Chapter 3

ROAD SAFETY REVIEW: METHODOLOGY

3.1 INTRODUCTION

The aim of road safety reviews is to identify hazards and/or safety deficiencies in road design, layout, and road furniture. The road safety review process is divided in three phases, the office review, the field review, and the final report.

The office review primarily consists of a comprehensive site description and a complete crash data analysis. The field review includes a road survey, conducted with the aid of recommended manuals and provided checklists, and speed data collection and analysis. The final report summarizes the results of both the office and the field review. The report should be concise and succinct, with clear identifications of problems and recommendations.

Road safety reviews are applicable to all types of existing roadways and at every stage of their development. However, the procedure followed in this document focuses on local roads situated in urban and suburban areas.

Road safety reviews should be undertaken by a team of people who have experience and up-to-date expertise in road safety engineering and crash investigation and prevention, linked to an understanding of traffic management and highway design. When necessary other fields such as road user behavior, enforcement, and maintenance should be represented on the team (Austroads, 2002).

3.2 OFFICE REVIEW

3.2.1 Site Description

The first task is a comprehensive description of the road safety review site. This description should contain geographic information, demographic data and could even include a brief paragraph describing location history. Providing a global picture of the area may assist in making decisions or adjustments to temporal variations if needed during the review.

Once the location is described, the roadways selected to be analyzed must be characterized. The data provided in this section are obtained without visiting the site. This description includes land classification, functional classification of the roadways and other relevant characteristics such as speed limit. If available, detailed maps and GIS data of the site should be incorporated in this section. The roadway inventory, included in the field review section, contains a more exhaustive description of the selected roadways.
3.2.2 Crash Data Analysis

Crash data are used to help understand why crashes occur, to help identify high-crash spots, to aid in the choice of safety programs or countermeasures, and to assist evaluations of countermeasure effectiveness. The main purpose of crash analysis is to improve safety by identifying crash patterns and reducing the number of crashes by adopting suitable countermeasures (CTRE, 2002).

The primary source of crash data is the local law enforcement agencies. Crash data are recorded primarily by the police on report forms soon after a crash occurred. One police report form is filled out per crash. Most states have a standard crash report form used by all police officers within the state. This form requests information on the drivers and passengers, the vehicles, the roadway, and the conditions at the time of the accident. In addition to that, most forms require a sketch of the crash that shows vehicle paths and objects struck, and a brief description of the crash (Hummer, 1994).

Every crash analysis has some limitations that must be kept in mind by the analyst. When analyzing crash data, one important restriction is the difficulty in recognize the legitimacy of crashes. While some crashes are certainly safety related, others may be an unlucky issue rather than an unsafe maneuver.

Another limitation is that motorists do not report all traffic crashes to the police. However, the major reason that crashes are not reported is that they were not severe enough. Most states have thresholds of property damage below which police decline to investigate the crash. Other states do not report crashes that do not involve a personal injury. Sometimes, motorists do not report crashes for fear of higher insurance rates or police do not report crashes on private property.

The underreporting needs to be considered in the analysis because a study relying on reported crashes will probably underestimate the total number of crashes. For that reason, analysts should include an awareness of this underestimation by writing in terms of “reported crashes” instead of simply “crashes” (Hummer, 1994).

Data from three to five years are needed to develop a crash study. In this study, the period reviewed comprises from 1998 to 2002; five years of crash data are analyzed.

The first task is to validate the data. The crash reports need to be checked one by one to ensure that they are suitable and correspond to the selected location and are valid for the review. Once the data are filtered, the analysis can be conducted.

First, to obtain an overview, crash rates are computed, which allow comparisons among different locations. Secondly, conducting a more detailed analysis, the crash data are classified into three categories: location, crash pattern, and major cause.
3.2.2.1 Crash Rates

To perform a complete crash analysis and evaluation, the data should be normalized by crash rates. Crash rates allow comparing crash data of different sections of roadway with different lengths and traffic volumes. Crash rates for sections are expressed in terms of crashes per million vehicle miles and computed using the following equation:

\[ R_{sec} = \frac{1,000,000 \times C}{365 \times T \times V \times L} \]

where

- \( R_{sec} \) = crash rate for the section
- \( C \) = number of reported crashes
- \( T \) = time frame of the analysis
- \( V \) = Traffic flow, AADT (Annual Average Daily Traffic)
- \( L \) = length of the section

Obviously, comparing locations by crash rate requires traffic volume data. Crash rates must account for exposure, which is the opportunity for a crash to occur, and traffic volumes are one of the most used factors to measure exposure. Crash rates for sections also require the length of the roadway segment that is being analyzed (Hummer, 1994).

The number of reported crashes to calculate crash rates corresponds to the validated data; only the reports obtained and confirmed as valid should be counted. This practice might underestimate the actual crash rate but ensures a more rigorous comparison between the different roadways analyzed.

3.2.2.2 Crash Data Classification

The next step in the crash data analysis is to classify the reported crashes by three aspects: location, pattern, and cause.

- Crash data by location

The crash reports are examined looking at the exact location where the crash occurred. The analyst summarizes the crashes by spots along the street. Spots are short segments of the roadway that help identify problem “point” locations such as intersections, curves or short bridges (Hummer, 1994). The results obtained are presented on a map of the zone that gives a visual scheme of crash trends.

