

*Standing Committee on Geometric Design (AFB10) and  
Hermanus Steyn, Chair*

*Standing Committee on Operational Effects of Geometrics (AHB65)  
Jeffrey Shaw, Chair*

## **Geometric Design and Operational Effects of Geometrics**

*Committee on Operational Effects of Geometrics (AHB65)*

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The Transportation Research Board (TRB) Geometric Design and Operational Effects of Geometrics Committees congratulate TRB on its 100th Anniversary. In recognition of this historic milestone, the two committees are jointly preparing this Centennial paper to celebrate the important advances in the field of highway geometric design that have taken place over the past century. The members and friends, past and present, of these committees are very pleased with the collective achievements and contributions toward those advances, and look forward to continuing their partnership into TRB's second century.

## **PAST**

### **Committee History and Background**

The 1929 TRB Annual Meeting highlighted reports that identifying research needs to address design, operations and safety. The *Report of Committee on Highway Traffic Analysis* highlighted topics such as "Traffic Planning is an Engineering Problem", "Type of Transportation to Central Business Areas", "Traffic Lane Markings", "Responsibility for Providing Pedestrian Traffic", "Left Turns", "Independent Routes for High and Low Speed Traffic", and "Forms of Traffic Investigations", as well as discussions related to parking, signalization and traffic capacity. The Report of Committee on Causes and Prevention of Highway Accidents stated that the "analysis of problems upon which help can be expected through research, and suggestions as to needed research projects". To this day, the TRB committees continue to address the needs to research the interaction between design, safety and operations.

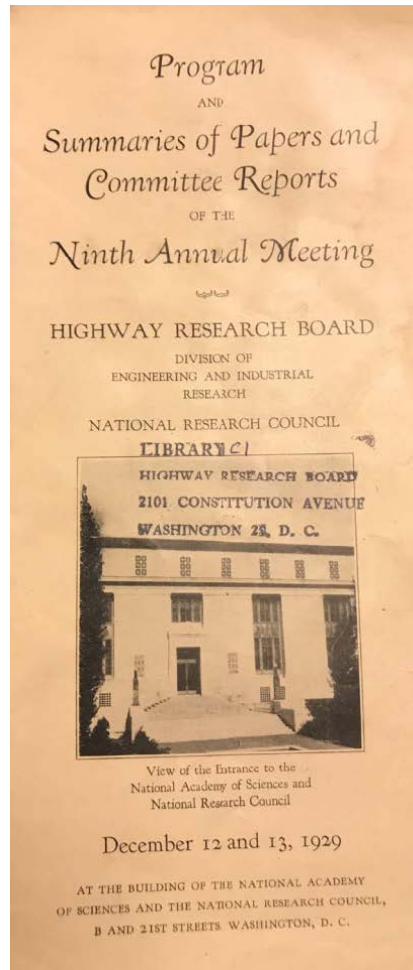


Figure 1. Photo. Program Cover from 1929 Highway Research Board 9th Annual Meeting (Source: TRB Archives)

The Geometric Design and Operational Effects of Geometrics Committees both trace their origins to the post-World War II era, coinciding with the Interstate era and an unprecedented transportation public works boom. From 1946 through 1973 there are various references to both Committees in historical TRB literature. The first Geometric Design committee chair was D.W. Loutzenheiser, who also served as a chief design engineer for the Bureau of Public Roads, the predecessor of the Federal Highway Administration. Both committees took their current form in the 1970s. The Geometric Highway Design committee, and on June 19, 1973 the Standing Committee on Geometric Design (AFB10) was formed and the Standing Committee on Operational Effects of Geometrics (AHB65) was formed February 2, 1977. Table 1 lists the chronological history of committee chairs according to TRB records.

Table 1. Chronological History of Committee Chairs

AFB10 Geometric Design Committee		AHB65 Operational Effects of Geometrics Committee	
Chair Name	Appointment Date	Chair Name	Appointment Date
D.W. Loutzenheiser	01/01/1946	Asriel Taragin	02/01/1953
W.A. Wilson	03/06/1967	John Hutchinson	02/01/1967
Bernard Rottinghaus	06/19/1973	Julie Fee	02/01/1973
Geoffrey Nairn	02/01/1979	Stanley Byington	02/01/1976
John Glennon	02/01/1985	Sheldon Schumacher	02/01/1980
John Mason	02/01/1991	Jerome Hall	02/01/1986
Daniel Fambro	01/02/1997	Daniel Turner	02/01/1992
Elizabeth Hilton	11/01/1999	Douglas Harwood	02/01/2002
Brian Ray	04/15/2006	Ray Krammes	04/15/2005
Eric Donnell	04/15/2012	Kay Fitzpatrick	04/15/2011
Hermanus Steyn	04/15/2018	Jeffrey Shaw	04/15/2017

### Purview of the Committees

#### *Geometric Design Committee*

The Geometric Design Committee is concerned with highway and street geometric design elements that affect safe and efficient operations for all users and contexts. This committee focuses on expanding knowledge regarding highway and street geometric design elements that affect safe and efficient operations for all users and contexts. The committee develops research needs statements and communications findings that advance design criteria, guidance, methods, and performance-based roadway design objectives. The committee facilitates domestic and international dialogues and idea exchanges between researchers and practitioners while supporting emerging and developing professionals. The Geometric Design committee reports to the Design Section (AFB00) within the TRB Technical Activities Division. The committee maintains an informational website and repository of committee documents at <http://sites.kittelson.com/TRB-AFB10>.

