100 YEARS TRB
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Standing Committee on Traffic Control Devices (AHB50)
Tim Gates, Chair

A Century of Traffic Control Devices and What Lies Beyond

H. GENE HAWKINS JR., PH.D., P.E., *Texas A&M University*
PAUL J. CARLSON, PH.D., P.E., *Road Infrastructure Inc.*

ABSTRACT
Traffic control devices have evolved from hand-painted traffic signs with no national coordination to a well-coordinated system of signs, markings, signals, and other devices used to communication information to road users. The MUTCD is the standards document for TCDs. As TCDs have evolved, so has the MUTCD. This paper traces the development of TCDs over time and also looks into the potential future of TCDs.

INTRODUCTION
When the Highway Research Board held its first Annual Meeting in 1922, traffic control devices (TCDs) were in their infancy. There were no national guidelines, traffic signs were the primary type of device, and there was less than a decade of experience with any type of traffic signals or pavement markings. During the intervening century, experience, research, and technology have led to numerous improvements in the use, performance, and impact of TCDs. Recent advances in technology hold the potential for even more advancements in the role and value of TCDs.

As the Transportation Research Board (TRB) approaches its centennial celebration, the TRB Committee on Traffic Control Devices developed this paper describing the evolution of TCDs as mirrored through the evolution of the *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD is, and always has been, a national standard for TCDs. As such, meaningful traffic control device advancements are ultimately implemented by incorporating them into the MUTCD. Traffic control devices and the MUTCD have gone through several evolutionary eras as shown in Table 1. The traffic control device advancements identified in this paper are generally organized alongside these eras.

TABLE 1. Summary of Traffic Control Device Evolution Through the MUTCD

MUTCD Edition	TCD/MUTCD Era	No. of Pages	No of Parts	Size (inches)	Thickness (inches)
N/A	Developmental	N/A	N/A	N/A	N/A
1935	Standardization	166	4	6×9	⅜
1942		208	4	6×9	⅜
1948	Transition	223	4	6×9	⅜
1961		333	6	6×9	⅝
1971[A]	Stable	377	8	6×9	¾
1978		425	9	6×9	1⅜
1988		473	9	6×9	1⅜
2000	Modern	982	10	8½×11	1⅝
2003		754[B]	10	8½×11	1¼
2009		864	9	8½×11	1⅝

Notes: [A]FHWA assumed MUTCD ownership (through present day).
[B]Reduced number of pages achieved by reduced font size, margins, and line spacing.

PIONEERING TRAFFIC CONTROL DEVICES

Although initially developed in the 19th century, automobiles did not begin to appear in numbers until the early 20th century. The initial movement toward a surface transportation system based on automobile travel occurred prior to and during World War I. During this period, automobiles and trucks became common, government agencies began considering the development of a roadway network, and early versions of TCDs began to appear.

Traffic control devices began to appear on streets and highways by the 1910's. Although subject to some debate, one document indicates that the first centerline was used in Michigan in 1911, the first electric traffic signal installation was installed in Cleveland in 1914, and the first Stop sign was installed in Detroit in 1915 (*1*). Unfortunately, there was little coordination in the use of these devices between different localities and there was no national system of TCDs. Traffic control devices took whatever form the inventor wanted. The early traffic signal development utilized railroad signals as the basis for traffic applications. The earliest traffic signals used semaphores for right-of-way, some with and some without lighted indications. Many of the early signals were placed in signal towers located in the middle of the intersection. Traffic signs used a variety of shapes, colors, and messages. Most traffic signs were hand-painted and many were placed by automobile clubs and/or police departments. Pavement markings were rarely used as most roads were two-lane roads and some were not even wide enough for two vehicles to pass side-by-side. Figure 1 illustrates a few of the pioneering TCDs. (*1*).

Figure 1. Pioneering Traffic Control Devices

EARLY EFFORTS TOWARD REGIONAL AND NATIONAL TCD PRACTICES

Automobile and truck travel began growing rapidly following the end of World War I. As the number of vehicles and amount of travel exploded in the 1920s, agencies began looking at various options for a coordinated system of roadways and TCDs.

One of the earliest efforts toward establishing a basis for uniformity in signing and marking took place in 1922, when several individuals made tour of various states to try to work out some uniformity in highway signing (*2*). The findings from the trip were reported to the 1923 annual meeting of the Mississippi Valley Association of State Highway Departments (MVASHD). That body agreed on a signing plan that established the sign shapes used today. It called for distinctive shapes to be used for different conditions of danger with the progression in shapes from a circle to a square intended to indicate increasing levels of danger as indicated below (*2*). The round and octagonal signs were selected as the most dangerous because they required the most cutting and wastage and had the fewest number of installations (*3*).

- Round: Used only to warn of a railroad crossing.
- Octagon: Used only to signify a stop.
- Diamond: Used to indicate ordinary conditions of danger requiring precaution at all times.
- Square: Used to indicate intermittent danger conditions requiring little more than ordinary care.
- Rectangular: Used to indicate regulatory or directional information.

- Cut-Out: Used a distinctive shape different from the above to identify highway routes.

Shortly after the MVASHD meeting, the Minnesota Department of Highways published the *Manual of Markers and Signs*, which is believed to be the first state manual for signing (*1*). This manual used the sign shapes recommended by the MVASHD, but required a yellow background instead of white. Other states also developed standards for TCDs. Figure 2 illustrates pavement markings used in Massachusetts and standard signs used in Idaho in the early 1920's.

