with pedestrian movements than vehicles do and are less likely to cause serious injury. Bicycle-pedestrian conflicts should be given less weight than motor vehicle-pedestrian conflicts. I do not propose specific language.

Other considerations

Engineering study required

Section 2B.11, admittedly consistent with prior practice, permits stop signs to be posted based on engineering judgment. Sections 2B.11 and 2B.12 should have a standard requirement that stop control shall be based on an engineering study.

Stop signs have a high cost (Fitzpatrick et al. Table 29; my calculations above and below). They increase vehicle wear, pollution, and carbon emissions. They can potentially increase crashes and midblock speeds (Ewing (1999) p. 120, Fitzpatrick et al. (2015) p. 30.) The cost of an injury crash, whether prevented by warranted stop signs or caused by unwarranted stop signs, is much greater than than the cost of an engineering study. A one time cost of a few hundred or a few thousand dollars is justifiable to ensure that the benefits exceed the costs.

Under sections 3C.02 and 3C.04 an engineering study rather than engineering judgment is called for before marking crosswalks even when an unmarked crosswalk is implied by law. Why should stop signs, which change right of way rules, have a lesser standard?

Transition to yield control

I found this warrant confusing: “arrangements are being made for the installation of . . . YIELD control at a roundabout.” It is unclear to me whether this refers to the period when a roundabout is being planned, the period of construction, or a period after construction when the contractor discovers it forgot to order YIELD signs. If a roundabout is merely planned I see no reason to make an exception to the stop sign warrants. The intersection should be signed as it presently exists. I have proposed clearer text below based on the assumption that this was meant to be used while

construction is in progress. The engineer creating construction drawings should be responsible for temporary traffic control.

I have also suggested that the transition to final YIELD control should be at substantial completion of road configuration rather than final payment to contractor. It is the habit of many agencies to leave temporary traffic control in place until the contract is formally complete. As an extreme example, I–84 east of Waterbury, Connecticut had a 45 mph speed limit for several years after the last work on the road surface. The drains under the road needed to be rebuilt so the contract was not over and the "work zone" speed limit remained.

No control and yield warrants

What is the reason for section 2B.09 option "D. There are no marked crosswalks or bicycle lanes on any approach"? Marked crosswalks are generally allowed midblock with no traffic control and are explicitly allowed at uncontrolled intersections by guidance in section 3C.02. Because yield control does not benefit pedestrians, the effect would be to require stop signs to be added whenever a crosswalk is painted. This will lead to even more overuse of stop signs.

If bicycles are thought to benefit especially from yield control at low volume intersections, FHWA should specify whether the yield signs belong on the approach with or without bicycle lanes.

According to sections 2B.09 and 2B.10 stop control is supposed to be used at any intersection with an acute angle. I do not think this is appropriate. The general requirement is then followed by listing various exceptions where yield control is allowed (options (B), (D), (E), and (F)). There is no apparently coherent principle. I propose instead that a lower volume warrant be used for minor road stop control acute angle intersections. A documented safety problem would also justify stop control under other warrants.

Proposed changes

In section 2B.06 change the guidance at line 28 to read

> Motor vehicles should be counted on each approach. When engineering judgment determines that a substantial number of bicycles or pedestrians cross the intersection, those road user types should be counted separately. Pedestrians should be counted when crossing an approach where stop signs are under consideration. When a queue of motor vehicles forms and bicycles bypass the traffic queue and enter the intersection with less than 30 seconds of delay, those bicycles should not be counted. Otherwise bicycle counts should be added to motor vehicle counts to produce a total count of vehicles. Vehicles making right turns should be omitted from

traffic counts when engineering judgment determines they have a low rate of conflict and good visibility of conflicting traffic, such as when turning right onto the stem of a T intersection.

In section 2B.07 line 27 change “one of more” to “one or more” (typo).

Add guidance to section 2B.09:

Section 2B.09 No Intersection Control

Support: An intersection is uncontrolled unless stop or yield signs are posted as described in the following sections or signals are used as described in part 4. The Uniform Vehicle Code prescribes driver behavior at uncontrolled intersections. Uncontrolled intersections usually work well when

A. . . .

B. . . .

Guidance: When engineering judgment determines that total vehicular volume is less than 150 vehicles per day and operating speed is below 45 miles per hour, intersections should be left uncontrolled unless there is a documented safety or operational problem, even if not all of the preceding factors are present.