#### *Operational Effects of Geometrics Committee*

The Operational Effects of Geometrics Committee is concerned with highway geometric design and its impact on traffic operations and safety of all users. The committee serves an important role in bridging the professional domains of geometric design, safety, and operations and advancing the research and practice of incorporating safety and operational considerations into highway design. The committee seeks to improve the understanding of the safety and operational effects of highway geometrics, assist with the development of tools that quantify those effects, and facilitate the application of the best available knowledge, understanding, and tools in practice. The Operational Effects of Geometrics committee reports to the Operations Section (AHB00) within the TRB Technical Activities Division. The committee maintains an informational website and repository of committee documents at <https://sites.google.com/site/trbcomahb65/home>.

## Evolution of the Committee

Both the Geometric Design and Operational Effects of Geometrics committees have grown and evolved over the years. Figure 2 provides a timeline of various policies that played important roles in shaping the transportation industry, while also influencing the issues and priorities for research conducted by the two committees.

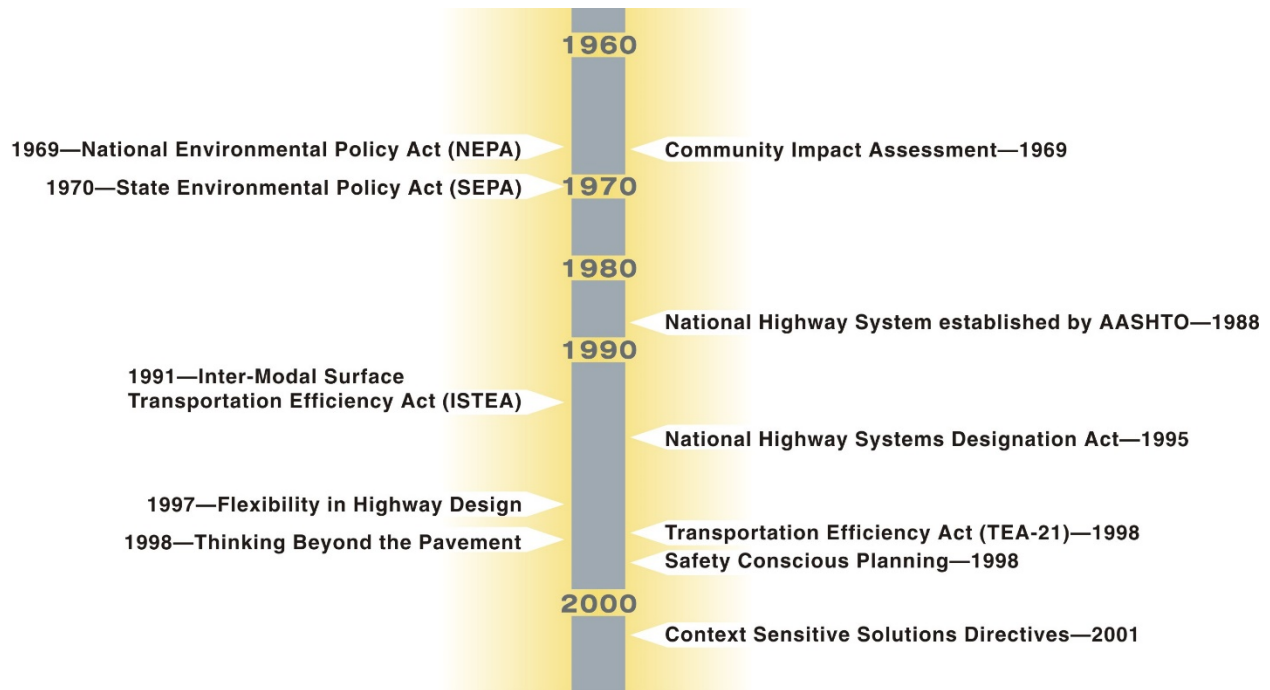


Figure 2. Key Policies Timeline. Source: Kittelson & Associates

The evolution of the committees echoes the milestone historic events within the U.S. highway transportation industry depicted in Figure 3, such as:

- The idea of regional, and then National, interconnected networks of high-speed, limited or managed access, divided highways, became reality within the United States. Experience with these were seen as early as the 1920s with limited-access parkways and tolled roads in the Northeast United States, followed by planning efforts for fully access-controlled freeways in Southern California immediately following World War II in the late 1940s, and ultimately realized as the basis of the legislation that became the National Interstate Highway System (IHS) Act in 1956 (Figure 4). The planning, design and construction of the IHS would continue from the 1950s into the 1990s, allowing for research and development about highway geometric design and effects on safety and operations to take place in real time and inform changes to criteria as time went on. See example of historical sight distance research and development in Figure 5.
- An emphasis on improved roadside design that began in the late 1960s and emphasized the responsibility of highway agencies to reduce the risk of injuries to drivers and occupants of vehicles that run off the road through better roadway and roadside design, often by removal and relocation of roadside objects and/or placement of traffic barriers.