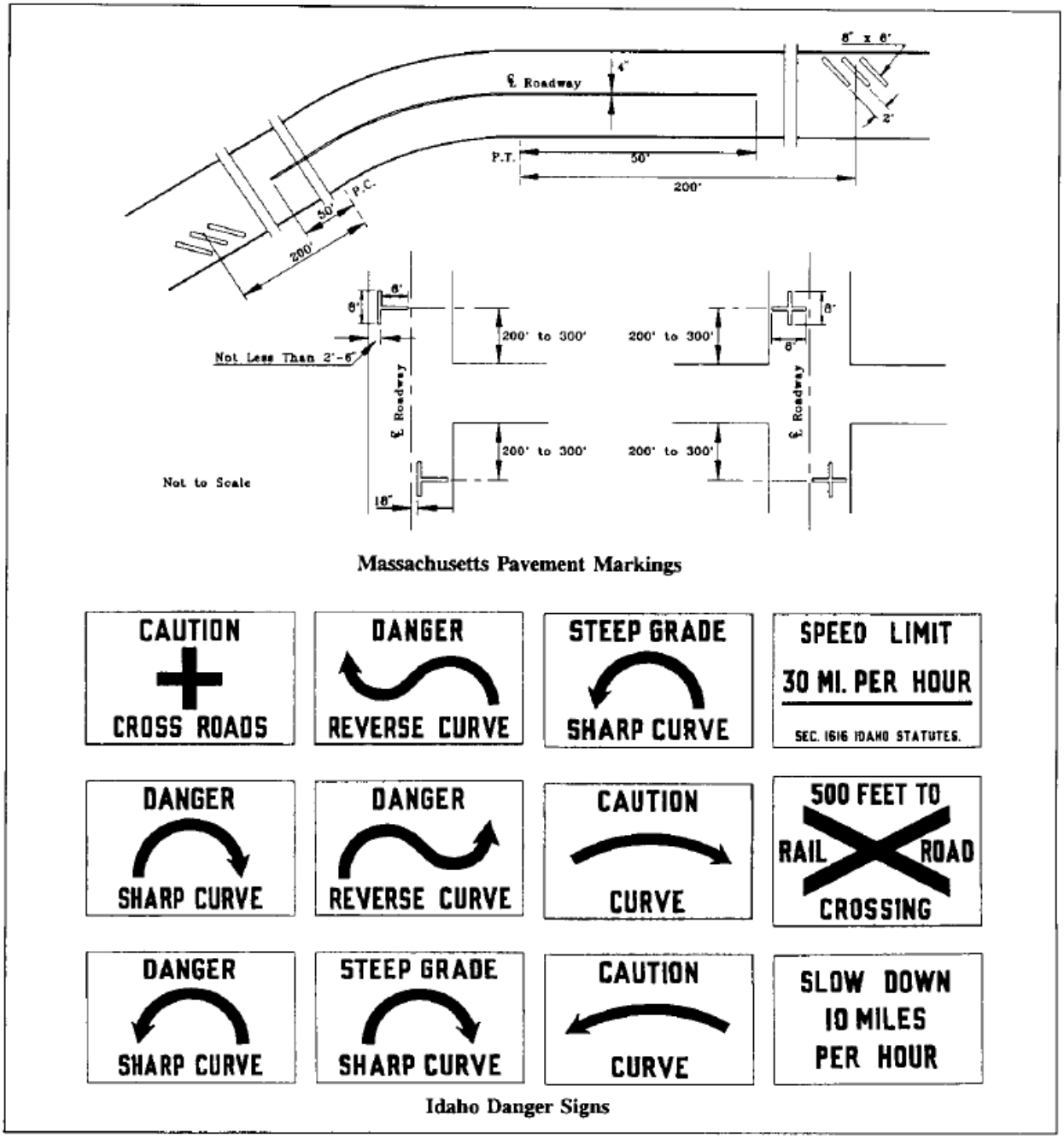


Figure 2. Early Traffic Control Devices in the 1920s

The First National Conference on Street and Highway Safety (NCSHS) was held in Washington, D.C. in December 1924. This was the first of several NCSHS conferences that addressed the challenges associated with motor vehicle travel. The conference was called by the Secretary of Commerce for "the devising of means and the making of recommendations toward the lessening of the numberless accidents which now kill and maim so many of our citizens" (*5*). The conference made many recommendations for improving highway safety, including recommendations for improving of signs, signals, and markings. One of the first called for sign uniformity throughout the United States. The conference report recommended adoption of the code of colors for both signs and signals as indicated below (*4*).

- Stop: red for signals, white on red for signs
- Proceed: green for signals, white on green for sings
- Caution: yellow for signals, black on yellow for signs
- Cross Roads: purple or other distinctive color for signals, white on purple for intersections

The report also addressed the use of pavement markings, which recommended limiting use to hazardous locations. White and black were the recommended colors for pavement markings, depending upon which provided the better contrast with the pavement. .

At its 1924 meeting, the American Association of State Highway Officials (AASHO) which had been created in 1916, created the Joint Board on Interstate Highways to formulate and promulgate a system of numbering and marking highways of interstate character. The Joint Board first met in April of 1925 and immediately began its primary responsibilities of determining routes for a nationwide road system and devising a uniform scheme for designating these routes. The Sign Committee of the Joint Board defined a system of signs based on four characteristics: a distinctive shape, a distinctive color, a descriptive word, and a descriptive symbol. The recommendations of the Joint Board were published in a 1925 report which included recommendations on a national system of signing (*5*). Figure 3 illustrates a few of the signs presented in an appendix of that report.

