The Influence of Human Factors on Access Management Design

Authors: Karen K. Dixon and Robert D. Layton

Corresponding Author's Contact Information:

Karen Dixon
Oregon State University
School of Civil & Construction Engineering
220 Owen Hall
Corvallis, OR 97331-3212

Phone: 541-737-6337
Fax: 541-737-3052
Email: karen.dixon@oregonstate.edu

Abstract:

Human factors are a critical component to appropriate access management design; however, current access management design techniques rarely consider the robust nature of the human element explicitly. For example, a constant perception-reaction time and deceleration rate are commonly used, yet the variation in facility function, speed, adjacent land-use, level of conflict, and transit / bicycle / pedestrian activity are excluded from direct consideration. In addition, a single height of object for stopping sight distance is assumed to be approximately 2 ft (0.6 m) based on current AASHTO standards, with the 0.5 ft (150 mm) basis retained by several states. For access management applications, object height could be represented better by vehicle headlight/taillight height or, for some situations, curb height (0.5 ft [150 mm]) or pavement surface (effectively an object height of 0 ft [0 mm]).

One of the major techniques for determining driveway spacing and location is based on the stopping sight distance of approaching vehicles. Perception-reaction time is a direct component of stopping sight distance; however, the most frequently assumed 2.5-second perception-reaction time, shown by current research to be a conservative value, does not consider the level of conflict present at the location. This value also does not take into account road complexity, traffic volume, ambient lighting, vehicle mix, or similar known elements common to many road environments. In addition to the perception-reaction time, the expected driver performance is influenced by driver work load impacts such as intersection frequency, proximity to interchanges, driver fatigue level, presence of bicycles and pedestrians, as well as the presence of raised medians. The concept of decision sight distance is more appropriate for many access management applications since it directly reflects the increased level of complexity for different road environments (such as rural versus urban); however, decision sight distance also does not explicitly address the numerous and diverse characteristics common to the complex driving task and specific driver abilities.

This paper addresses the various influences of driver characteristics on the optimal spacing, location, and design of access management facilities. These characteristics can include consideration of driver's field of vision (based on perceived approach speed), visual ability, cognitive ability, mobility, and age and experience. To adequately consider the wide variation of these driver characteristics as they relate to specific access management decisions and unique contextual environments, the authors assess the effects of current design decisions, and how such assumptions contrast to more human-related specificity.

Background

The safe and effective operation of all highway facilities requires the consideration of three primary elements of the roadway: the driver, the vehicle, and the roadway. An understanding and consideration of each of these elements is necessary to determine appropriate design features, traffic control measures, and access management strategies. Designing for the human element is essential for providing safe and effective highways. It has been estimated that driver characteristics and behavior directly contribute to approximately 90-percent of highway crashes. Human factors associated with the driver's performance include the driver's physical abilities as well as psychological influences.

According to the Transportation Research Board *Access Management Manual* (*1*), access management is the "systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway." Many highway design and traffic control strategies focus on the expected human interactions with the infrastructure configuration at these critical access locations. Some of these measures, such as, stopping sight distance, are also presently used for making access management decisions and developing related designs. However, numerous vehicle conflicts, increased infrastructure complexity, and a larger required visual field involve more human factors than currently used to address access to land use activities. Stopping sight distance, which incorporates the human factors of perception-reaction time and comfortable deceleration rate, is the primary geometric measure used to design a highway alignment and to provide sight distance to traffic controls. However, the perception-reaction times required for a driver to observe and react to the potential multiple conflicts and diverse conditions at access locations may be longer than required for stopping sight distance.

A fresh and objective look at the human factors and characteristics affecting access management is warranted to assure all important issues are considered. Issues that should be reviewed include:

- Driver vision and object visibility;
- Driver workload;
- Cognitive limits, especially for the elderly;
- Driver expectancy;
- Suitability of and guidelines for sight distance; and
- Importance of uniformity in design and information presentation.

Some of these issues require a review of current research and knowledge on human factors from the perspective of access management; however, it is also likely that new research is required.

Goal of This Paper

Human factors are critical determinants for the design, operation, control and safety of roadways. More attention has been paid in the recent past to the influence of the characteristics of drivers, pedestrians, and bicyclists on the geometric and operational features of highway facilities. Before the 1984 American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (commonly referred to as the *Greenbook*) was published, the design perception-reaction time of 2.5 seconds for calculating the stopping sight distance primarily reflected driver behavior for highway design. The 1984 AASHTO *Greenbook* introduced another design measure known as the decision sight distance. Though the use of this new sight distance metric was proposed but not required, it recognized the increased perception-reaction time needed to accommodate designs where conditions are complex, and conflicts are numerous *(2)*. The decision sight distance concept also incorporated reaction times associated with non-stop maneuvers.

More recently, the impact of various human factors on the design and control of roadways has been explored and incorporated into design and traffic control standards, such as, the 2003 *Manual on Uniform Traffic Control Devices for Streets and Highways (3)* and the 2004 *AASHTO A Policy of Geometric Design of Highways and Streets (4).* These enhancements to current standards are due to a better understanding by the industry of the numerous and widely varying effects of drivers and pedestrians, often with a particular focus on the elderly. The studies of elderly characteristics have shed information on the multitude of human factors influencing the impacts of driver behavior on highway operations and safety.

Design and control give primary consideration to the roadway mainline alignment, with separate analysis for the roadside design. However, access management decisions must be made based on the entire road cross-section at locations along arterials where conditions are complex, conflicts are numerous, and influencing factors are varied. At such locations, the workloads for drivers and pedestrians are heavy, requiring them to concurrently observe traffic conditions, turning movements, pedestrians, traffic controls, driveway locations, driveway traffic, roadway geometrics, driveway design features, and similar road characteristics.

A major objective of access management is to control the number and severity of conflicts. These conflicts arise due to the various land use activities, the prevailing traffic operations and speeds, and the presence of drivers, pedestrians and bicyclists. The human element can vary widely in age, familiarity with the area, and driver knowledge. The impacts and interactions of all these factors result in very complex conditions where access must be accommodated, designed or controlled.

Important Human Factors

An appreciation and understanding of human behavior and abilities are needed to determine their influence on access management decisions and design. The physical abilities and psychological limitations of drivers impact these criteria and are reviewed in the following sections.

Humans are sequential processors. This means that drivers can quickly scan, sample, select, and process information one element at a time. They focus on the situations and conditions that they deem to be most critical for the safe operation of their vehicle. Therefore, complex situations create unsafe or inefficient operations because it takes so long for drivers to identify and process the information. This means that as complexity increases a longer perception-reaction time must be available. The visual limitations combined with cognitive constraints and complexity of traffic conditions require much longer processing times, and thus longer perception-reaction times.

Visual Stimuli

The primary stimulus for operation and safe control of vehicles is vision. The physical composition of the eye and its functioning constitute limits that must be considered when evaluating access management decisions and designs. As shown in Table 1, drivers lose their ability to see objects clearly as the angle from the axis of focus increases.