Figure 6 shows an example of an early roadway design with such hazards. The hearings conducted in 1967 by the Public Works Committee of the U.S. House of Representatives (chaired by Representative John A. Blatnik) and the publication of the American Association of State Highway Officials (AASHO, now AASHTO) “Yellow Book” in 1968 were instrumental in guiding research in to the 1970s and 1980s.

- The passage of the National Environmental Policy Act (NEPA) in 1970 provided greater accountability and transparency in the planning and design of highway improvement projects. Implementation of NEPA set the stage for public involvement and consultation regarding Federal Aid funded road projects, eventually culminating in the Context Sensitive Design (CSD) and Context Sensitive Solutions (CSS) approaches that are in practice today.
- The move toward greater consideration of human factors in the driving task and the development of the positive guidance concept in the 1970s. In 2012, the Human Factors Guidelines (HFG) for Road Systems, Second Edition, was published by TRB. The HFG consists of a synthesis of guidelines, informed by research conducted over many years, that provide human factors principles and findings for consideration by designers, traffic engineers and safety practitioners.
- The development of new technology and software that made the geometric design process more efficient and effective, including the development of computer-aided design and drafting (CADD) systems and design visualization techniques, performance analysis packages such as the Highway Capacity Software (HCS), and eventually integrated suites such as the Interactive Highway Safety Design Model (IHSDM). Technological improvements to the design process began in the 1970s and have advanced continuously ever since.
- In the 1980s, the emergence of Access Management as a concept led to research that explored relationships between operations and traffic safety, and resulted in strategies that had profound impacts on city and community planning, land use and development that still stands today. This area of research was among the earliest to focus largely on non-freeway facilities, and articulating the value of separating and/or channelizing vehicle movements.
- As technology continued to take significant leaps in to the 1990s, the idea of Intelligent Transportation Systems (ITS) became an imperative for State DOTs. What was promulgated throughout that time continues today under the umbrellas of Transportation Systems Management and Operation (TSMO), and which will likely to continue into a future featuring Connected and Automated Vehicles (CAV).
- Both committees prepared millennium papers in 2004 that highlighted state of the practice, key issues, trends, and anticipated future topics. These papers may be found at <http://www.trb.org/publications/PubsMillenniumPapersTitle.aspx>. The paper prepared by the Geometric Design committee was *Geometric Design: Past, Present, and Future* (authors Fambro, Collins, Vedova, Leisch and Mason). The paper prepared by the Operational Effects of Geometrics committee was *Operational and Safety Effects of Highway Geometrics at the Turn of the Millennium and Beyond* (authors Harwood, Hummer and Knapp).



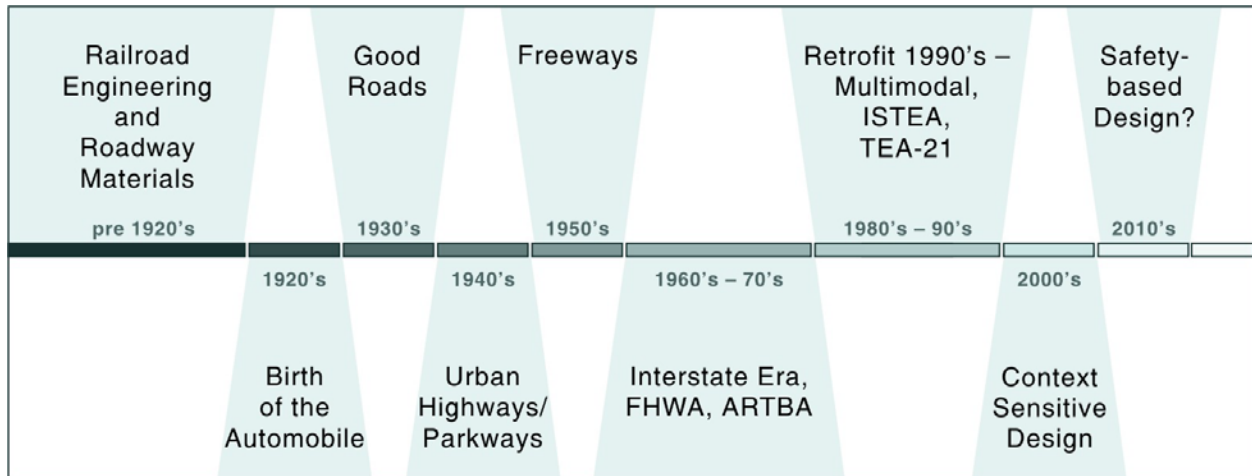


Figure 3. Modern History of Roadway Transportation Timeline (Kittelson & Associates, Inc.)



Figure 4. Federal Aid Highway Act Signed by President Eisenhower on June 29, 1956 to create today's interstate system (source FHWA Turner-Fairbank Highway Research Center website, 2008)

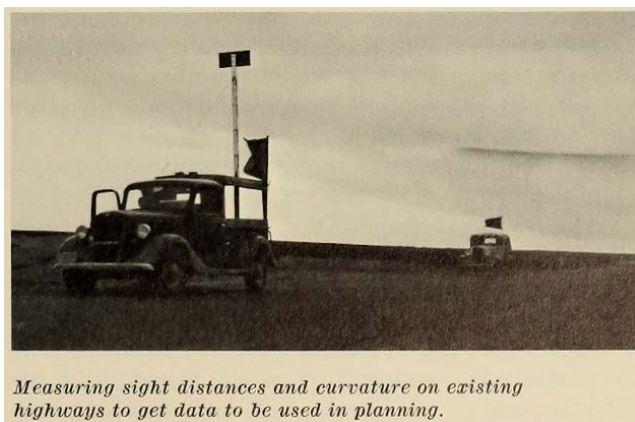


Figure 5. Early research and development on measuring highway sight distance. United States Federal Highway Administration. (1977). America's highways, 1776-1976. U.S. Dept. of Transportation, Federal Highway Administration, p. 269.