Figure 3. Signs from the 1925 Joint Board Report

NATIONAL STANDARDS FOR TRAFFIC CONTROL DEVICES

The early work of the Joint Board and National Conference led to parallel efforts to develop national guidelines for TCDs. The Joint Board effort, led to the publication of the first national signing manual in 1927 by AASHO, the Manual and Specifications for the Manufacture, Display, and Erection of U.S. Standard Road Markers and Signs (*6*). This manual described a system of standard signs for rural highways. The document did not address markings or signals. Signs in the manual used a black legend on a yellow or white background. Yellow warning signs included the circular railroad sign and the octagonal stop sign. Yellow caution series signs included diamond (slow) signs and square (caution) signs. White signs included regulatory and

guidance signs. Figure 4 illustrates some of the signs from this manual. This manual was revised in 1929 and 1931.

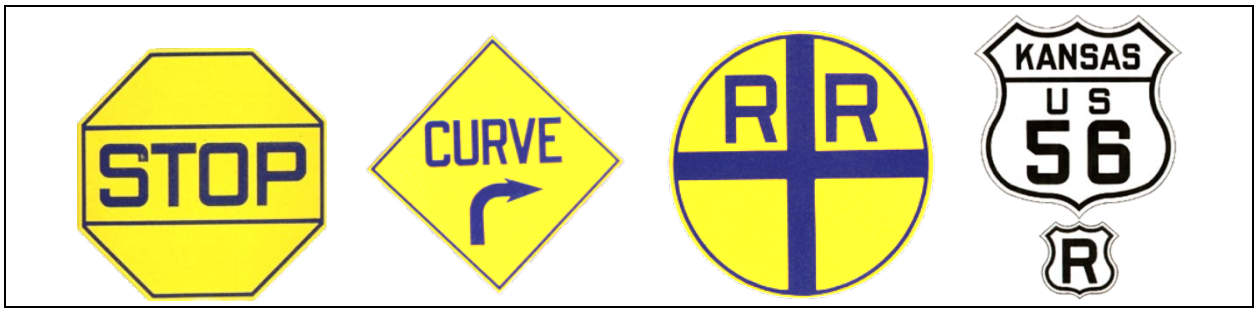


Figure 4. Signs from the 1927 AASHO manual

Activities resulting from the second National Conference on Street and Highway Safety led to the publication of the Manual on Street Traffic Signs, Signals, and Markings (*7*), which provided guidelines for signs, signals, and markings used in urban areas. This was the first set of national guidelines to address all three types of TCDs: signs, markings, and signals. Among the significant elements of this document is that it recommended a three-color signal, but permitted the use of a two-color signal. It provided for the use of white, black, or yellow pavement markings based on which provided the best contrast with the pavement surface. The signs in the urban manual were similar to those of the rural manual, except that the Stop sign used a red legend on a yellow background. Figure 5 illustrates some of the signs from the urban manual.

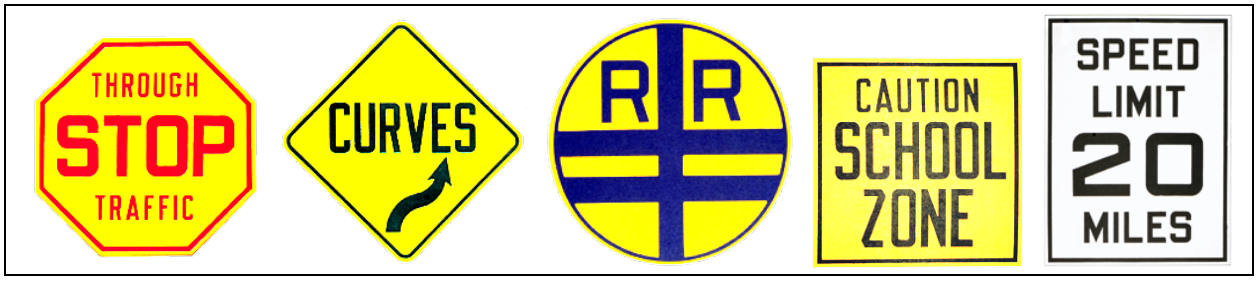


Figure 5. Signs from the 1930 NCSHS urban manual

The conflict of having separate manuals for rural and urban conditions was quickly recognized, and effects began toward combining the AASHO and NCSHS manuals into a single national manual. AASHO and the NCSHS started by creating the Joint Committee on Uniform Traffic Control Devices (JC), which first met in 1932. After diligent effort, the JC published the first edition of the MUTCD in 1935. The second MUTCD was published in 1942, primarily to address issues associated with traffic control in wartime situations, including blackout conditions. Detailed information about the content and significant changes associated with these first two MUTCD editions is presented in a separate paper by Hawkins (*8*).

Traffic Control Devices in the First MUTCD

The first MUTCD was published in 1935 as a mimeographed publication following its approval by AASHO, the NCSHS, and the Secretary of Agriculture. At that time, the federal roadway agency (Bureau of Public Roads) was within the Department of Agriculture. A second version of the 1935 MUTCD was published in 1937 as a typeset document that had a professional

publication appearance. After gaining some experience with the content of the first MUTCD, the JC developed a 25-page revision which was published in 1939.

For the most part, the signs in this manual replicated the content of the earlier traffic control device documents. The Stop sign continued to be yellow. Other regulatory signs (such as Speed Limit and Parking signs) were black on white. There were several categories of black on yellow warning signs: slow (diamond) that required a speed reduction, caution (square) that required care, but not necessarily a speed reduction, and the railroad warning signs. One of the significant changes is that the symbol in the Railroad sign changed from a plus to a St. Andrews cross. The new manual also recommended that the outline of STOP, railroad advance, and slow-type warning signs be illuminated at night, with the idea that such illumination would make motorists conscious of the meaning of the shapes of the signs, without having to see the legend. Guide signs were white on black rectangular signs with the long dimension horizontal, except for the route marker, which continued to use the U.S. Highway shield developed by AASHO in 1925. Figure 6 illustrates a few of the signs from the 1935 MUTCD.