Table 1. Cone of Vision

Angle	Quality
3-5° cone	Best vision – can see texture, shape, size, color, etc.
10° cone	Clear vision – critical traffic control devices should be in this cone
20° cone	Satisfactory vision – regulatory and warning traffic control devices must be this cone of vision
~ 90° cone	Peripheral vision – only movement can be seen with this vision

Drivers cannot see all objects in the visual field clearly, so they must scan the visual field. Drivers fix their attention down the roadway in the cone of clear vision at about 100 ft (30.5 m) for a speed of 30 mph (48 km/h) or 120 ft (36.6 m) at 55 mph (88.5 km/h) on the average *(5)*. They then shift their vision to the right and left to keep track of traffic conditions, pedestrians and local activities. As depicted in Table 2, the eye movement time includes the time required for drivers to shift their eyes and to focus on an object. At times, drivers return to fix their eyes on the same target. The total times of fixations on a target, including transition times are called a glance.

Table 2. Eye Movement Time

Eye Movement	Time
Shift to New Position	0.15 - 0.33 sec.
Fix or Focus on Object	0.20 - 0.35 sec.

It takes roughly a minimum of 0.5 seconds for a driver to shift his or her eyes and focus (i.e. to glance at a target). Thus, a full cycle to scan right and back to the left takes at least 1 second for simple conditions. If there is glare, it takes about 3 seconds or more to recover full visual acuity and 6 seconds or longer to recover from bright to dim conditions.

Peripheral vision is reduced as speed increases (see Table 3). Consequently, a larger area next to the roadway is blurred requiring the driver to look in that direction to ascertain the presence of conflicts, such as pedestrians or approaching vehicles. Further, there is a significant loss in peripheral vision for the elderly driver or pedestrian.

Table 3. Peripheral Vision as Related to Speed

Speed	**Cone of Vision** (from line of sight)
40 mph (64.5 km/h)	37 °
50 mph (80.5 km/h)	29 °
60 mph (96.5 km/h)	20 °

Important Visual Functions. Various measures of visual acuity provide measure of how well drivers can see. These are the measures of static visual acuity, dynamic visual acuity, contrast sensitivity, and peripheral visual field. These measures of visual ability alone are not sufficient to describe the ability of drivers to master the complex driving task. According to Owsley et al., the cognitive information processing of the visual information is also required *(6)*.

Static Visual Acuity. Static visual acuity is the ability to see stationary details. For younger drivers, the average visual acuity is 20/20, whereas the average for older drivers at age 65 is 20/30. For drivers over 65 the average static visual acuity has dropped to 20/70 *(7)*. The ability to see detail in signs, markings, and geometric features is governed by the static visual acuity of the driver. Further, the static visual acuity is a function of the background, brightness, contrast, and time for viewing. The visual clutter along arterials is problematic for the static acuity of drivers, especially the elderly.

Dynamic Visual Acuity. Dynamic visual acuity is the ability to resolve the details of a moving object. Most of the process of seeing involves dynamic visual acuity for a driver that is in motion and includes reading signs, seeing driveways, observing pedestrians, and determining the movement of other vehicles. Dynamic visual acuity reduces as the speed of the target increases. According to Burg, a driver is unable to keep track of an object moving at an angle change above 30 degrees/second with smooth eye movement *(8)*. Dynamic visual acuity improves with a longer viewing time, more illumination, and greater familiarity. There is gradual deterioration of dynamic visual acuity with advancing age.

Contrast Sensitivity. A primary ability of human vision is the ability to analyze contrast information, thereby enabling people to see patterns in the visual field. A study by Horswill et al. found that hazard perception-response time increases significantly with loss in contrast sensitivity for drivers *(9)*. Contrast sensitivity is more important than visual acuity for nighttime driving. Older drivers have less contrast sensitivity than younger drivers, requiring higher levels of contrast and more time to adjust to dark conditions. Pedestrian crossings and driveways on arterials often have inadequate contrast.

Glare Sensitivity. Glare is defined as a level of brightness in the visual field that is significantly greater than the level of illumination to which the driver's eyes are accustomed. Research has found reduced contrast sensitivity and static visual acuity when glare exists for elderly drivers *(10)*. Glare is presented by many sources, including roadside illumination, traffic signals, oncoming headlights, and sun positioning. Arterial roadways notably have many and diverse sources of glare.

Depth Perception. Depth perception is the ability to determine the distance to and relative depths of objects. The eye can assess the distance to an object by shifting from the near view to the far view. This ability is increasingly lost to the elderly driver due to hardening of the optic lens and weakening of the ocular muscle. Depth perception is useful in assessing speed of oncoming vehicles, the gaps between vehicles, and distance to roadside features, such as driveways. This ability is critical for making left turns and safely navigating across the path of approaching traffic safely.

Nighttime Vision. Virtually all measures of vision deteriorate with lower levels of illumination. Lower levels of illumination are especially problematic for the elderly driver. The amount of light needed to see objects increases with age; by age 75, drivers need about 32 times the illumination needed at age 25.

Drivers see differently with nighttime vision with discernment by silhouette and by reverse silhouette. Discernment by silhouette is achieved by seeing dark objects against a dark background, provided by the uniform brightness of the pavement and the area transverse to the roadway. Darker objects placed on these backgrounds are then visible. Discernment by reverse silhouette occurs with bright areas or objects against a dark background, the pavement, and when pedestrians and vehicles are illuminated as with street lighting. The brightness of pavement for nighttime vision can be provided by illumination to give uniformity, adequate brightness, and no glare.

Table 4 summarizes the various visual functions and their associated definitions and potential problems.

Table 4. Summary of Important Visual Functions

Visual Function	Definition	Potential Problem
Static Visual Acuity	Ability to see detail	Visual clutter along arterials
Dynamic Visual Acuity	Ability to see moving object detail	Assessing speeds and movement of other vehicles
Contrast Sensitivity	Ability to analyze contrast and see patterns	Hazard perception time increases with contrast loss
Glare Sensitivity	Level of brightness in visual field greater than ambient condition	Results in losses in static visual acuity and contrast sensitivity
Depth Perception	Ability to determine distance and relative object depth	Loss in depth perception impacts ability to assess speeds, gaps, and distance to objects
Night-time Vision	All vision measures are diminished with less illumination	Drivers must see in silhouette or reverse silhouette. Elderly in 70s need 32 times as much light as someone in their 20s

Perception-Reaction Time

The perception-reaction time for a driver includes four components that are assumed to make up the perception-reaction time. These are referred to as the PIEV time or process.

- Perception - the time to see or discern an object or event;
- Intellection - the time to understand the implications of the object's presence or event;
- Emotion - the time to decide how to react; and
- Volition - the time to initiate the action, for example, the time to engage the brakes.

Human factors research has defined the recommended standard perception-reaction times as 2.5 seconds for design and 1.0 seconds for operations and traffic control *(3, 4)*. These perception-reaction times were based on observed behavior for the 85th percentile driver; that is, 85-percent of drivers could react in that time or less. More recent research has shown these times to be conservative for design.

Wortman and Mathias reported both "surprised" and alerted 85th percentile perception-reaction times for control *(11)*. They measured the perception-reaction time in an urban environment following the illumination of the yellow signal indication until brake lights appeared. The Wortman and Mathias research found:

- Alerted 85-percent perception-reaction time - 0.9 seconds, and
- "Surprise" 85-percent perception-reaction time - 1.3 seconds.

This research shows that the perception-reaction time of 1.0 second for control is reasonable. However, where a signal head is around a curve or hidden by trees, the perception-reaction time should be greater, probably 1.5 seconds.

Recent studies have evaluated the validity of 2.5 seconds as the design perception-reaction time. As summarized in Table 5, four recent studies have shown maximum values of 1.9 seconds as the perception-reaction time for an 85th percentile time and about 2.5 seconds as the 95th percentile time. This suggests that 2.5 seconds is longer than required, but the longer time may be appropriate for older drivers faced with complex traffic conditions *(12)*.