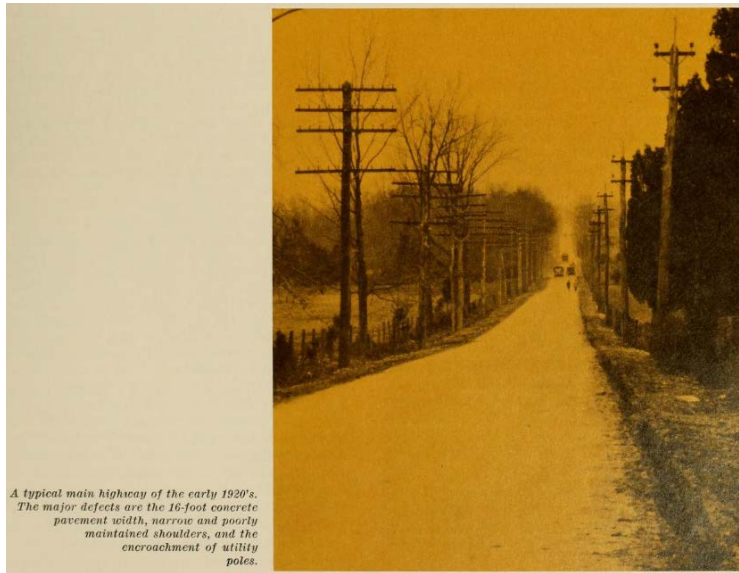


Figure 6. 1920's roadway showing roadway and roadside features that have since been addressed through modern design. United States Federal Highway Administration. (1977). *America's highways, 1776-1976*. U.S. Dept. of Transportation, Federal Highway Administration, p. 389.

## Major Accomplishments to Date

### *Research Symposia*

The Geometric Design and Operational Effects of Geometrics committees have been especially successful in convening joint symposia over the last 25 years, which have served to deploy timely research and create opportunities for committee members and friends to identify, articulate and prioritize new research needs. Figure 3 below provides a timeline of the major symposia that these committees have sponsored since 1995. The different symposia are discussed in more detail in the following sections.