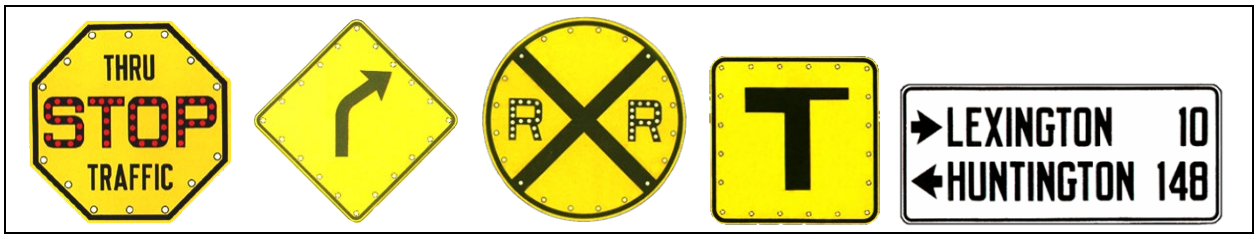


Figure 6. Signs from the 1935 MUTCD

Worth noting is that the signs of this era used a block letter alphabet, as can be seen in Figure 6. Most signs of the time were stamped from steel blanks and both the border and legend were embossed. Signs were then dipped in a vat of yellow paint. After drying, the sign was run through rollers coated with black paint, which colored the raised legend of the sign. The block letter alphabet was more adaptable to embossing in steel than the rounded alphabet that became common in later times.

The first MUTCD continued the practice of recommending pavement markings at specific types of locations where there were greater hazards (such as hillcrests, railroad grade crossings, and large volumes of traffic). Lines were 4 to 8 inches wide and could be white, yellow, or black, depending on which color provided the greatest contrast with the pavement surface.

The 1935 MUTCD was the first to establish the three-color traffic signal as the standard and only acceptable version of a traffic signal. It was also the first to provide warrants for traffic signals installation. All signals used 8-inch round indications, including those for pedestrian movements. Other traffic signal features included in the 1935 MUTCD were the green arrow indication (only green), and the WALK pedestrian signal indication (the word WALK within a circular indication).

Traffic Control Devices in the Second MUTCD

The onset of World War II placed many demands on highway travel and traffic control in the United States. Therefore, the JC was reconvened in May of 1942 to consider revisions to the MUTCD. At its first meeting, the JC unanimously agreed to direct its energies to the preparation of a manual of emergency standards for TCDs adapted to existing and foreseeable wartime

conditions. This decision was necessitated by the shortage of materials which made it more difficult to adhere to accepted standards for TCDs. However, the migration of war workers and military personnel into unfamiliar areas made it even more urgent to preserve recognized standards in TCDs. In addition, the demands for blackout and dimout traffic control placed new requirements on the use of TCDs. Therefore, the first major function of the JC was to determine which standards were of greatest importance and how they could be maintained with limited or available substitute materials. The other major function of the JC was to serve as a liaison agency between the military and civil authorities for the movement of authorized civilian traffic under emergency conditions. The result was the War Emergency Edition of the MUTCD, which was published in November 1942. It was basically a condensed version of the 1935 edition, incorporating the 1939 revision and revising material to save materials and provide guidelines for TCDs to be used in blackout conditions.

TRAFFIC CONTROL DEVICES IMPROVEMENTS IN THE TRANSITIONAL PERIOD

Near the end of the war, the JC began working on a new edition of the MUTCD that would be put into use after the war ended. The result was the 1948 MUTCD. The time between the publication of the 1948 MUTCD and the late 1960s represented a transitional period for TCDs as the number of automobiles mushroomed, along with a corresponding increase in cross-country automobile travel. During this transitional era for TCDs, the emphasis was on improving the national consistency of TCDs and adapting to higher volumes and faster speeds of vehicular travel. Some of the most significant traffic control device improvements during this transitional period are described below.

- Traffic Signs
  - Significant signing improvements introduced with the 1948 MUTCD include:
    - The square signs in the first two MUTCDs were eliminated or converted to diamond shapes.
    - The sign fonts changed from the block letter style to the rounded letter style still in used today.
    - Retroreflectivity technology transitions from the use of "cats-eyes" reflector elements to fully retroreflective sign faces, including the introduction of retroreflective sign sheeting.
    - Advisory speed plaques were introduced.
    - Sign sizes and letter heights increased.
    - Example signs from the 1948 MUTCD are shown Figure 7.

Figure 7. Signs from the 1948 MUTCD

- Significant signing improvements introduced between the 1948 and 1961 MUTCDs include:
  - The 1954 MUTCD revision changed the color of the Stop sign from yellow to red and prohibited the display of secondary messages on the face of the Stop sign. The same revision also introduced the Yield sign. Both are illustrated in Figure 8.
  - AASHO published the *Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways* in 1958 to fill the gap between the MUTCD standards and the traffic control needs of Interstate Highways (*9*). This publication introduced the use of white on green freeway guide signs, including the use of lower case letters, and several other signs specifically designed for freeway applications. This publication also introduced the Interstate Highway route shield. Figure 9 illustrates some of the signs from the AASHO manual or one of its later revisions.
- Significant signing improvements introduces with the 1961 MUTCD include:
  - Change in yield sign – still yellow
  - Freeway signing adopted from AASHO manual.
  - Start toward using symbols signs
  - Change in the design of the US Highway route marker
  - Addition of civil defense signing to address nuclear attack concerns.
  - Some of the signing changes introduced in the 1961 MUTCD are shown in Figure 10.