Table 5. Brake Reaction Times Studies

Source	85th	95th
Gazis, et al. *(13)*	1.48 sec.	1.75 sec.
Wortman, et al. *(11)*	1.80 sec.	2.35 sec.
Chang, et al. *(14)*	1.90 sec.	2.50 sec.
Sivak, et al. *(15)*	1.78 sec.	2.40 sec.

Some researchers have suggested that the perception-reaction should reflect the complexity of traffic conditions, expectancy of drivers, and the driver's state. They suggest that the perception-reaction times may be altered accordingly, as shown in Table 6 *(14)*.

Table 6. Perception-Reaction Times Considering Complexity and Driver State

Classification	Driver's State	Complexity	Perception-Reaction Time
Low Volume Road	Alert	Low	1.5 sec.
Two-Lane Primary Rural Road	Fatigued	Moderate	3.0 sec.
Urban Arterial	Alert	High	2.5 sec.
Rural Freeway	Fatigued	Low	2.5 sec.
Urban Freeway	Fatigued	High	3.0 sec.

Source: Change, Messer, and Santiago (14)

Studies have shown that there is no significant difference in reaction times between younger and older drivers *(16, 17)*. It has been suggested that this is due to the tradeoffs between driver age and driving experience *(8)*. Although the perception-reaction times for elderly drivers are not significantly longer than for the average younger driver, a design perception time for elderly drivers of 3.0 seconds has been recommended by AASHTO *(10)*. This provides more time for the elderly driver to understand conditions and decide how to respond.

This information provides a base understanding of vision and reaction time for the more complex, higher workload conditions for access management decisions.

Cognitive and Psychological Functions

Driving is a complex dynamic task that is heavily dependent on the context where it occurs, i.e., driver's familiarity, traffic conditions and weather *(18)*. The major components have been isolated to understand the mental/ psychological tasks of safe driving.

Attention. Attention to the driving task is extremely important to safe driving. It has been estimated that 25-percent to 50-percent of crashes are the result of inattention *(19)*. Recent studies, for example, have shown that texting is four times as likely to lead to a crash.

Selective attention is the selection of the most critical information out of the mass of information presented. Selection and appropriate use of the critical information is the most basic aspect of driving. As people age, they have more difficulty selecting and processing the critical information.

Divided attention is concerned with taking information from more than one source at once, and performing more than one task at once. This ability to multitask is important in driving where the driver must steer, brake, select a safe path, avoid other vehicles, process traffic control information, and navigate all at the same time. The efficiency of performance of these divided attention operations are a function of familiarity, the number and variety of the activities, and the working memory capacity. Arterials with their high volumes, high speeds and numerous conflicts present the driver with their greatest challenge for divided attention.

Working Memory Capacity. Working memory capacity relates to the mental cognitive ability to process new information while storing and analyzing known information. The working memory capacity is the amount of information that a driver can receive and process at a time. A rule of thumb has estimated an average workload of seven items as the typical working memory capacity *(20)*. The addition of two more items borders on sensory overload. It is felt that the working memory capacity for the elderly is less. High volume, high speed arterials with multiple access points, numerous conflicts, median openings, pedestrians and traffic controls can readily exceed seven critical items.

The response of drivers to significant increases in traffic congestion and speed is to pay less attention to the periphery or less important targets, that is perceptual narrowing or "tunnel vision" *(21)*. Thus, as the work load increases due to traffic volume and speed increases, the visual field size that the driver takes into account is reduced. Pedestrians and bicyclists are targets that likely would receive less attention from drivers on higher volumes, higher speed arterial since they are farther removed from the roadway.

Decision Making. The reasoning required for decision making incorporates the application of rules and personal values to select from the various alternatives presented. The decision speed, and response selected to a particular situation is likely to be quite different for a young driver versus an elderly driver. Sufficient time to make the appropriate decision is critical to the safety of any situation. Midblock locations are likely to have widely varying driveway designs, driveway frequencies, median opening designs and roadway cross sections that collectively would tax the driver's decision making skills.

Navigation or Wayfinding. The navigation or wayfinding is the ability of a person to analyze location specific information and navigate successfully to his or her desired destination. Although the navigation subtask of driving is low in priority for safe operation, it can become problematic as drivers try to read maps, remember their route, or read street name signs while in traffic. Speed differentials and non-uniform traffic operations may result as drivers search for the appropriate access point.

Analysis of Speed and Gap Acceptance Behavior. Drivers and pedestrians have difficulty estimating the speed of approaching vehicles and deciding on a safe gap in traffic in which to cross or turn left. Virtually all ages of drivers and pedestrians have difficulty estimating the speed of oncoming vehicles accurately. Further, because of their reduced ability to detect angular movement, older drivers have a diminished ability to judge safe gaps in the traffic stream to cross or turn left. Older drivers accept gaps based on the distance length of the gap, not time length.

Analysis of crash data for access locations has shown that about 70-percent of midblock and intersection crashes are left-turn related. Access management decisions involving left turning traffic must accommodate these turning constraints.

Table 7 provides a summary of the definitions and potential problems of cognitive and psychological functions.

Table 7. Summary of Cognitive and Psychological Functions

Cognitive & Psychological Functions	Definition	Potential Problem
Attention	Focusing on and selection of most critical information	Divided attention to other less important information & tasks
Working Memory Capacity	Memory capacity to process new information while storing and analyzing known information	Conflicts and conditions exceed effective workload capacity, reaching sensory overload
Decision-Making	Reasoning required to apply rules & values to select from alternatives	Sufficient time to make the appropriate decision required, increases with conflicts and complexity
Navigation or Wayfinding	Ability to analyze information to get to desired destinations	Map-reading and street name sign identification in traffic can cause erratic operations
Speed and Gap Analysis	Drivers must estimate speeds and gaps between other vehicles to operate safely	Drivers have difficulty estimating speeds and gaps for on-coming vehicles

Driver Expectations or Expectancy. Human factors have been used in highway design and control, but have primarily focused on the required perception-reaction time, driver comfort in decelerating, and recognition of complexity of conditions. More recently, driver expectations have been addressed to determine locations or conditions that create unsafe operations by violating a driver's habits, experience, or training. Descriptive examples and anecdotal information on expectancy have been provided, but no specific rules to treat expectancy issues have been set forth.

Driver expectations, or expectancy, arise from the cognitive analysis of the roadway features layout and environmental information presented as the driver approaches a roadway location. Drivers are led to expect a particular operation condition based on the information presented to them. They use both formal and informal information.

- Formal information – this includes the traffic-control devices and primary geometric design features of the roadway, but does not include the roadside features, such as ditch lines, guardrail, and other street furniture.
- Informal information – this includes roadside features and land use features, such as brush lines, tree lines, fences and information signing.

Drivers develop expectations on how to drive a roadway through experience, training and habit. At times these expectations are in error because they use inappropriate informal information, or the formal information provided is not proper or gives confusing mixed messages. Often, the information at a location is conflicting, and drivers who are familiar with the location will read traffic conditions differently than unfamiliar drivers. Traffic conditions vary dramatically on major facilities; consequently, the information that drivers receive from other vehicles and conflicts is constantly changing.

