Lecture T4 – Sight Distance

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Introduction

The driving task comprises navigation, guidance and control: reading maps and signs, following the road and maintaining a safe path in response to traffic conditions, steering and speed control. These tasks require the driver to receive and process inputs, consider the outcome of alternative actions, decide on the most appropriate, execute the action and observe its effects through the reception and processing of new information. The driver relies primarily on the visual sense to get information.

After a person visually detects and recognizes a given situation, a period of time elapses before muscular reaction occurs.

Introduction

Reaction time is appreciable and differs between persons. It also varies for the same individual, being increased by fatigue, drinking, and other causes. The AASHTO brake reaction time for stopping has been set at 2,5 seconds to recognize all these factors. This value has been adopted in South Africa.

Often drivers face situations much more complex than those requiring a simple response such as steering adjustment or applying the brakes.

Introduction

Recognition that complex decisions are time-consuming leads to an axiom in highway design that drivers should be confronted with only one decision at a time, with that decision being binary, e.g. “Yes” or “No” rather than complex.

Clear sight lines and adequate sight distances are provided to allow time for decision making and, wherever possible, margins are allowed for error and recovery.

The Parameters of Sight Distance

General

A critical feature of safe road geometry is adequate sight distance. As an irreducible minimum, drivers must be able to see objects in the road with sufficient time to allow them to manoeuvre around them or to stop. Other forms of sight distance are:

Passing sight distance, which is required for substantial portions of the length of two-lane roads;

Intersection sight distance, to allow a driver on the minor road to evaluate whether it is safe to cross or enter the opposing stream of traffic;

The Parameters of Sight Distance

Decision sight distance where, for example, a driver must be able to see and respond to road markings;

Headlight sight distance, typically applied to sag vertical curves, and

Centreline barrier sight distance.

It is also necessary to consider the terrain or obstructions on the inside of horizontal curves when evaluating adequate sight distance.

The Parameters of Sight Distance

Deceleration Rates

Although research in North America has shown that drivers can choose (or apply) a deceleration of greater than 5 m/sec^2, there is a large degree of variability in driver and vehicle capabilities and the 90th percentile deceleration is of the order of 3,4 m/sec^2.

The Institute of Transportation Engineers' Traffic Engineering Handbook states that decelerations of up to 3,0 m/sec^2 are reasonably comfortable for passenger car occupants. The South African National Road Agency (SANRAL) has adopted this rate of deceleration for its own design purposes.

The Parameters of Sight Distance

Object Height

The object height to be used in calculation of stopping sight distance is often a compromise between the length of the resultant sight distance and the cost of construction. Stopping is generally in response to another vehicle or large hazard in the roadway. To recognize a vehicle as a hazard at night, a line of sight to its headlights or taillights would be necessary. Larger objects would be visible sooner and provide longer stopping distances. To perceive a very small hazard, for example, a surface obstruction, a zero object height may be necessary.

The Parameters of Sight Distance

The designer should adopt an object height based on the probability of a particular object occurring on the roadway. For stopping sight distance, a conservative tail light height of 0,60 metres is recommended. If fallen trees or rocks are a real risk, an object height of 0,15 metres is recommended.

For passing sight distance, an object height of 1,30 m will allow the driver to discern the top of an oncoming car. A zero object height is recommended where road washouts are a serious risk. It is also recommended for pavement markings in situations such as at intersections or interchanges, where these provide essential guidance.

Stopping Sight Distance

The minimum sight distance on a roadway should be sufficient to enable a vehicle travelling at the design speed on a wet pavement with bald tires to stop before reaching a stationary object in its path. Stopping sight distance is the sum of two distances:

the distance traversed by the vehicle from the instant the driver sights an obstruction to the instant the brakes are applied, referred to as brake reaction distance $s_b = vt_r$ and

Stopping Sight Distance

the distance required stopping the vehicle from the instant the brakes are applied, called stopping distance.