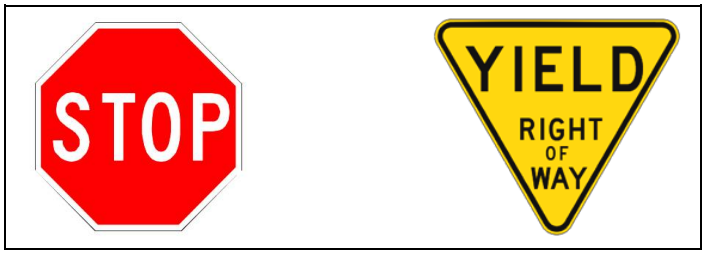


Figure 8. Signs from the 1954 Revision of the 1948 MUTCD

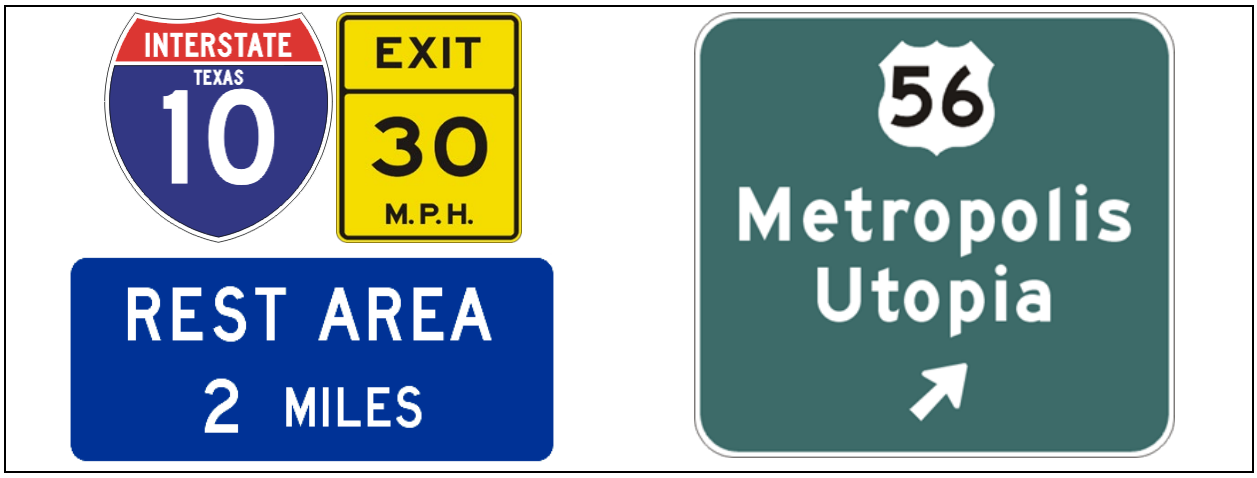


Figure 9. Signs from the 1958 and later AASHO Interstate Signing and Marking Manuals

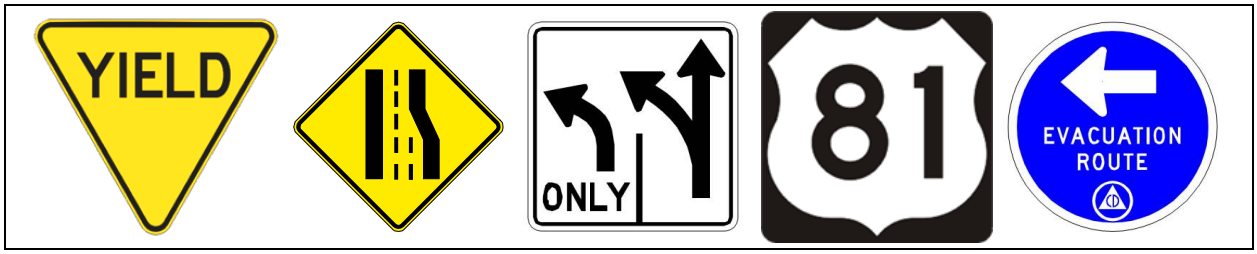


Figure 10. Signs from the 1961 MUTCD

- Pavement Markings
  - Significant marking improvements introduced with the 1948 MUTCD:
    - Use of yellow color limited to the double yellow centerline and the barrier line of a no-passing zone marking.
    - Edge lines were discouraged to minimize confusion with lane lines or centerlines.
  - Significant marking improvements introduced with the 1961 MUTCD:
    - Encouraged optional use of edge lines.
- Traffic Signals. The basic appearance of traffic control signals remained relatively stable during the transition period. Most of the changes associated with signal control related to operational issues such as vehicle detection, interconnection, and multiple timing plan control. A few of the more significant visible changes include:
  - IN the 1948 MUTCD, the number of required signal faces for an approach was increased to two.
  - The additional of a circular WAIT pedestrian signal indication in the 1948 MUTCD. The 1948 MUTCD also allowed the use of rectangular indication that displayed the words WALK and DON'T WALK. The circular pedestrian signals were eliminated in the 1961 MUTCD, which specified the use of either rectangular red DON'T WALK and green WALK indications or orange DON'T WALK and shite WALK indications in the 1961 MUTCD.
  - Introduction of 12 inch signal indications in the 1961 MUTCD.