Adequate perception-reaction time is needed to allow time for drivers to make the proper decision when information conflicts and driver expectancy may be in error. Further, high volume and high speed conditions with the added complexity and heavier driver workloads require longer decision times and compound any problems arising from driver expectancy.

The conditions prevalent at many access management locations make them prime candidates for expectancy problems. Regulatory and warning signs are mixed in with commercial signs and information. Signs at access driveways to businesses are not uniform in size, color, shape or location. Driveway designs differ dramatically within a block.

Table 8 provides a summary of the issues and potential problems for driver expectancy.

Table 8. Summary of Expectancy Issues

Issues	Concern	Potential Problem
Information Type	Formal Information • Design alignment, regulatory and control signs, etc. Informal Information • Information signing, roadside features, etc.	Drivers are confused by conflicting formal and informal information
Uniformity	Use design, control and regulatory information in uniform fashion	Drivers anticipate uniform standards for design, control and regulation
Consistency	Use similar design and control features within an area	Design and controls that differ may cause confusion, e.g., ramps on both left and right

Measures That Should Be Based on Human Factors

There are many access management situations where human factor impacts, as previously discussed, should be incorporated more completely into design and control options. These may include sight distance, preview distance, object height, signing and marking, interchanges, lighting, medians, and driver expectancy. Each of these issues is discussed in the following sections.

Sight Distance for Access Management

The sight distance measure used to guide access management decisions or design should be tailored to the access conditions to be treated. Sight distance is based on:

- Perception-reaction time,
- Speed,
- Comfortable deceleration rates,
- Driver characteristics,
- Target object height,
- Pavement surface texture, and
- Conflicts present.

Perception-Reaction Time. Perception-reaction times must be longer where volumes are high, conflicts are numerous, and the visual field is enlarged to accommodate the geometrics and activities on both sides of the roadway. The ability to perceive conditions for access decisions are significantly affected by a myriad of conditions, including:

- Number of conflicts,
- Complexity of the environment,
- Large visual field,
- Complexity of the design and control,
- Lack of uniformity in driveway design,
- Driver expectations and experience,
- Driver's state of alertness, and
- Presence of elderly drivers.

The importance of complexity of conditions and the driver's state of alertness on driver's perception-reaction time for simple conditions is clearly shown by a reformatting of Table 6 and depicting the information as shown in Table 9.

Table 9. Perception-Reaction Times vs. Complexity and Alertness

Alertness	**Complexity**		
	Low	Moderate	High
Alert	1.5 sec.	- - -	2.5 sec.
Fatigued	2.5 sec.	3.0 sec.	3.0 sec.

Source: Adapted from Sivak et al., 1982 (15)

As is easily seen, both increased complexity and increased fatigue increase perception-reaction time.

Research by Lerner et al. evaluated perception-reaction times as a basis for decision sight distance *(22)*. As shown in Table 6, high functioning arterial locations apparently have longer perception-reaction times than the 2.5 seconds currently used for design. Table 10 demonstrates the 85th percentile values range from 4.2 to 7.1 seconds from day to night for various age groups.

Table 10. Median and 85th Percentile Perception-Response Time by Age and Day / Night Conditions for Arterials

Age Groups	Perception-Response Time (seconds)			
	50th Percentile		85th Percentile	
	Day	Night	Day	Night
20 - 40	2.0 sec.	2.8 sec.	4.2 sec.	5.2 sec.
65 - 69	2.8 sec.	2.4 sec.	7.6 sec.	4.9 sec.
70+	3.4 sec.	2.8 sec.	7.1 sec.	5.6 sec.

As shown earlier, drivers have difficulty seeing and understanding situations with numerous conflicts and complexity. Further, the larger visual field requires extensive scanning and selection of appropriate targets. Complex designs, such as skewed driveways, directional median openings, separate turn lanes and two-way left-turn lanes, add to the level of conflict and confusion. All of this requires more time for drivers to perceive and react to conditions appropriately.

Stopping Sight Distance. The stopping sight distance used for most design is based on a 2.5 second perception-reaction distance plus the braking distance to a stop at an assumed comfortable deceleration rate of 11.2 ft/sec^2 (3.4 m/sec^2) *(4)*. From that distance, a driver must be able to see a 2 ft (0.6 m) object from a 3.5 ft (1.07 m) eye height and stop safely. Stopping sight distance is measured to one clearly discernible hazard in the middle of the roadway. As shown in Figure 1, the application of stopping sight distance is depicted as the distance required for the vehicle at location "A" to completely stop without impacting the hazard in the road, in this case a dog. This type of sight distance clearly ignores other potential conflicts such as bicycles, pedestrians, and driveways that may occur along the roadside at the same time. Consequently, stopping sight distance has limited applications for access management since stopping sight distance's primary application is on one object of focus.

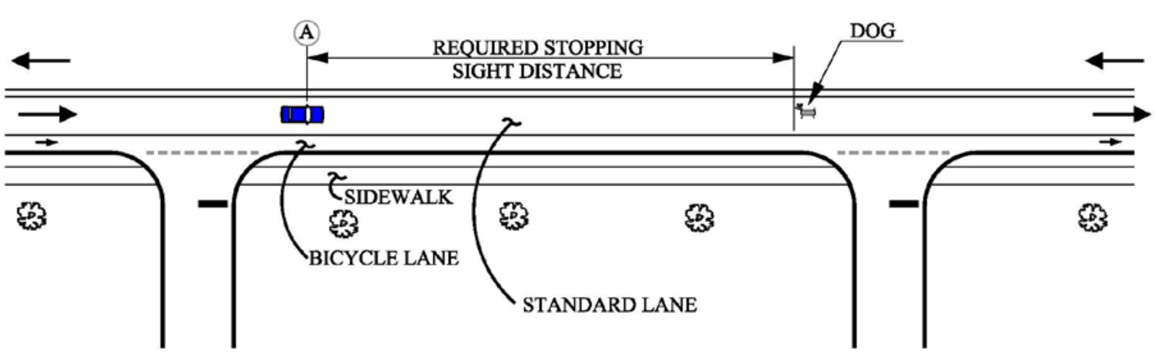

Figure 1. Required Stopping Sight Distance Application

Figure 2 depicts the numerous potential conflicts that a driver must perceive and react to in the vicinity of a driveway. As shown in Figure 2, conflicts often associated with urban driveway locations for which a driver must perceive and appropriately respond to may include the following:

- Driveway location and geometric configuration,
- Potential conflicts between bicycles and turning motor vehicles,
- Potential conflicts generated by pedestrians crossing the road at a mid-block location in the vicinity of driveways or transit stops,
- Potential conflicts between pedestrians crossing the driveway and motor vehicles entering and exiting the driveway,
- Vehicles departing the driveway (see the vehicle at location "D" in Figure 2),
- Vehicles turning right into the driveway (see vehicle at location "B" in Figure 2), and
- Opposing direction vehicles turning left into the driveway (see vehicle at location "C" in Figure 2).

For each of these features, there may be a variety of sight distance considerations. Though stopping sight distance may be one component of assessing driveway operations, the list of potential conflicts associated with a driveway as depicted in Figure 2 may also be addressed by avoidance maneuvers or simple speed adjustments. For these reasons, decision sight distance may be an appropriate metric to consider for operational analysis, though the current pre-maneuver time assumptions should be re-visited for access management applications. (The next section includes a discussion about decision sight distance.)