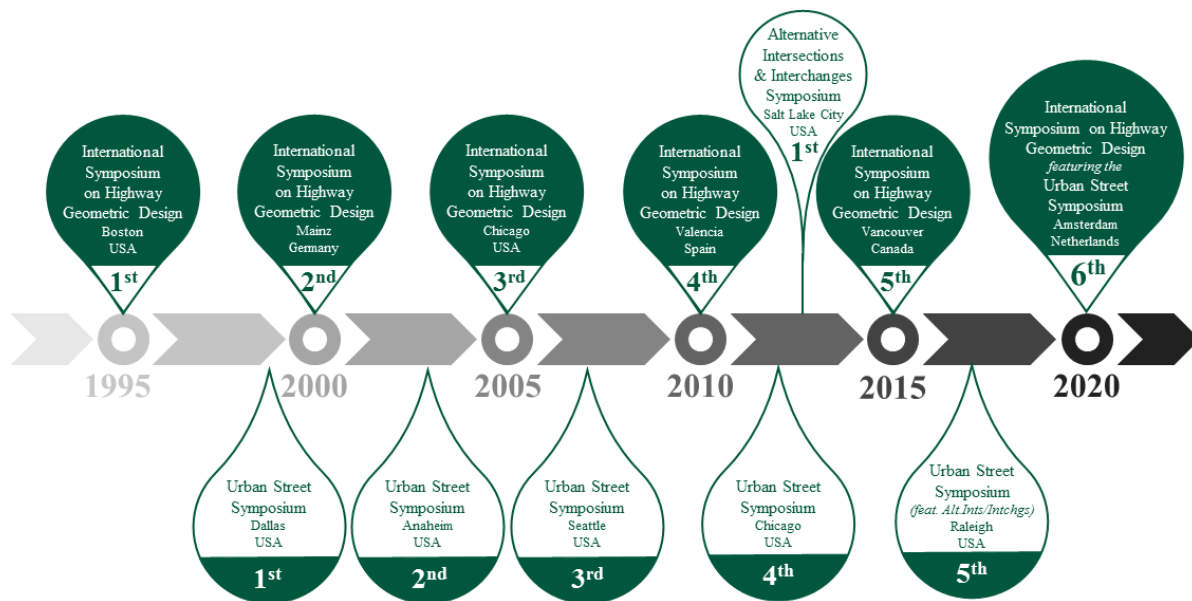


Figure 7. Timeline of Sponsored Research Symposia

### International Symposium on Highway Geometric Design (ISHGD)

The ISHGD began as an effort to share international practices and research on topics that are broadly related to the geometric design of highways. The first symposium was held in 1995 in Boston (Massachusetts), U.S. The ISHGD has been held every five years since, alternating between North America (Chicago, 2005; Vancouver, 2015) and an International locale (Mainz, Germany, 2000; Valencia, Spain, 2010). The 6<sup>th</sup> ISHGD is currently being planned for Amsterdam, Netherlands in June 2020. The ISHGD has been consistently well-attended, with over 300 registered participants each time, representing dozens of countries from across the globe. The ISHGD succeeded in bringing together, on an international level, the communities of research/academia, policy makers and design practitioners to learn from each other and inspire new ideas to explore and implement when returning home. The format of the ISHGD is built around core plenary sessions that feature country reports on recent developments in geometric design practices, policy and tools. There are also technical track lectern sessions, technical tours of local facilities or projects, and a commercial exhibition of institutions, companies and vendors. Prior to the opening and closing plenary sessions, one or more workshops are offered that attendees may also register for and participate in.

### Urban Street Symposium (USS)

The USS was started to stimulate the pursuit and deployment of research and innovation related to urban and suburban street design practices. The USS provides a forum to contrast and discuss alternative design practices suitable for urban and suburban roads and streets, to document and widely share these practices, and to provide a mechanism for technology deployment and training to practitioners advancing projects for State and local governments. The first USS was held in Dallas (Texas) in 1999. Subsequent USS' were held every 3-5 years in a different U.S. city each time, in hopes of providing opportunities for attendees to explore and experience innovative urban and suburban street design features unique to that locale. The format of the USS follows closely the format of the ISHGD, but with additional emphasis on active participation through field-based tours, mini-workshops and poster sessions. Notably, while the



USS started as a conventional TRB-sponsored event, it has evolved into what is presently a partnership-style approach with local professional associations and sponsors. This has included Institute of Transportation Engineers (ITE) districts and sections, the American Society of Civil Engineers (ASCE), the U.S. Access Board (an agency of the U.S. Department of Justice), and the American Association of State Highway and Transportation Officials (AASHTO) Technical Committee on Geometric Design, and many private companies (consultants and vendors). Furthermore, the USS has more recently attracted the support of other TRB committees beyond Geometric Design and Operational Effects of Geometrics; the fifth USS was also supported by the Access Management Committee (AHB70) and the Highway Capacity and Quality of Service Committee (AHB40). In 2020, the sixth USS will be featured within the sixth ISHGD in Amsterdam, Netherlands, marking its first time in an international venue. The USS maintains a website of past papers and proceedings at <https://www.urbanstreet.info/>.

### **Joint TRB Subcommittee on Intersections (aka the IJS)**

The IJS was first constituted in 2005 to focus exclusively on exploring geometric design and its effects within the context of intersections. The creation of the IJS coincided with a growing interest in the U.S. with many types of alternative and innovative intersection designs, building upon roundabouts having been formally introduced with the publication of the Roundabouts Informational Guide by the Federal Highway Administration in 2000. The IJS was originally sponsored by the Geometric Design and Operational Effects of Geometrics committees, and its members quickly set out to develop and nurture ties to other TRB committees that would naturally have a vested interest in intersections-related research. This included the Access Management committee (AHB70), the Safety Data, Analysis and Evaluation committee (ANB20), the Pedestrian Committee (ANF10), and the Traffic Signal Systems committee (AHB25), all of which eventually became official sponsoring committees of the IJS. More recently, the Bicycle Transportation Committee (ANF20) and the Highway Safety Performance committee (ANB25) have become regular contributors to the discussions within the IJS, helping to influence the topics identified for potential research. At the time of the IJS origins, there was also a Joint Task Force on Roundabouts (which eventually became standing committee ANB75), so the IJS consciously chose to exclude roundabouts-related matters from its scope. However, there is presently an effort to collaborate more closely with the Roundabouts committee, since many of the issues that concern the IJS are shared by both groups. The IJS took the initiative to hold the first Alternative Intersections & Interchanges Symposium, held in 2013 in Salt Lake City (Utah). The IJS maintains an informational website at <https://sites.google.com/site/trbijsub/home>.

### **Working Relationship with AASHTO Technical Committee on Geometric Design (TCGD)**

For nearly 20 years, the Geometric Design and Operational Effects of Geometrics committees have nurtured a mutually productive relationship with the AASHTO Technical Committee on Geometric Design (TCGD). The AASHTO TCGD has primary responsibility for the maintenance and update of the AASHTO publication “A Policy on Geometric Design of Highways and Streets”, known colloquially as “the Green Book”, as well as a companion publication, “A Policy on Design Standards for the Interstate System”. The most recent editions of these publications are the 7<sup>th</sup> (2018) and 2<sup>nd</sup> (2016), respectively.