TRAFFIC CONTROL DEVICE STABILITY

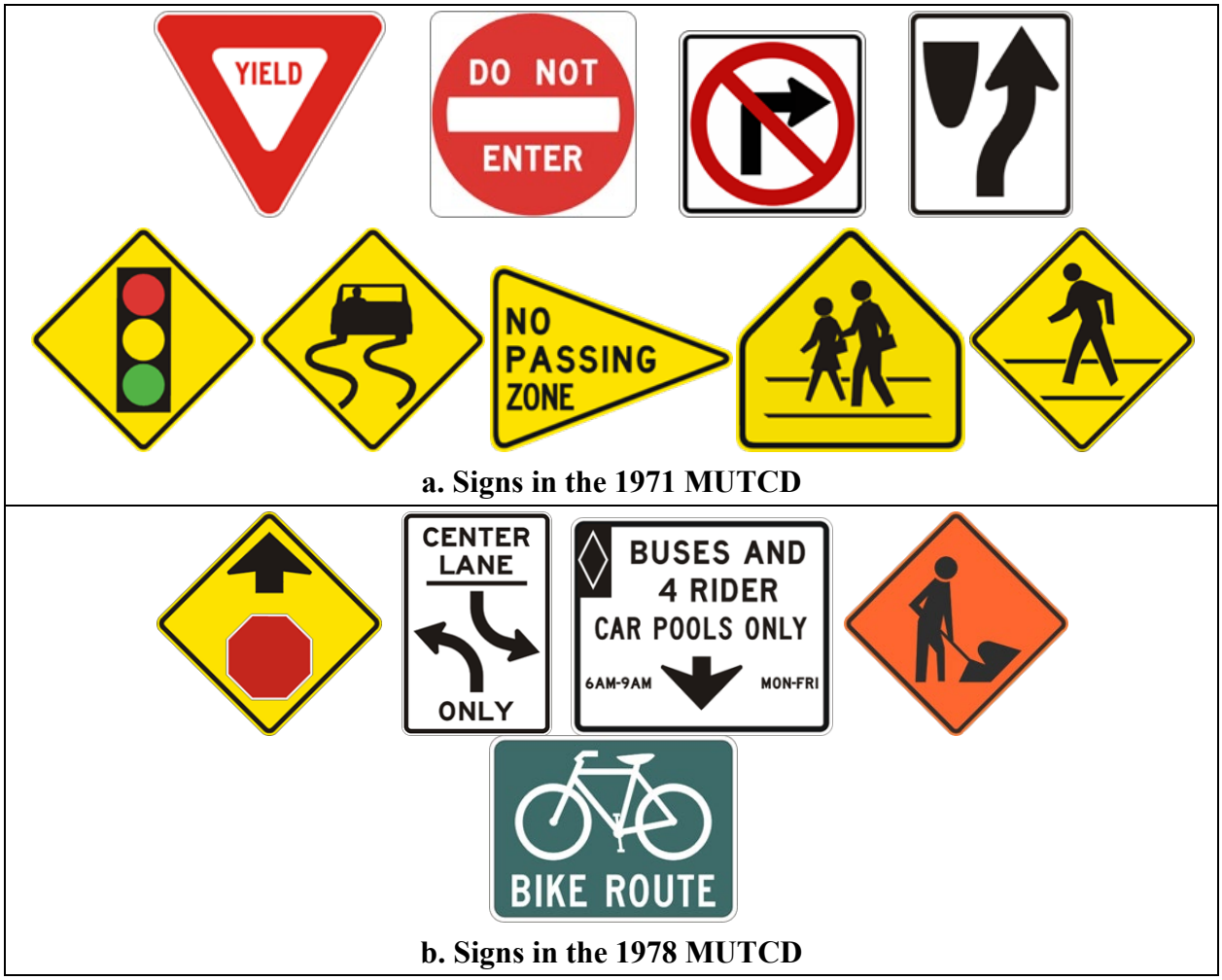
The period between the publication of the 1971 MUTCD and the end of the 20th century represented a period of relative stability in the development of TCDs. The 1971 realized the implementation of several improvements over those in the earlier TCD era, but once implemented, advances were largely related to the introduction of new symbols signs. For the remainder of the century, MUTCD changes were primarily revisions of the 1971 MUTCD, occasionally republished as a new edition (new editions were published in 1978 and 1988).

Throughout the 1960s, significant research was devoted to improving TCDs, particularly in the area of new symbol signs. These improvements were introduced in the 1971 MUTCD, which represented a significant change in both format and content from the previous edition. The following represent some of the most important changes and improvements introduced in the 1971, 1978, and 1988 editions:

- General content:
  - The Federal Highway Administration took ownership of the MUTCD after publication of the 1971 edition. As such, the FHWA became the final decision-making authority for all changes to the MUTCD. In 1979, the FHWA announced the intent to process all future changes to the MUTCD using the federal rulemaking process.
  - It was the first MUTCD to provide formal definitions for "shall, should, and may" (although previous editions had used these terms, they had never been defined in the MUTCD itself).
  - New parts were added, including school areas (1971), railroad grade crossings (1978), and bicycle facilities (1978).
  - Each of the MUTCD editions were revised numerous times: 1971 –eight times, 1978 – four times, and 1988 – seven times.
  - The third revision of the 1988 MUTCD, published in 1993, was a completely new version of the work zone traffic control part of the MUTCD (Part VI).
- Signs:
  - Many new symbols signs were added to the 1971 MUTCD to replace or supplement previous word message signs. Additional symbols signs were added in later editions. Some of the symbol signs which were introduced in the 1971 and 1978 MUTCDs are shown in Figure 11.
  - Several new sign shapes and colors were introduced in 1971. New shapes included the pennant and pentagon (different shapes for school and county roads). New colors included orange for work zone signs and broader use of red in a variety of signs. The Yield sign color changed from yellow to red/white. Green also became the standard background color for guide signs. The 1971 edition continued to allow black on white guide signs on conventional highways but this option was eliminated with the 1978 MUTCD. A 1998 revision of the 1988 MUTCD added the fluorescent yellow-green color for schools, pedestrian, and bicycle signs.
  - The original route marker design for US Highways (Figure 4 and 7) was removed from the 1971 MUTCD.
- Markings:
  - The 1971 MUTCD specified the use of yellow for separating opposing directions of travel, eliminating the use of white as a center line marking. In the 1978

MUTCD, yellow was specified for the left edge line on one-way or divided roadways.