Section 2B.10 should be rewritten as a set of warrants for converting no control to yield control, and converting stop control to yield control. Yield signs should not be an afterthought that might be considered instead of a stop sign. They are an intermediate level of control between no control and stop signs.

In section 2B.11, adopt the UK values for sight distance to bring clarity to the subject. Also change accident counting as mentioned above, and change “two-way” to “minor road” as an editorial change. Strike the functional classification rules. Functional classification makes sense to chose road priority for yield signs, but stop signs should not be posted unless measurable conditions require them.

Section 2B.11 Minor Road Stop Control

Standard: The decision to use stop control shall be based on an engineering study.

Guidance: Stop control on the minor road approach or approaches to an intersection should be considered when an engineering study indicates that one or more of the following conditions exist:

A. Sight distance from a passenger vehicle at the edge of the major road to approaching traffic on the major road is less than given in Table 2B.XX.

B. Crash records indicate there are three or more reported crashes in a 12-month period or three or more reported injury crashes in a 36-month period, correctable by minor road stop control.

C. Vehicular volume (sum of all approaches) exceeds 1,800 vehicles per day or 140 vehicles in the peak hour.

D. Vehicular volume (sum of all approaches) exceeds 1,000 vehicles per day or 80 units in the peak hour and the approach to be controlled intersects with the major road at an acute angle of less than 75 degrees.

E. Conditions that previously supported installation of an all-way stop control under all-way stop control criteria no longer exist.

Table 2B.XX Sight distance warrant for minor road stop control[6]

85th percentile (mph)	Visibility (feet)
20	50
30	100
40	150
50	230
60	300
70	400

(Values may be interpolated.)

Strike proposed section 2B.14 (sight distance). Change the remaining all-way stop warrants to read:

Section 2B.12 All-Way Stop Control

Standard: The decision to establish all-way stop control at an unsignalized intersection shall be based on an engineering study considering all-way stop control warrants A, B, and C below. The satisfaction of an all-way stop control warrant or warrants shall not in itself require the installation of all-way stop control at an unsignalized intersection.

Guidance: The engineering study for all-way stop control should include an analysis of factors related to the existing operation and safety at the intersection, the potential to improve these conditions, and the applicable factors contained in the following warrants.

Standard: When warrant A is satisfied and all-way stop control is used, stop sign beacons shall be provided as described in section 4S.05.

Guidance: Notwithstanding the following warrants, all-way stop control should not be used when approach volumes are highly unequal.

Support: Road users will not stop if they do not see a need.

Section 2B.13 All-Way Stop Control Warrant A: Crash experience

Support: This warrant provides for all-way stop control to address safety concerns when the benefit of crash reduction exceeds the cost of requiring all vehicles to stop at all times.

[6]From DfT p. 18 with meters converted to feet.

Option: All-way stop control may be installed at an intersection where an engineering study indicates that conditions A and B are both met.

A. There are five or more reported crashes in a 12-month period or five or more reported injury crashes in a 36-month period that were of a type susceptible to correction by the installation of all-way stop control; and

B. The crash rate exceeds two per million vehicles entering. A traffic model may be used instead if it shows net benefit after accounting for traffic delay, fuel consumption, and the values of crashes likely to be prevented.

Guidance: When sight distance is adequate only angle crashes and pedestrian injuries crossing the major street should be counted. At intersections with poor sight distance the engineering study should examine whether abrupt maneuvers contribute to other types of crashes.

Section 2B.14 All-Way Stop Control Warrant B: Minor street delay

Support: This warrant provides for more equal sharing of an intersection that would otherwise have long delays to side street traffic.

Option: All-way stop control may be considered when an engineering study indicates that condition A and either condition B or C is met:

A. The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 units per hour for each of any 8 hours of an average day.

B. The vehicular volume entering the intersection from the minor street approaches (total of both approaches) averages at least 60% of the major street volume for the same 8 hours, with average delay to minor street vehicular traffic of at least 30 seconds per vehicle during the highest hour.

C. The vehicular volume and pedestrian volume from the minor street approaches (total of both approaches) each average at least 40% of the major street volume for the same 8 hours, with average delay to each type of traffic of at least 30 seconds during the highest hour.