Stopping sight distance may be appropriate to determine driveway location and spacing. The visual block created by vehicle and pedestrian conflicts at upstream driveways suggests that driveways on high volume arterials should be spaced at stopping sight distance *(23)*. The object of concern for safety here is one clearly discernible object.

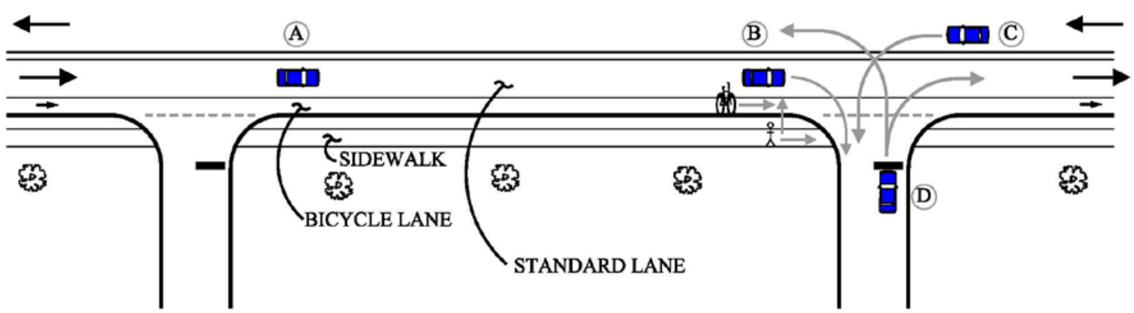

Figure 2. Potential Driveway Conflicts That Require Adequate Sight Distance

Decision Sight Distance. As previously discussed and demonstrated in Figure 2, there are several limitations of existing stopping sight distance standards for use in access management decisions. They can also include the longer perception-reaction times required and varying object heights. Decision sight distance with the longer perception-reaction times would be more appropriate for most access management decisions and designs. Current decision sight distance measures are broken down into decision sight distance to a stop in urban and rural areas, and decision sight distance for a speed path or direction change in urban, suburban or rural areas. These distances are acceptable until more definitive research identifies the level of conflict and driver workload for various facility classes, volume levels and entering driveway volumes. Decision sight distance to a stop would typically be applicable to two-lane two-way facilities or roads with one lane on either side of a two-way left turn lane. Decision sight distance for a speed, path or direction change would typically be applicable to a multilane facility. It would be desirable to add decision sight distances to a stop in suburban areas. Table 11 also includes a suggested suburban decision sight distance to stop recommendation (not currently included in the AASHTO *Greenbook (4)*).

Table 11. Decision Sight Distance

US Customary Units

Design Speed (mph)	Decision Sight Distance for Maneuver (ft) [Pre-Maneuver Time (seconds)]					
	Pre-Maneuver: Stop			Pre-Maneuver: Avoidance		
	Rural [3.0 sec.]	Suburban [6.0 sec.]	Urban [9.1 sec.]	Rural [10.2 to 11.2 sec.]	Suburban [12.1 to 12.9 sec.]	Urban [14.0 to 14.5 sec.]
25	180	280	400	375	400	525
30	220	350	490	450	535	620
35	275	425	590	525	625	720
40	330	505	690	600	715	825
45	395	590	800	675	800	930
50	465	680	910	750	890	1030
55	535	775	1030	865	980	1135
60	610	875	1150	990	1125	1280
65	695	980	1275	1050	1220	1365
70	780	1090	1410	1105	1275	1445
75	875	1200	1545	1180	1365	1545
80	970	1320	1685	1260	1455	1650

Metric Units

Design Speed (km/h)	Decision Sight Distance for Maneuver (meters) [Pre-Maneuver Time (seconds)]					
	Pre-Maneuver: Stop			Pre-Maneuver: Avoidance		
	Rural [3.0 sec.]	Suburban [6.0 sec.]	Urban [9.1 sec.]	Rural [10.2 to 11.2 sec.]	Suburban [12.1 to 12.9 sec.]	Urban [14.0 to 14.5 sec.]
50	70	115	155	145	170	195
60	95	145	195	170	205	235
70	115	175	235	200	235	275
80	140	210	280	230	270	315
90	170	245	325	270	315	360
100	200	285	370	315	355	400
110	235	325	420	330	380	430
120	265	365	470	360	415	470
130	305	415	525	390	450	510

Source: Adapted from AASHTO Policy on Geometric Design of Streets and Highways, 2004 (4)

Preview Sight Distance

The preview sight distance of 5 to 7 seconds may be employed where minor changes in geometrics or access are introduced, such as the introduction of a median, an exclusive right turn lane or a directional median opening, as long as the necessary signing and markings are present. The 5 second preview time should be applied to lower speed, minor arterials and a 7 second preview for higher speed, higher volume arterials.

Object Height

It is not reasonable to use one arbitrary object height for all access management decisions and designs. The object height that must be seen for access management is dependent on what feature or activity is being evaluated. The AASHTO object height of 2 ft (0.6 m) is specified, although many jurisdictions (including the Washington, Oregon, and California Departments of Transportation) still retain the 0.5 ft (150 mm) assumed object height. Curb cuts may also use 0.5 ft (150 mm) where a vertical curb exists. Driveway and turn lane geometrics would be better served with a 0.0 ft object height, or pavement level sight distance. This 0.0 ft object height is consistent with design guidelines for bicycle facilities (*24*). Where vehicles are queued for entering at a driveway or turn lane, a 2 ft (0.6 m) object height can be employed, representing headlight or tail light height.

Signing and Marking

The concepts of "positive guidance" should be implemented on arterials where access must be provided. The numerous conflicts, high speed operations, and visual clutter often presented by roadside activities result in a large workload for drivers. Positive guidance assures information is presented uniformly, consistently, unambiguously and with adequate conspicuity for safe operations by drivers.

It is clear from the discussion of driver's vision, perception-reaction, and cognitive abilities that clear indications of access management sites should be provided. Geometric features and traffic control locations for access management, such as driveways, pedestrian areas, and median openings should be clearly signed and marked.

Interchanges

Interchanges are typically the ultimate location for traffic volumes and conflicts, a mixture of local and through traffic, varying vehicle sizes, driver expectancy, and mixed land use. Many drivers are unfamiliar with the location and are in transition from high speed controlled access driving to lower speed operations at locations with significant access. Consequently, for the present decision sight distance should be applied in these locations, and typically the suburban or urban category should be used since volume levels are often higher than local rural conditions, even though the interchange may be located in a rural area. The uniqueness of the land use activities, access problems, and operations around interchanges make this a fertile area for research.

Lighting

Artificial illumination may be required at certain access locations. Where volume levels are high, speeds or speed differentials are high, and conflicts are numerous, the ability to see and react to conditions is critical. Interchanges and high volume major intersections are such locations.

Research has shown that illuminated intersections have fewer collisions and, in fact, safety increases with the increased intensity of lighting.

Medians

Medians have proven their worth as a major valuable access management strategy for improved operations and safety. However, they should still be recognized for their dramatic impacts on limiting negative human factors effects.

Medians reduce conflicts by approximately 50-percent and eliminate severe conflicts, i.e., left turning movements. Two-way left turn lanes reduce the severity of the left turning conflicts, but do not eliminate them. Medians also reduce the visual field by half by eliminating all of the oncoming roadway area. The added curb on the left introduces a hazard that must be well designed and well marked.

The presence of a median allows the driveway spacing to be reduced by half by eliminating the visual blocks from left turning vehicles and the resulting conflicts *(25)*.