- Signals:
  - The 1971 added red and yellow arrow indications and placed limits on the use of the green arrow.
  - With broader use of arrow indications, the 1971 MUTCD required all arrow indications to be 12 inches.
  - The color for pedestrian signals was set as Lunar White for WALK and Portland Orange for DON'T WALK.



a. Signs in the 1971 MUTCD

b. Signs in the 1978 MUTCD

Figure 11. Symbol Signs from the 1971 and 1978 MUTCDs

RETHINKING THE MUTCD CREATES THE MODERN MUTCD

Even before the publication of the 1988 MUTCD, the FHWA began to solicit comments on the need for a new format for the MUTCD (*10*). One of the challenges of using the mature MUTCD editions in an era of increased tort claims was that the manual contained numerous confusing phrases that were subject to various interpretations, particularly when considered by a jury of

laypeople. Examples of such phrases include "it is desirable that," "shall preferably be," "may be required," "may be justified," "shall be permitted," "it is necessary that," "normally should," and "is intended for use." The National Committee on Uniform Traffic Control Devices (NCUTCD, a descendent of the original Joint Committee) responded to this by creating a blue ribbon committee in 1989 to evaluate the MUTCD. The committee agreed that a new format was needed and recommended that all MUTCD language be reformatted into headings (Standard, Guidance, Option, Support) with a specific operative word to be used with the first three headings (shall, should, may). Throughout the 1990s, the NCUTCD worked on reformatting and rewriting the MUTCD, submitting drafts of their work to the FHWA as the work progressed. The FHWA published drafts of individual parts of the MUTCD as a series of proposed rules in the Federal Register for public comment. The result of this effort was the 2000 MUTCD, which is also referred to as the Millennium MUTCD. Thus began the modern era of TCDs. Other MUTCD editions of the modern era were published in 2003 and 2009. The 2003 MUTCD was published primarily to address numerous shortcomings and errors that had been included in the 2000 MUTCD.

The 2000 MUTCD contained many first for the MUTCD, some of which are listed below:

- First to use the four headings for MUTCD content.
- First to be published on 8½×11 inch paper.
- First to be published in a digital (PDF) format.
- First to be made available on the internet.
- First to use metric dimensions.

Other significant traffic control device changes implemented in the modern era MUTCD editions include:

- A section containing individual definitions was restored in the 2000 MUTCD and has been expanded in later editions (it had been removed from the 1978 and 1988 editions).
- New parts were added to address low-volume roads and light-rail grade crossings in 2000. The light-rail grade crossing part was combined with the railroad-highway grade crossing part in the 2009 MUTCD. Chapters for toll road, managed lanes, and changeable messages signs were added to the MUTCD in the 2009 edition.
- The MUTCD was applied to the use of TCDs on private roads open to public travel with the publication of the 2009 MUTCD.
- The 2009 MUTCD was the first to provide numbering of individual paragraphs.
- Each of the modern era MUTCDs were revised at least once (2000: 1 revision, 2003: 2 revisions, 2009: 2 revisions).

Traffic control device improvements introduced during the modern era (2000, 2003, and 2009 MUTCDs) include:

- Signs:
  - For the first time, the MUTCD defined a desired legibility index for traffic signs (introduced at 40 ft/in in the 2000 MUTCD, changed to 30 ft/in the 2009 MUTCD.).
  - Several changes to individual signs including the elimination of the symbolic lane ends sign
  - The crosswalk lines were eliminated from the Pedestrian Crossing and School crossing signs (2000 MUTCD).
  - The symbolic lane transition sign (W4-2) sign was deleted from the 2000 MUTCD and then added back into the MUTCD in the 2003 edition using a new symbol.

    - The addition of fluorescent coral (pink) as a new color to be used for incident management signs (2000 MUTCD).
    - Signs with metric legends (such as metric speed limits signs) were provided in the 2000 and 2003 MUTCDs but deleted from the 2009 MUTCD.
    - Minimum levels of retroreflectivity were added to the 2003 MUTCD as Revision #2, establishing quantitative maintenance criteria for traffic signs.
    - Traffic sign sizes were increased for many signs in the 2009 MUTCD to better meet the needs of the older driver population.
    - More detailed criteria for the use of signing for changes in horizontal alignment were added to the MUTCD in 2009.
    - Preference for diagrammatic freeway guide signs was replaced with a requirement to use the arrow per lane guide sign for optional lanes on all new installations.
    - The optional use of yellow for school signing was eliminated in the 2009 edition.
    - The 2009 established a requirement to use Stop or Yield signs at railroad-highway grade crossings.
- Markings:
    - A new Yield Line (sometimes called the sharks tooth marking) was added to the 2000 MUTCD.
- Signals:
    - In-roadway lights for pedestrian crossings were added in the 2000 MUTCD.
    - Countdown timer in pedestrian signals were introduced in the 2003 MUTCD.
    - The 2009 MUTCD limited the ability to use 8 inch signal heads to a very limited number of specific situations.
    - In the 2009 MUTCD, signal backplates were required for signals in specific circumstances and the number of signal heads was increased to one per lane on approaches with higher speeds.
    - The 2009 MUTCD added the use of the flashing yellow arrow to indicate permissive left turns.
    - The 2009 MUTCD introduced the use of the pedestrian hybrid signal.