Support: See section 2B.06 for counting of bicycles that bypass a queue of motor vehicles.

Section 2B.15 Transition to roundabout or signal control

Option: While a roundabout is under construction and roadways are not in their final configuration, all way stop signs may be used as an interim measure as specified in construction plans.

Guidance: YIELD control should be used as soon as construction is substantially complete regardless of the formal status of the construction contract.

Option: When an engineering study determines traffic signals are urgently needed, all way stop control may be installed as a short term measure while signals are being installed.

Guidance: The signal option should not be used unless the signals are in the budget for the current or next fiscal year or have been placed in the five year Transportation Improvement Program.

Section 2B.16 Other factors

Support: The preceding warrants support consideration of all-way stop control but do not require all-way stop control. When they are met, any of the following factors (among others) might weigh in favor of all-way stop control.

A. A high number of left-turn conflicts.

B. An intersection of two residential neighborhood collector (through) streets of similar design and operating characteristics where all-way stop control would improve traffic operational characteristics of the intersection.

C. Atypical pedestrian and/or bicycle movements that have been observed to result in an unusually high number of conflicts.

D. Highly restricted visibility that can not be ameliorated by clearing roadside obstructions.

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A Cost calculations

I will estimate the costs and benefits of some stop signs approved in my area. The signs are consistent with the subjective "anything goes" policy proposed for the 11^{th} edition MUTCD but not consistent with the objective crash and delay warrants. On all these streets average free-flow traffic speed is close to 30 miles per hour.

According to the 2001 AASHTO Green Book (pp. 44–45) a typical car driver will stop from 30 mph in 175 feet and accelerate back to speed in 225 feet. This corresponds to about 10 seconds of lost time (allowing a second or so of time stopped). The value of time in an urban area is about $24 per hour (Blincoe et al., 2015, p. 103). Each stop is worth 7 cents of time.

The cost of fuel burned is a bit less, about 3 cents per stop. It takes about .01 gallon to accelerate to 30–35 mph[7]. I will take $3 gallon as a typical price of gas and $0.50 per gallon for externalities.[8] I have neglected health effects following Fitzpatrick et al. (2015), who reported (p. 59) that "that costs associated with pollution from emissions would be very low compared to other costs in the analysis."

Each stop causes about 10 cents of harm. Only traffic that would not otherwise have had to stop should be considered, i.e. major road traffic when a two way is converted to four-way. As mentioned above, the benefit is considered to be $4,000 per property damage accident prevented and $52,000 per minor injury prevented. None of the intersections previously had long delays to minor street traffic.

[7] As an approximation: A 2,000 kg vehicle at 15 m/s speed has 225,000 Joules of kinetic energy, divide by 30 MJ/liter energy density of gas/ethanol blend, divide by engine efficiency of 25%, result is 25 mL or $\frac{1}{125}$ gallon.

[8] Based on the Biden administration's recent statement that the social cost of carbon should be considered $50 per ton. A dollar per ton corresponds to a penny per gallon. EPA or OMB may provide different guidance before the final rule is published.

B Case studies

Here are some examples of how engineers serve their employers instead of the public to approve nuisance stop signs. (Some of these violate the state supplement to the MUTCD, but MassDOT does not enforce its rules.) Ironically, when the warrants are actually met engineers are much more cautious about approving all way stop signs. Stopping 10,000 vehicles per day could mess up traffic for a long way around. Stopping 2,000 vehicles per day is just doing a favor.

Waltham, Massachusetts

Around 2007 an all-way stop appeared at the intersection of Woerd, Riverview, and Rumford Avenues (which I walked through often). It was ordered by the city council based on resident concerns. Later an objection was raised: under state law an engineering study is required. City traffic engineers were asked to find a reason to keep the stop signs. They settled on sight distance. They reported one corner had a sight distance only 52 feet because there was a shrub on the corner. I measured over 150 feet sight distance at the same corner. I was measuring from where a driver would decide where to pull out. They must have been standing 15 feet or more back from the intersection. And more importantly, the shrub that limited sight distance had been planted *after* the stop sign was posted, in violation of a city ordinance requiring corners to be kept clear. But the report did not recommend removing the shrub.