Driver Expectancy

Driver expectancy impacts are complex and multifaceted. Consequently, it is difficult to identify a set of rules and recommendations to address resulting problems. There are a number of correctable situations, however, that arise from driver expectancy for access management locations.

Traffic lanes at intersection or driveway approaches should be matched with lanes exiting the intersection. Further, offset of lanes more than 50-percent create confusion and should be marked with supplemental pavement marking (often referred to as mini-skips or chicken tracks). In addition, the curb alignment should, to the degree possible, match the path that the driver must drive. Drivers often use the curb as an indicator for their projected vehicle path.

Driveways can be designed along an arterial to help drivers identify driveway locations and expected operations. The entrance to driveways should always be encountered followed by the exit unless separated by significant distances. When auxiliary lanes, such as right-turn lanes, are provided their alignment should be oriented so as to reduce driver confusion. Figure 3 depicts two common driver expectancy errors that often occur in urban regions. First, in Example “A”, a bicycle lane is dropped without warning or reason at an intersection, leaving the bicyclists to fend for themselves. In Example “B”, a right turn at a driveway can trap drivers unless the design communicates to the driver that this is a local site specific design. The right-turn lane bay taper should be short and the lane length equal to the stopping distance.

Driver expectancy issues may also result from unexpected design configurations. For example, the location depicted in Figure 4 shows a location where the horizontal curve does not meet the tangent smoothly, resulting in a kink. As a consequence, the curb intrudes into the roadway in the near view when drivers are focused on the tangent in the far view. Tire marks can already be observed on this curb. This type of driver expectancy problem at access points can be identified and corrected based on physical evidence similar to the tire marks.

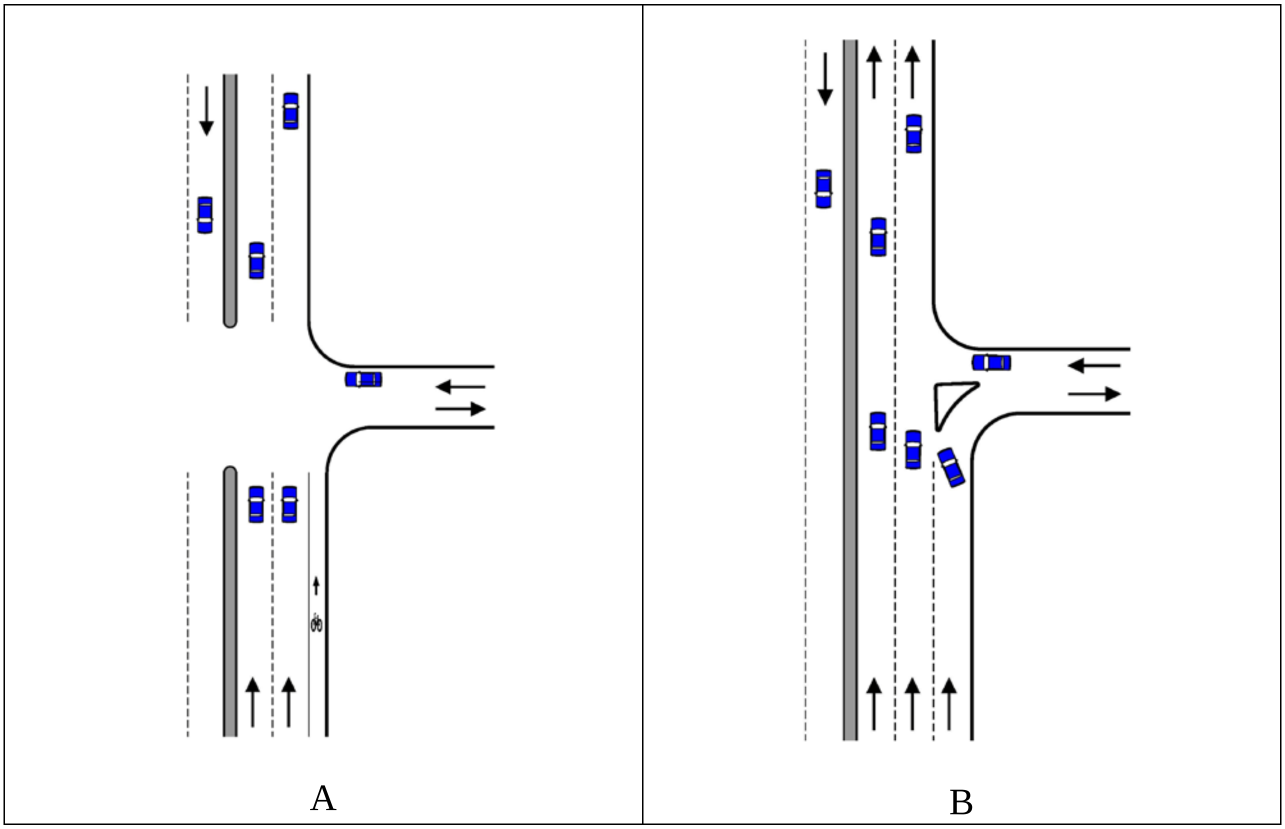

Figure 3. Example of (A) Non-Continuous Bicycle Lane at Intersection and (B) Confusing Right-Turn Lane at Driveway

Figure 4. Geometric Kink Creates Driver Confusion

Recommended Practices Considering Human Factors

A variety of access management applications can currently incorporate human factor issues into the design process. Some recommended practices based on in-depth consideration of human factors include median treatments, median openings, auxiliary lane designs, driveway island treatments, pedestrian mid-block crossing treatments, and maximum size street identification signs. These recommended practices are discussed in more detail in this section.

Median Use

Use medians or median barriers, per local established policy, on all major arterials. Where medians are placed, the conflicts from left-turns are eliminated dramatically reducing the work load of drivers. As shown earlier, 70-percent of intersection or driveway crashes are related to left-turns. Medians also reduce the visual field by 50-percent and may also reduce headlight glare. Medians provide area to accommodate left-turn lanes which also assist in controlling left-turn conflicts.

Where major street volumes are not sufficient to warrant medians for the entire length of a block, i.e. less than 24,000 vehicles per day according to the *Access Management Manual* (*1*), medians can still be used for the functional intersection lengths at the ends of the block. This median application controls the most problematic human factor effects of visual acuity, high work load, judgment of gaps for left-turns from driveways near the intersection, and left-turn conflicts. Drivers are forced to make right-in right-out movements to a driveway. Left-turns and U-turns are relocated to the intersection where they are protected and can be handled with a traffic signal.

Design and Locate Directional Median Openings to Enhance Traffic Operations

Median openings accommodate otherwise restricted cross traffic movements at locations where traffic volumes dictate the need for a median break due to local operational demands. Eighteen major conflicts occur through a full median opening, while only four major conflicts occur where there is a directional median opening to both sides of the roadway. Vehicles are removed from the traffic stream with fewer conflicts, and drivers have time to decide where it is safe to cross. Workload is subsequently reduced and drivers, particularly elderly drivers, are not pressured to turn through gaps that are too short.

Use Median Opening Design and Control that is Based on Human Factor Needs

Use a standard design that leads drivers to proper use of the opening (*26*). A standard design presents the same look and operation at all median openings (see Figure 5). It is also important to locate a DO NOT ENTER sign at the exit from the median opening. Markings and signs are required to communicate fully the appropriate operations. Directional median openings should be marked with lane arrows. Confusion on the part of the driver in a left-turning vehicle is eliminated resulting in higher exiting speeds into the median opening and smoother operations.