The mutual accomplishments of these three committees are numerous, and have been built upon a commitment to meet regularly by coordinating mid-year summer meetings. These

meetings go back to 2002, and have taken place at TRB facilities in Woods Hole, Massachusetts, and Irvine, California, as well as at AASHTO summer meetings put on by the parent standing committee of the TCGD. They have also been co-located with major symposia, such as the ISHGD and USS, or other major meetings. Meeting together in this way has led to identification and prioritization of many research efforts, as well as jointly advancing new tools and technologies such as the Highway Safety Manual. In 2013, the joint meeting in Irvine focused exclusively on the application of the AASHTO Highway Safety Manual (HSM) 1<sup>st</sup> Edition, and attracted the attendance of the Access Management committee (AHB70) and the Highway Safety Performance committee (ANB25). The most recent joint meeting that was held in Franklin (Nashville), Tennessee, in 2018, focused not only on the changes to the AASHTO Policy on Geometric Design of Highways and Streets “Green Book” with the 7<sup>th</sup> Edition, but also feedback from attendees for establishing a vision for what the 8<sup>th</sup> Edition should look like in the future. Notably, two key research publications (NCHRP Report 785: Performance-Based Analysis of Geometric Design of Highways and Streets and NCHRP Report 839: A Performance-Based Highway Geometric Design Process) that informed the Green Book 7<sup>th</sup> Edition originated through these three committees.

Perhaps the most significant product of the collaboration of these three committees is the number of research need statements and funded projects. By working together, and jointly identifying, articulating, prioritizing and advancing key research, the most vexing problem with research has been overcome – the process of advancing research to implementation. Since 2004, more than 65 research need statements have been developed and 18 of these have been funded through the National Cooperative Highway Research Program, with a cumulative value of \$9.1 million.

#### *Geometric Design Strategic Research Agenda (as E-C110 in January 2007)*

The objective of this publication was to document the efforts leading up to and resulting from a Strategic Geometric Design Research Needs Workshop held in Williamsburg, Virginia, in July 2004. This workshop was a joint effort by the three committees noted above. This document contained 22 research need statements (RNSs), organized in a prioritized and chronological order, intended to inform the long-range (10-15 years) geometric design research program by agencies such as AASHTO, FHWA, and other research sponsoring agencies. The link to this publication is <http://onlinepubs.trb.org/onlinepubs/circulars/ec110.pdf>

In 2014, due to the material success of their efforts for the preceding 10 years, both the Geometric Design and Operational Effects of Geometrics committees were awarded the Committee Blue Ribbon for “Jointly developing a strategic geometric design research program in consultation with AASHTO Technical Committee on Geometric Design”.

#### **Production of the Highway Safety Manual**

At the 2000 TRB Annual Meeting, seven TRB standing committees endorsed the Highway Safety Manual concept that had emerged in the preceding years, including the committees on Geometric Design and Operational Effects of Geometrics. A joint subcommittee was then formed to coordinate more detailed planning and initial development activities. In 2003, the joint subcommittee was designated as a TRB Task Force for the Development of the Highway Safety Manual. The first edition of the Highway Safety Manual was published as an AASHTO document in 2010. The Task Force became the permanent Standing Committee on Highway Safety Performance (ANB25).

## **PRESENT**

### **State of the Practice and Best Practices**

#### *Performance-Based Practical Design*

Geometric design guidance and criteria are published in the AASHTO Green Book. As the Green Book has undergone various iterations and updates, there has been an increasing emphasis on design flexibility, rather than a prescriptive, standards-driven approach, to developing projects in different communities and contexts. This is arguably the result of a convergence of the CSD/CSS evolution described earlier in this paper, along with financial realities and imperatives that most agencies face. Performance-Based Practical Design (PBPD) takes a principles-based approach that relies on performance metrics to inform design choices and development of alternatives. There are a variety of new tools available to design professionals that facilitate performance-based decisions, including the *Highway Safety Manual (AASHTO)*, *Highway Capacity Manual (TRB)*, *Interactive Highway Safety Design Model (FHWA)* software, *SafetyAnalyst (AASHTO)* software, and the *User and Non-user Benefit Analysis for Highways (AASHTO)* guidebook. These tools, developed from research identified by the members and friends of these committees, allow design professionals to assess the expected safety and operational performance of geometric designs, and to quantify the benefit-cost ratio of various alternatives, for transportation projects. Quality geometric designs should involve finding an optimal solution among competing constraints – there is a need and challenge within the profession to further integrate many of the tools into a complete, multi-objective system capable of simultaneously assessing system performance.

#### *Alternative Intersections and Interchanges*

Alternative intersection and interchange designs have proliferated rapidly in the United States. Examples that are now routinely considered include the diverging diamond interchange (DDI), displaced left-turn (DLT) intersection, median U-turn (MUT) intersection, restricted crossing U-turn (RCUT) intersection, and quadrant roadway intersection (QRI). Designers need to better understand the safety and operational effects associated with these intersection and interchange forms relative to more conventional forms, and need to better understand driver informational needs (e.g., signing and pavement markings) so that design criteria and guidance can reflect “best practices.” FHWA published a series of informational guides that provide guidance for these alternative intersections and interchanges. There is also ongoing research for a focus on pedestrians and bicycles at these types of intersections/interchanges. As practitioners grow more familiar and comfortable with these intersections, it is more likely that variants and combinations will emerge, creating opportunities for additional research.

#### *Managed Facilities/Lanes*

The Geometric Design and Operational Effects of Geometrics committees have had good working relationships with the Managed Lanes committee (AHB35), finding mutual interest in exploring research related to the design criteria and performance characteristics that are related to design elements. As a growing number of States and metropolitan areas look to leverage strategies such as high occupancy vehicle (HOV) lanes, HOV with tolls or variable pricing (HOT) lanes, and express toll lanes, the need for tailored design guidance also grows. In the

past, the committees have jointly explored basic design of managed lanes, focusing on lane separation and ingress/egress features. Presently, there has been discussion related to determining the effect that multiple weave movements introduced by managed lanes may have on general purpose lanes, to evaluate whether there are other design scenarios for ingress/egress that could mitigate or avoid negative impacts.