These two components, using a reaction time of 2,5 seconds and a deceleration rate of 3,0 m/s^2, result in the relationship

$$s = v\,(0{,}694 + 0{,}013v)$$

where: s = stopping sight distance, m
v = initial speed, km/h

Stopping Sight Distance

Stopping sight distances calculated using this equation are given in Table 4-1, rounded up for design purposes.

In the measurement of stopping sight distance, the driver's eye height is taken as being at 1,05 metres and the object height is 0,6 metres. It is important however to consider the vast array of geometric design guidelines that are applicable across the African continent and around the world, and to apply the applicable values accordingly.

Stopping Sight Distance

Effect of gradient on stopping sight distance

When a highway is on a gradient, the equation for stopping sight distance becomes

$$S = vt_r + v^2/2g(f + G)$$

Where: G = percentage gradient divided by 100, with upgrades being positive and downgrades negative and the other terms as previously stated.

Stopping Sight Distance

Variation of stopping sight distance for trucks

The recommended minimum stopping sight distance model directly reflects the operation of passenger cars and trucks with antilock braking systems. Trucks with conventional braking systems require longer stopping distances from a given speed than do passenger cars.

However, the higher driver eye heights (with concomitant longer sight lines) and lower speed limits for trucks compensates for these differences.

Stopping Sight Distance

There is, however, evidence to suggest that the sight distance advantages provided by the higher driver eye level in trucks do not always compensate for their inferior braking.

To balance between the costs and benefits in designing for trucks, truck stopping sight distances should be checked at potentially hazardous locations. In general, the deceleration rate for trucks is 1,5 m/s^2. The driver's eye height is taken as being at 1,8 m and the object height is as previously described.

Passing Sight Distance

On a two -lane rural road, the passing manoeuvre is one of the most significant yet complex and important driving tasks. The process is relatively difficult to quantify, primarily because of the many stages involved, the relative speed of vehicles and the lengthy section of road needed to complete the manoeuvre.

Road safety, capacity and service levels are all affected by the passing ability of faster vehicles. This ability is influenced by a variety of factors, including traffic volumes, speed differentials, road geometry and human factors.

Passing Sight Distance

The minimum sight distance required by a vehicle to overtake safely on two -lane single carriageway roads is the distance which will enable the overtaking driver to pass a slower vehicle without causing an oncoming vehicle to slow below the design speed.

The distances usually given are those required to enable an overtaking driver to complete or abort a manoeuvre already commenced, with safety.

Passing Sight Distance

Passing manoeuvres involving trucks, particularly in South Africa, require longer distances than those indicated. Designers must take this into account for roads where significant percentages of heavy vehicles are expected in the traffic stream.

The designer should seek opportunities to introduce passing lanes on two –lane roads, particularly where the terrain limits sight distance.

Passing Sight Distance

A report on a review and evaluation of research studies concluded that passing and climbing lane installations reduce collision rates by 25 per cent compared to untreated two-lane sections.

Sections with adequate passing sight distance should be provided as frequently as possible.

As a general rule, if passing sight distance cannot be economically provided at least once every 2 km, passing lanes should be considered.

Decision Sight Distance

Stopping sight distances are usually sufficient to allow reasonably competent and alert drivers to stop under ordinary circumstances. However, these distances are often inadequate when:

Drivers must make complex decisions;

Information is difficult to perceive, or

Unexpected or unusual manoeuvres are required.

Limiting sight distances to those provided for stopping may also preclude drivers from performing evasive manoeuvres, which are often less hazardous and otherwise preferable to stopping.

Decision Sight Distance

It is evident that there are many locations such as exits from freeways, or where lane shifts or weaving manoeuvres are performed where it would be prudent to provide longer sight distances. In these circumstances, decision sight distance provides the greater length that drivers need. If the drive r can see what is unfolding far enough ahead, he or she should be able to handle almost any situation.

Decision sight distance, sometimes termed anticipatory sight distance, is the distance required for a driver to:

Decision Sight Distance

detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually cluttered;

recognize the hazard or its potential threat;

select an appropriate speed and path; and

initiate and complete the required safety manoeuvre safely and efficiently.