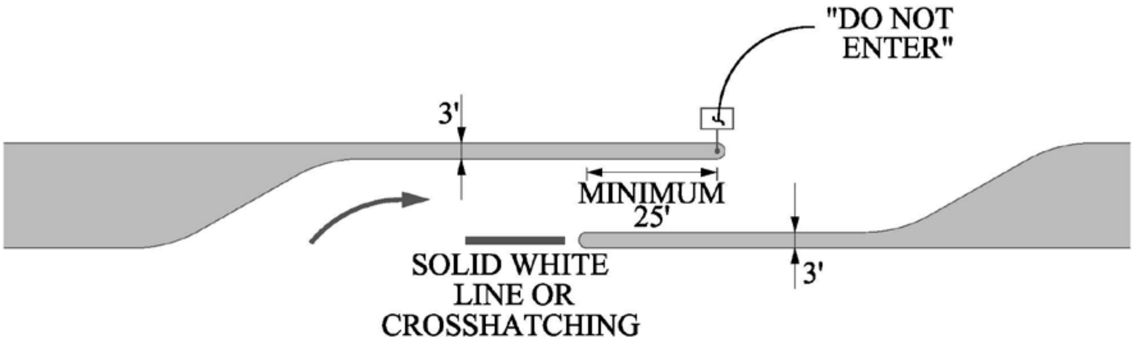

Figure 5. Example Standard Design for Median Opening

Use Auxiliary Lanes on All Major Arterials Regardless of Current Demand

Use of left-turn lanes on all major arterials leads drivers to expect that a left-turn lane will always be provided. The heavy workload and conspicuity problems at intersections support the use of these common auxiliary lanes. They remove turning traffic from through lanes and give time for drivers to select safe gaps in traffic or control their turn movements by a traffic signal phase. Removal of slower turning vehicles and the turning conflicts helps to maintain operating speeds and enhance the opportunity for coordination between signalized intersections. The more uniform speeds and fewer conflicts improve the level of operations and increase safety.

Right-turn lanes should be used where demand volumes are substantial enough to justify them. The presence of a right-turn lane reduces the impacts of the losses in static and dynamic visual acuity and glare sensitivity. Separating all the traffic movements in their own lanes also reduces conflicts, workload, and conflicting expectations. Lane lines and arrows should always be provided for turn lanes.

Use Right-turn Lanes at Driveways Where Major Street and Driveway Demands are High

When right-turning vehicles exit from the right lane of an arterial into a driveway, a potential high speed differential may result. The use of a right-turn lane into the driveway can reduce the relative speeds between vehicles exiting the driveway and on-coming vehicles. A right-turn lane can also improve visibility for the drivers of vehicles located at the driveway waiting to enter the roadway. The right-turn lane can also help to eliminate confusion for the driver of the vehicle exiting the driveway by clearly demonstrating the intention of the approaching vehicle to turn at the driveway. Further, this configuration removes the approaching vehicle as a potential visual block for other on-coming through vehicles.

Use "Pork Chop" Designs at Driveways to Help Define the Driveway Operations

"Pork chop" designs are sometimes violated by drivers who choose to ignore the directional indication of the island (*27*). These islands, however, do help clearly define how the driveway is supposed to operate. They reduce the number of potential conflicts, improve the conspicuity of the driveway and associate markings, enhance curb visibility, and define expected paths for vehicles. The operation is simplified and confusion of drivers is reduced. The improved operations and safety outweigh the limited violations by some drivers.

Control or Eliminate Pedestrian Crossings at Major Intersections in Favor of Mid-Block Crossings

Use well-marked and well-signed mid-block crossings in preference to pedestrian crossings at major signalized intersections. The volumes of various movements, complex phasing and long walking times produces a confusing and hazardous location for crossing pedestrians. Further, this configuration destroys the efficiency of the signal timing at the intersection, creating longer cycle times. Crossing the pedestrians at mid-block locations has been proven to be safe and effective when executed properly. A traffic signal that is coordinated with signalized intersections on either side of the crossing can provide effective progression. The sight distance is improved, conflicts are fewer, conflicts are better controlled, and expectancy for pedestrians and drivers is clear.

Use Maximum Size Street Identification Signs in Accordance with the Manual on Uniform Traffic Control Devices (3)

Maximum size street identification signs and mid-block signs identifying upcoming streets would assist with navigation or wayfinding. The numerous conflicts, high speeds, high volumes, and visual clutter along arterials make it difficult for drivers to find their street. The resulting confusion, particularly for older drivers, creates a hazardous situation. The larger street signs and the supplemental "next street" signs help drivers identify and select their destination street with minimal confusion.

Use Lighting at High Volume Intersections, Interchanges, and Major Pedestrian Sites

Complex high volume sites as well as sites with heavy pedestrian activity should be illuminated. The poorer nighttime vision, the difference in the way people see at night, and the longer perception-reaction times at night all point to the visibility hazard introduced at night, and reinforce the need for illumination at critical spots. Improved lighting and power technology has resulted in more affordable nighttime lighting at key locations.

Interchanges and high volume major intersections warrant illumination. Locations with significant nighttime pedestrian activity also justify lighting. This illumination may be implemented in isolated spots rather than continuously along the length of the arterial.

Use Uniform Driveway Design, Signs, and Markings

Driveways should be consistently designed and delineated along arterials to help drivers identify these access locations. Driveways could be marked with reflectorization at curb returns and driveway edges, or with a device specifically designated for that location, such as a two foot high delineator with three white reflectors. (Property owners often mark their own driveways with reflectors in an effort to enhance visibility.) Pavement arrows should be used to designate lane assignment on multilane driveways to eliminate confusion and erratic operations.

At Interchange Areas, Use Decision Sight Distance

The complexity of conditions, uniqueness of land use types, variety of traffic and vehicles, and presence of conflicts justify the use of decision sight distance in interchange areas until more specific measures and guidelines are developed. The vehicles exiting the freeway have been operating at high speeds with full control of access, and must quickly adapt to lower speed, numerous conflicts, and often access points to varied land use activities. A change in driver expectations and smooth transition into the surface street environment must be undertaking with care. Decision sight distance provides a greater distance than alternatives and permits extra pre-maneuver time to see and adapt to these lower-speed and high-activity conditions.

Research Recommendations

The inclusion of human factor effects in access management decision making requires new research into the behavior, understanding, and measures of these effects. Some of the interactions and synergism are so complex that they cannot be predefined, and will only be understood after focused research is undertaken. Consequently, there are a number of areas in which access management would benefit from research. These include:

- Perception-reaction time for difference access management conditions and objects;
- Determination of workload measures for various conflicting conditions; and
- Determination of the impact of various street and driveway demand volumes on driveway location, spacing, and design.

Each of these general research areas is reviewed in the following sections.

Perception-reaction times

A number of perception-reaction time applications should be evaluated and established. These include the major road driver's perception-reaction time to:

- A vehicle waiting to enter at a driveway;
- Specific driveway configurations including full radius return curb driveways, drop curb driveways, and dust pan driveways;
- A vehicle waiting in the left-turn queue;
- A vehicle waiting in the right-turn queue;
- A pedestrian waiting to cross the roadway; and
- A bicyclist in a bicycle lane on the major roadway.