### **Current Issues, Needs and Gaps**

Urban streets are designed with the intent to offer accessibility and safety for all users. To facilitate these design objectives, low posted speed limits are often established. A couple of current needs are:

#### *Speed Management*

There are more than 32,000 fatal crashes annually on the highway and street network in the United States. Approximately 30 percent of fatal crashes are speeding-related. While some states are raising posted speed limits in response to increasing vehicle speeds on high-speed roadways, there is a movement in other states to develop self-explaining and self-enforcing roadways (or design for target speeds). This concept involves use of geometric design elements or traffic calming measures to manage speeds, with the intended outcome of fewer speeding-related crashes. These TRB committees has an opportunity to support this effort by developing research needs statements to support development of self-enforcing and self-explaining road initiatives, and then assisting in the marketing, outreach, and dissemination of research findings.

#### *Multimodal Planning and Design*

Transportation professionals around the world are challenged to improve the safety and mobility of their transportation network to serve multimodal users (cars, bicycles, pedestrians, transit, and freight). Corridor improvement projects are typically major investments that require balancing competing demands and working within severe constraints. State departments of transportation and local agencies are re-evaluating and updating their project development process, integrating performance based practical design, considering and developing tools to quantify multimodal operations and safety, working within physical constraints areas to minimize impacts, considering human factors, as well as evaluating trade-offs and prioritizing needs based on corridor needs. These TRB committees can bring various needs together and work with multiple committees to address multimodal needs.

### **Relationship and Alignment with other Committees**

The Geometric Design and Operational Effects of Geometrics committees have liaison opportunities with several TRB committees to continue addressing issues from a collective and collaborative approach rather than working in “silos”. Over the last 5-10 years, our committees have conducted and facilitated workshops bringing various TRB committees together; including Roadside Safety Design (AFB20); Highway Capacity and Quality of Service (AHB40); Highway Safety Performance (ANB25); Safety Data, Analysis, and Evaluation (ANB20); Pedestrians (ANF10); Bicyclists (ANF20); Transit Capacity and Quality of Service (AP015); Tort Liability and Risk Management (AL070); and, Performance Measurement (ABC30). Furthermore, the AASHTO Technical Committee on Geometric Design, as well as the recently established AASHTO Council on Active Transportation committees, offer liaison and collaborative opportunities to develop and disseminate future research.

### **International Member/Participation and Younger Member Participation**

Both the Geometric Design and Operational Effects of Geometrics committees have excellent track records and healthy participation by members and friends that fall in to the International and Younger category definitions. The contributions to our committee efforts by International members is likely due to relationships built through the International Symposium efforts described earlier. This has led to sustained participation by members from countries outside North America, which is evident in both the attendance at TRB events and in the papers submitted for the Annual Meeting each year.

### **FUTURE**

#### **Trends/Emerging Issues**

It is an exciting time for the transportation research community. Even in the 5-10-year horizon, there are many developments that are only today in their infancy that could develop quickly enough in this timeframe to revolutionize how we plan, design and operate our road networks. From a joint committee perspective, it will be important to continue to foster the relationship with the AASHTO design community, as well as develop and nurture new relationships with associations that are at the forefront of urban mobility innovation, including ITE and the National Association of City Transportation Officials (NACTO). A diverse panel of viewpoints and experiences will provide our committees with the ability to identify the most urgent research needs and adapt and evolve to meet those research challenges. Among the challenges that lie ahead, the following issues are expected to require significant committee attention.

#### *Transportation Performance Management (TPM)*

The emergence of TPM, codified in Moving Ahead for Progress in the 21<sup>st</sup> Century Act (MAP-21, 2012) and Fixing America's Surface Transportation Act (FAST Act, 2015). FHWA defines TPM as "a strategic approach that uses system information to make investment and policy decisions to achieve national performance goals". Of special interest to these TRB committees are the TPM metrics that the states must use as the basis for national goals, measures, targets, plans, and reports and their relationship to the geometric design of highways and streets. One example is the operational measure of reliability, which further characterizes the operational performance of a highway, recognizing that measures such as speed, capacity and delay vary based on many factors, including sensitivity to geometry.

#### *AASHTO Green Book, Future 8<sup>th</sup> Edition*

AASHTO is discussing a comprehensive update and restructuring the Green Book for the 8<sup>th</sup> Edition (GB8). Through nationwide stakeholder outreach and literature reviews, the GB8 Visioning project (*NCHRP Project 20-07, Task 423, Planning for a Comprehensive Update and Restructuring of AASHTO's A Policy on Geometric Design of Highways and Streets [Green Book 8 Visioning Project]*) will result in a document framework that supports a data-driven, performance-based design process. The effort will outline a detailed roadmap that prioritizes topics and considerations for developing and implementing the 8<sup>th</sup> Edition of the Green Book. The Green Book 8 Vision will set the foundation for the most comprehensive update of the Green Book since the 1<sup>st</sup> Edition in 1984 and support industry trends toward flexible transportation solutions supporting livable communities and multimodal planning.