There had been 4 property damage and 2 injury accidents at the intersection in the previous decade; there was 1 injury accident in the following decade. The apparent benefit from stop signs is $68,000 per decade. With peak hourly volume around 150 on the major street we can estimate 5 million unnecessary stops per decade at a cost of $500,000 over the same period. Obviously the cure is far worse than the disease. Notice that sight distance only one third of stopping sight distance (according to the city) was not very harmful. The accident rate was about one per million vehicles.

City engineers managed to find inadequate sight distance at almost all of the intersections where the city council had demanded stop signs. (The oldest stop signs, before the process became politicized, had been obviously installed for genuine safety concerns.) If any of the eight sight lines could be said to be inadequate, by any invented measurement or standard, then all-way stop signs were “warranted” regardless of volume or crash history. Meanwhile, intersections with much less sight distance did not get stop signs because the city council did not ask.

The MUTCD needs to be clear that sort of excuse-making is not acceptable, even if engineers are forced to say “no” to the city council. Sight distance is too vague to be allowed as an all-way stop warrant and it is not evidently harmful.

Newton, Massachusetts

From the May 27, 2004 traffic council minutes approving all-way stop signs at Central Street and Woodland Road:

> The volume warrants for a stop sign are not met and there were 3 accidents on record during the last 3 years (where 5 are normally a baseline requirement). Nonetheless, [the traffic engineer] felt that there was a basis for considering a stop sign due to sight visibility constraints and to eliminate confusion. He received 10 letters of support for this proposal; one neighbor present favored alternatives to a stop sign.

There had been 5 property damage accidents and 1 injury accident in the previous 12 years. There were 3 property damage accidents with and 2 injury accidents in the next 12 years. This was not an effective use of stop signs.

From the October 19, 2004 traffic council minutes approving all way stop signs at Ward Street (one way), Hammond Street, and Woodchester Drive:

> [The traffic engineer] said the wide radius encourages speeding. Traffic counts were not met for a stop sign, but he added that the crossing guard at that corner felt the stop sign had improved safety at the corner.
>
> Residents urged the council to consider safety of all aspects of the street by addressing speeding, visibility, pedestrian safety on streets and sidewalks.

In the 12 years before there had been 2 property damage and 2 injury accidents at the intersection. In the 12 years after there were 3 property damage accidents. This was not an effective use of stop signs.

May 30, 2013 vote to approve change from two way to all way stop control:

> [The traffic engineer] provided Council members with existing conditions, stop sign traffic warrants, existing traffic data, sight distance data and photos. Criteria for multi-way stop sign warrants shall include a) five or more reported crashes in a twelve-month period that are susceptible to correction by a multi-way stop installation and b) minimum traffic volumes. He said that existing traffic data proves three accidents between 2010 and 2012. The 8-hour traffic volume averages 320 vehicles per hour on Cabot Street and 110 vehicles per hour at East Side Parkway and Westchester Road. [The traffic engineer] agrees this intersection meets the warrants for a stop sign because of limited stopping sight distance and limited intersection sight distance. He suggests the installation of two stop signs . . . The stop sign will allow for the installation of new crosswalks.

In the previous eight years there were 6 property damage only and 2 injury accidents. In the eight years since there has been one property damage accident. The cost of the

stop signs was $200,000 per year. The benefit was $16,000 per year if we credit the stop signs for preventing 5 property damage and 2 injury accidents. Clearly these stop signs hurt far more than they help.

Lincoln, Massachusetts

An engineer's review of the intersection of Silver Hill and Weston Roads in Lincoln, Massachusetts conceded that it did not meet all-way stop warrants. But residents wanted stop signs. He wrote:

- All-way stop control will serve to help mitigate reduced sightlines.
- All-way stop control will force operating speeds . . . which are more approprite for existing geometric conditions and constraints.
- All-way stop control will help avoid possible confusion for motorists . . . who may errantly assume vehicles to their right have a stopped condition

He didn't measure sight distance. Speed control is not a legitimate use of stop signs. And the speculation of confusion is belied by the crash rate, which averaged less than one per year within 500 feet of the intersection with no angle collisions at the intersection.

At the public hearing it was clear that residents did not care about intersection safety. One resident said anybody who got hurt by the stop signs had it coming. The real motive was to discourage commuter traffic.

Obviously the signs have not improved safety. There was no safety problem to improve. But by adding 3,400 unnecessary stops per day the town has cost society about $125,000 per year.

FHWA needs to provide better standards to deter nuisance stop signs.