Because decision sight distance gives drivers additional margin for error and affords them sufficient length to manoeuvre their vehicles at the same or reduced speed rather than to just stop, it is substantially longer than stopping sight distance.

Decision Sight Distance

Drivers need decision sight distances whenever there is likelihood for error in either information reception, decision-making, or control actions. Critical locations where these kinds of errors are likely to occur, and where it is desirable to provide decision sight distance include:

Approaches to interchanges and intersections;

Changes in cross-section such as at toll plazas and lane drops;

Design speed reductions, and

Decision Sight Distance

Areas of concentrated demand where there is likely to be "visual noise", e.g where sources of information, such as roadway elements, opposing traffic, traffic control devices, advertising signs and construction zones, compete for attention.

Minimum decision sight distances that should be provided for specific situations are given in the appropriate design guidelines, an example of which is shown in Table 4-3.

In measuring decision sight distances, the 1 050 mm eye height and 0 mm object height have been adopted.

Headlight Sight Distance

Headlight sight distance is typically used in establishing the rate of change of grade for sag vertical curves. At speeds above 80 km/h, only large, light coloured objects can be perceived at the generally accepted stopping sight distances.

For night driving on highways without lighting, the length of visible roadway is that which is directly illuminated by the headlights of the vehicle. This length is typically shorter than the minimum sight distance. When headlights are operated on low beam, the reduced candlepower at the source and the downward projection angle significantly restrict the visible length of roadway surface.

Headlight Sight Distance

Also, a general limit of 120 to 150 metres sight distance is all that can be safely assumed for visibility of an unilluminated object on a bitumen surfacing. This corresponds to a satisfactory stopping sight distance for 80 to 90 km/h or a decision time of about 5 seconds at 100 km/h.

Barrier Sight Distance

Barrier sight distance is not a geometric design factor, but is rather an operational guide to the driver to promote safety on two-lane roads. Barrier sight distance is the limit below which overtaking is legally prohibited.

A logical basis for the determination of the barrier sight distance is that it should at least equal twice the stopping sight distance. Values given in the SADC Road Traffic Signs Manual approximate this approach.

Barrier Sight Distance

Barrier sight distance is be measured to an object height of 1,3 metre from an eye height of 1,05 m. . The object height is the height of an approaching passenger car. Hidden dip alignments are poor design practice, but are found on many rural roads. They typically mislead drivers into believing that there is more sight distance available than actually exists. In checking vertical alignment, designers should pay attention to areas where this deficiency exists, and ensure that drivers are made aware of any such inadequacies.

Restrictions on Sight Distance

Obstructions to sight distance on horizontal curves

Physical features, such as a concrete barrier wall, a bridge pier, a tree, foliage, the back slope of a cutting, or the outside of the travelled way can affect available sight distance. Accordingly, designs need to be checked in both the horizontal and vertical planes for obstructions. If the obstructions to sight distance are immovable, re-alignment may be necessary.

Restrictions on Sight Distance

Climatic restrictions to stopping sight distance

Certain areas of the country are prone to misty conditions and others subject to high rainfall. Mist and rain both cause reduced visibility. Where these are a regular occurrence, they tend to lie in belts across the landscape. Designers should acquire local knowledge about the quirks of the weather patterns and seek ways to reduce their effect. Where it is not possible to avoid a mist belt, the designer should pay particular attention to the concept of the "forgiving highway", by providing flat side slopes and avoiding alignments where short radius curves follow each other in quick succession.

Restrictions on Sight Distance

Steep downgrades followed by short radius horizontal curves are particularly to be avoided. A real effort should also be put into avoiding high fills.

Drivers are more likely to make incorrect decisions when under stress and designers should thus do everything possible to keep stress levels within manageable limits.

Restrictions on Sight Distance

Bridge Decks

Where a road passes under another on a sag curve it is possible that the deck can offer an impediment to sight distance. The line of sight is then restricted to that allowed by the soffit (bottom) of the deck. This is not a common occurrence but it is nevertheless necessary for the designer to be aware of this possibility.

Bridge parapets and barriers should also be designed so as not to impede sight distances at ramp terminal control sections.