*Allocation and Reallocation of Space in response to Market Demand and Community Influences*  
Demand for space within the public right-of-way will continue to grow to suit a wide variety of purposes, some that are only just now emerging and others that are not yet imagined. This will mean allocating and reallocating space to accommodate what is most demanded and supported by elected officials, appointed policymakers and community stakeholders. In terms of transportation mode share, it is expected that there will be a continuing demand to provide space for walking and biking, especially as knowledge improves about how geometric design elements influence the quality of experience and safety performance. This will likely include exploring the conflicts and trade-offs between walking and biking on or along facilities where motor vehicles may or may not be present, as well as incorporating an understanding of how road design affects public health outcomes through research pursued through the TRB Arterials and Public Health Task Force (ADD55T). More recently, market solutions involving on-demand electric-motor transport (“e-scooters”) and curbside service and delivery (“e-delivery”) are challenging road authorities and prompting debate over regulation and use. It is not yet known if or how these emerging market solutions will require research related to road geometry, but these topics are being raised within current committee deliberations.

#### *Connected and Automated Vehicles*

Efforts to prepare for and support implementation of Connected and Automated Vehicles (CAV) are shared by many TRB committees. The concerns of the Geometric Design and Operational Effects of Geometrics are mostly limited to whether and how CAV may affect road design criteria and/or the performance characteristics associated with fundamental design elements, even of things as ordinary as driveways. There may also be new design challenges, such as staging areas for storing and parking vehicles if CAV were to become more a shared mobility-based service as opposed to conventional models of individual ownership behavior. Presently, there is an ongoing NCHRP project *Impacts of Connected and Automated Vehicles on State and Local Transportation Agencies* (20-102) that is examining many different aspects of CAV. One of the projects, *Understanding the Impacts of the Physical Highway Infrastructure Caused by the Increased Prevalence of Advanced Vehicle Technologies* 20-102(15), is directly evaluating impacts of CAV on design-related aspects of infrastructure, and findings will be of interest to the Geometric Design and Operational Effects of Geometrics committees.

### **Influence on Committee Mission and Purview**

#### *Technological Aspects - Big Data and Artificial Intelligence*

The second Strategic Highway Research Program (SHRP 2) naturalistic driving study collected driver behavior data (speed, braking, and throttle inputs) in several regions throughout the United States. Additionally, this program developed a roadway information database that can be appended to the driver behavior data, which includes information about the horizontal alignment, vertical grade, and cross-section. Collectively, this wealth of data offers the potential to transform highway geometric design practice. The data can be used to evaluate existing design policy by determining the association between the driver, geometry, and crash or near-crash events. It is possible that new design criteria could be developed because of research using SHRP 2 data. The Geometric Design and Operational Effects of Geometrics committees will continue to be stakeholders in naturalistic driving data research.

Beyond SHRP 2 lies the exciting field of advanced driver-assistance systems (ADAS) and connected and autonomous vehicles (CAV). The ongoing development and implementation of these technological solutions will initially enhance the driving task for humans, and eventually relegate humans to only passengers. These fields include the software and algorithm development and machine learning that will further evolve our understanding of geometric design.

*Policy Developments - Quantifying Risk and Uncertainty in Transportation Design Criteria*

Surface transportation system design policies and guides, such as the AASHTO Green Book, provides minimum or limiting values for nearly all criteria. Examples of minimum geometric design criteria include the radius of curve, sight distance (stopping, passing, decision, and intersection), and rate of change for crest and sag vertical curves. While transportation designers use these criteria as deterministic values (i.e., they are fixed), many are based on models that have stochastic (i.e., variable) features. For example, the stopping sight distance model is the sum of the distance traveled during perception-reaction and the distance traveled during braking. Vehicle speeds, driver perception-reaction times, and driver deceleration rates are treated as fixed values in the model and are selected to represent “high” (e.g., 95<sup>th</sup>) or “low” (e.g., 5<sup>th</sup>) percentile values to cover a broad-range of scenarios likely encountered by drivers in the field; however, these variables are random and can be explicitly defined by a distribution. Risk and reliability applications have recently been used to evaluate the probability that geometric design criteria may not comply with minimum values based on distributions from field data. These applications provide an opportunity for designers to determine the probability that drivers may encounter circumstances on the roadway that do not comply with minimum or limiting design criteria. Other fields in civil engineering (e.g., water resources and structural engineering) have begun developing design criteria based on risk and uncertainty applications, and it seems likely that transportation design criteria may follow. This emerging issue provides for the opportunity to develop a unified research program to support risk-based geometric design criteria. Collaboration with the AASHTO Technical Committee on Geometric Design and the TRB Committee on Tort Liability and Risk Management (ALO70) exist to support this issue.

## **CLOSING**

This centennial paper has explored the past, present and future of the highway geometry discipline in the Transportation Research Board. The Committees on Geometric Design and Operational Effects of Geometrics have documented deep roots in TRB’s beginning, strong and impactful connections to AASHTO through research that led and is leading to products improving our highways and streets. The committees have established contemporary connections with other transportation modes and established a diverse collaboration across many subject areas beyond highways in TRB. They are well poised for the future challenges as transformative technologies emerge.

### **DISCLAIMER**

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