Workload Impacts

The impact of workload on perception-reactions times should be investigated. The workload measures would include traffic volumes, types of vehicles present, lane and median configuration, number of conflict points, and types of conflicts for a variety of these scenarios. The perception-reactions times should be studied to see the aggregate effect of workload.

Impact of Roadway and Driveway Volume on Driveway Spacing

The driveway spacing criteria that are presently given in the *Access Management Manual* (*1*) are based on measures of individual vehicle operations. Clearly, higher demand volume at a major driveway creates more conflicts, confusion and disruption to local conditions than for a lower volume driveway. The impact of driveway demand volume on driveway spacing should be investigated.

Locations with high major street volumes, such as those in the proximity of interchanges, also warrant additional investigation. The refinement of access management measures, access locations, and driveway spacing thresholds can help to guide new development around freeway interchanges. The placement or improvement of interchanges in already developed areas requires critical access management analysis. Many times the optimal or desired driveway spacing and access locations cannot be provided (often due to pre-existing development), and interchange access management research could help to determine acceptable access thresholds and their operational implications in these regions.

Conclusions

The situations where access management strategies and designs must be applied are often complex with numerous conflicts and often include contrary and competing issues. As shown in this paper, there are various multiple human factors that impact decisions at these locations.

Driver vision and performance are affected by the increased number of conflicts, larger required visual field, and more varied roadway elements present with access management. The large driver workload can tax the driver's cognitive ability and cause less time and effort to be exerted on secondary targets.

The sight distance required must take into account more conflicts and conditions than the design for horizontal and vertical alignments, so more perception-reaction time must be provided. This means that decision sight distance should be a key requirement for access management decisions and designs. Driver eye heights and object heights should be determined based on the most critical type of vehicle and the most critical target, such as vehicle tail lights, curb height or pavement markings, rather than generalized standards.

Uniformity and consistency in design and control devices must be provided because of the work load and problems with driver expectancy on arterials where access management strategies must be employed.

REFERENCES

1. Transportation Research Board (TRB). *Access Management Manual.* Transportation Research Board of the National Academies, Washington, D.C., 2003.
2. American Association of State Highway and Transportation Officials (AASHTO). *Policy on Geometric Design of Streets and Highways.* Washington, DC, 1984.
3. Federal Highway Administration (FHWA). *Manual on Uniform Traffic Control Devices for Streets and Highways.* United States Department of Transportation, Washington, DC, 2003.
4. AASHTO. *Policy on Geometric Design of Streets and Highways.* Washington, DC, 2004.
5. Alfonso, J., B. Brandelon, B. Huerre, and J.M.G. Sa Da Costa. Analysis of Driver's Visual Behavior. Technical Paper 931931. *Society of Automotive Engineers.* Warrendale, PA, 1993.
6. Owsley, C., K. Ball, M. Sloane, D. L. Roenker, and J. R. Bruni. Visual Perceptual/ Cognitive Correlates of Vehicle Accidents in Older Drivers. *Psychology and Aging.* Vol. 6, 1991, pp. 403-415.
7. Older Drivers: A Literature Review (No. 35), Department of Transport, London, UK. 2001.
8. Burg, A. *An Investigation fo Some Relationships Between Dynamic Visual Acuity and Static Visual Acuity and Driving.* Report 64-18. University of California, Los Angeles for the Los Angeles Engineering Department, CA, 1964.

9. Horswill, M.S., S. A. Marrington, C. M. McCulloughy, J. Wood, N. A. Pachana, J. McWilliam, and M. K. Raikos. The Hazard Perception of Older Drivers. *The Journal of Gerontology Series B: Psychological Sciences and Social Sciences.* Vol 63, No. 4, 2008, p. 212-218.
10. Staplin, L., K. Ball, D. Park, L. E. Decina, K. H. Lococo, K. W. Gish, and B. Kotwal. *Synthesis of Human Factors Research on Older Drivers and Highway Safety . Vol. I: Older Driver Research Synthesis*. Publication FHWA-RD-97-094. FHWA, U.S. Department of Transportation, 1997.
11. Wortman, R. H., and J. S. Matthias. Evaluation of Driver Behavior at Signalized Intersections. In *Transportation Research Record,* No. 904, Transportation Research Board of the National Academies, Washington, D.C., 1983, pp. 10-20.
12. Staplin, L., K. Lococo, and S. Byington. *Older Driver Design Handbook.* Publication FHWA-RD-97-135. FHWA, U.S. Department of Transportation, 1998.
13. Gazis, D. R., R. Herman, and A. Maradudin. The Problem of the Amber Signal in Traffic Flow. *Operations Research,* Vol. 8, No. 1. January-February, 1960, pp. 112-132.
14. Chang, M.- S., C. J. Messer, and A. J. Santiago. Timing Traffic Signal Change Intervals Based on Driver Behavior. In *Transportation Research Record,* No. 1027, Transportation Research Board of the National Academies, Washington, D.C., 1985, pp. 20-30.
15. Sivak, M., P. L. Olson, and K. M. Farmer. Radar-Measured Reaction Times of Unalerted Drivers to Brake Signals. In *Perceptual Motor Skills,* No. 55, 1982, p. 594.
16. Olsen, P. L., and M. Sivak. Perception-Response Time to Unexpected Roadway Hazards. In *Human Factors Journal,* Vol. 28, No. 1, 1986, pp. 91-96.
17. Underwood, G., N. Phelps, C. Wright, E. Van Loon, and A. Galpin. Eye Fixation Scanpaths of Younger and Older Drivers in a Hazard Perception Task. In *Ophthalmic and Physiological Optics Journal,* Vol. 25, No. 4, 2005, pp. 346-356.
18. Knoblauch, R., M. Nitzburg, R. Dewar, J. Templer, and M. Pietrucha. Older *Pedestrian Characteristics for Use in Highway Design*. Publication FHWA-RD-93-177. FHWA, U. S. Department of Transportation, 1995.
19. Shinar, D. *Driver performance and individual differences in attention and information processing, Vol. 1: Driver Attention.* Publication DOT-HS-8-01819-78-DAP, U. S. Department of Transportation, 1978.
20. "Human Factors for Safety Workshop," FHWA, Washington, DC.
21. Dewar, R. E., and P. L. Olson. *Human Factors in Traffic Safety. Second Edition.* Lawyers & Judges Publishing Company, Inc., Tucson, Arizona, 2007.
22. Lerner, N. D., R. W. Huey, H. W. McGee, and A. Sullivan. *Older Driver Perception-Reaction Time for Intersection Sight Distance and Object Detection, Final Report.* Publication FHWA-RD-03-168, 1995.
23. Layton, R. Discussion Paper 5A, Access Spacing Standards. *Access Management Project for Oregon Department of Transportation.* Oregon State University, Corvallis, Oregon, 1998.
24. AASHTO. *Guide for the Development of Bicycle Facilities.* Washington, DC, 1999.
25. Layton, R. Discussion Paper 5C, Stopping Sight Distance as a Criteria for Driveway Facilities. *Access Management Project for Oregon Department of Transportation.* Oregon State University, Corvallis, Oregon, 1998.
26. Florida. *Interim Median Handbook*, Florida Department of Transportation, Tallahassee, Florida, February 8, 2006.

27. Aksan, A. and R. Layton, "Right-In Right-Out Channelization". Presented at the 3rd National Conference on Access Management, Ft. Lauderdale, Florida, 1998.