A LOOK INTO THE FUTURE

Traffic Control Device Trends

Clearly, TCDs have evolved over time and will continue the inevitable change. Some of the most basic TCD features have changed such as their physical size, which has increased over time to accommodate older drivers and higher travel speeds. For instance, traffic sign sizes have increased over time and traffic signal lenses have evolved from 8-inch to 12-inch diameter. Road markings have evolved too and are more prominent than ever before, including the increased use 6-inch longitudinal pavement markings and the use of elongated route shields as pavement markings.

Advancements in technology are currently driving more changes to TCDs. For instance, light emitting diodes (LEDs) are used in conjunction with TCDs in a variety of applications. In some cases, they are used to provide more energy efficient TCDs such as in traffic signal lenses and replacing the incandescent bulbs in flashing beacons. LEDs often a variety of new opportunities such as different flash rates and dimmable flash intensities. LEDs are often combined with small solar panels to produce flashing signs in areas without power.

LEDs are also advancing into changeable message signs, offering a full range of color, and even motion (which is not yet approved in the US but used in other countries).

Color stable pigments and digital printing capabilities are also changing TCDs. Color stable pigments are being used with road marking materials to develop new area-wide markings with specific meanings such as green colored bike lanes and red colored transit lanes. Orange colored road markings for temporary traffic control are currently used in Canada and being testing in the US. Purple colored markings are used in some tolling areas. Digital printing of traffic signs is the latest technology used to make cost-effective and durable signs (as described earlier, signs were once made with embossed steel not now their mostly made with aluminum using a silk-screened process or made with electro-cuttable transparent colored films on retroreflective sheeting materials). The digital printing process allows practically any color or shade of color to be incorporated in sign designs such as city logos on street name signs.

While the population growth in the US is predicted to be modest over time, the growth is not expected to be even across the country. Populations in rural areas are expected to decline while populations in urban areas are expected to increase. This shifting population creates new challenges in the urban areas, where there has already been a steady stream of efforts to develop livable streets that are designed around non-motorized road users. It follows that many new TCDs and their applications will be designed to accommodate this urbanization trend.

Automated Vehicles

There is great excitement and even hype about the potential for vehicle technologies to automate the task of driving. And when vehicle automation progress is combined with the potential of connectivity and the shared economy, there are significant signs of an innovation revolution in the transportation sector where automation may one day revolutionize the movement of people and goods. It will take longer to unfold than the general media implies, but advances in sensors, communication and information technologies, artificial intelligence (AI), and entrepreneurial business models may be at such an important point of inflection as to almost guarantee significant future changes and, hopefully, benefits.

One of the questions that many road agencies are asking is, "what can we do to prepare our highways for this innovation—to help accelerate the benefits while not sacrificing the needs of human drivers in the mixed vehicle fleet era?"

To help answer that basic questions, the FHWA published 10 questions in the Federal Register in January 2018 with the intent to develop a better understanding of what was needed from the infrastructure side to support automated driving systems. In May 2018, the FHWA summarized the top themes from the request for information (RFI), including, "Greater uniformity and quality in road markings and TCDs would help enable automation. Having greater consistency in road markings and TCDs and an improved state of good repair benefits all road users, including automated driving systems."

In October 2018, the USDOT released their highly anticipated document, *Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV3.0)* (*11*). This document introduces guiding principles and describes the USDOT's strategy to address existing barriers to safety innovation and progress. One of the most noteworthy items described in this document is that the FHWA will pursue an update to the 2009 MUTCD, taking into consideration the needs of automated vehicle technologies, "The USDOT recognizes that the quality and uniformity of road

markings…support safe and efficient driving by both human drivers and automated vehicles (pg. 11)."

The NCUTCD has established a Task Force to evaluate how TCDs may evolve to support the deployment of connected and automated vehicles. Currently, the NCUTCD Task Force is focused on the area of uniformity, fueled in part by responses from the January 2018 FHWA RFI. The NCUTCD Task Force has been reviewing the MUTCD criteria with a new lens that represents a new design driver—the machine vision camera and software that enables vehicle automation features such as automated steering to keep vehicles in the travel lanes and traffic sign recognition to control speeds. The NCUTCD Task Force has developed a strawman proposal that includes potential areas within the pavement markings area that are proposed to tighten national uniformity in order to support automated driving systems while also being beneficial for human drivers, since there will be decades of a mixed driving fleet. The tightening of national uniformity in terms of TCD applications is one area where changes to the TCD space can support the deployment of AVs while improving safety for human-led vehicles.

MUTCD

In October 2018, the FHWA announced it is pursuing an update to the MUTCD "in preparation for the future of automated vehicles and to afford states and local communities with more opportunities to utilize innovation." According to the Deputy Federal Highway Administrator Brandye L. Hendrickson, "The new manual will be forward-looking in accommodating technologies necessary to support highway connectivity, automation and innovations that improve safety and efficiency." The new MUTCD is currently expected to be available before the end of 2020. The changes that will be in the next edition of the MUTCD will remain unknown until the FHWA releases a Notice of Proposed Amendments (NPA) for the MUTCD (expected in summer of 2019). However, since the last edition of the MUTCD, the NCUTCD has over 200 approved changes that are expected to be mostly if not completely incorporated into the 2020 MUTCD. These approved changes are available on the NUTCD website at: https://ncutcd.org/.

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