- Crash data by crash pattern

In this approach, the reported crashes are classified by two criteria: roadway location and type of collision occurred. The first classification done is according to the geometry of the location where the reported crashes occurred. Therefore, crashes are sorted by \textit{intersection}, (if it happens at an intersection), \textit{roadway section} (if it
happens on a segment of roadway) or out of the public roadway (this case covers driveways, front yards and others).

The second grouping is by type of crash. There are numerous geometries to classify crash types, but they can be summarized into three basic patterns. When a vehicle hits frontally another vehicle or an obstacle, usually a fixed object such as a tree or a pole running off the roadway, the crash could be classified as a head-on crash. When a vehicle loses control and hits the curbing roadway is also considered head-on-crash. If there are two vehicles involved and one hits another laterally, usually at intersections, an angle crash occurs. The last model is a rear end crash and occurs often in situations of congested traffic, one vehicle stops or slows down while the following one does not, hitting the rear part of the preceding vehicle. Figure 3-1 characterizes the three basic crash patterns.

![Diagram of crash patterns](image)

**FIGURE 3-1 Basic Crash Patterns.**

- Crash data by factor affecting crash

Crashes occur because of various factors including driver, vehicle, roadway and environment aspects. Therefore, it is very difficult to determine the sole cause of a crash. In general, 90 percent of crashes are caused by driver error or by the combination of an operator error and an additional factor (Austroads, 2002).

Focusing on crashes where speed is an influencing factor, the delimitation of which crashes are speed-related and which are not is reasonably complicated. The fact that a vehicle was exceeding the speed limit does not necessarily mean that this was the cause of the crash, but the probability of avoiding the crash would likely be greater if the driver or drivers had been traveling at slower speeds.

Crashes reporting a violation of the lawful speed limit must be obviously considered speed-related, but it is recommended to go one step further in the analysis. Driving too fast for the existing conditions is also a speed related failure. Crashes where the reported cause is failure to stop or yield could also present speed influence.
This is the case of some rear end crashes: the first vehicle stops and the following vehicle does not, causing the crash. The explanations for this type of crash are diverse: it could be simply driver inattention, brake failure or driving too fast for conditions.

The second topic to consider is that driving above the speed limit or too fast for existing conditions does not cover all speed issues. Most of the time, the risk is due to speed variance rather than speed itself. In a roadway where the average speed is 40 mph, a vehicle running at 20 mph is certainly a hazard.

In this study, all the crashes where speed could be a possible cause of the crash will be counted as an unsafe-speed-related crash. Not being able to stop when necessary, vehicle conflicts at intersections due to speed variance and running off the roadway are considered unsafe speed practices.

On the other hand, when the failure is due to a wrong maneuver such as inappropriate left turns, backing up from driveways without caution or driving on the wrong lane, the cause of the crash will be considered an improper maneuver.

Another important cause of crashes is driving under influence of alcohol or drugs. Fortunately, crash reports are unambiguous for these situations. When the cause of the crash is clearly attributed to driver fatigue, for example falling asleep, it should be classified as impaired driving. If the crash reports both driving under influence and another cause such speeding, it should be considered impaired driving.

When the situation is unclassifiable under any of those three groups: unsafe speed, improper maneuver and impaired driving, the crash will be considered caused by other reasons and counted apart. This is the case of sudden sickness of the driver, mechanical problems, severe weather conditions such as icy surface or external effects such as large animals on the roadway.

3.3 FIELD REVIEW

3.3.1 Road Survey

In the road survey, a review and documentation of the characteristics of the roadway need to be conducted. The road survey comprises not only the physical features of the roadway but also traffic operations, roadside development, different users of the roadway, and environmental conditions. “The Traffic Safety Toolbox”, published by ITE (1999), is a recommended reference to use when conducting the examination.

The elements to consider are divided into four major areas including geometric design elements, traffic control devices, roadway activity, and environmental considerations. Under each one of these categories, several aspects need to be examined and evaluated to complete the safety analysis. Table 3-1 summarizes the key elements of the road survey.
### TABLE 3-1 Elements of the Road Survey

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#### 3.3.1.1 Geometric Design Elements

Geometric design could be defined as “the process of applying some engineering principles to the design of transportation facilities to ensure safety and efficiency for all users” (AASHTO, 2001). Geometric design elements include a wide range of roadway features such as horizontal and vertical alignment, cross section, roadside development, intersections, pavement, lighting, and design speed.

A Policy on the Geometric Design of Highways and Streets (the Green Book), published by AASHTO (2001), contains the basic geometric design criteria that establish the physical features of the roadway.

- **Speed**

  Speed is a critical factor affecting safety. Speed reduces the visual field, restricts peripheral vision, and limits the time available for drivers to receive and process information.

  AASHTO describes three types of speed including operating speed, running speed, and design speed. *Operating speed* is the speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile speed is the most frequently used measure of the operating speed. *Running speed* is the speed at which an individual vehicle travels and is usually measured by the average speed. *Design speed* is a selected speed used to determine the various geometric design features of the roadway. All geometric design elements of the roadway should be
related to the design speed to ensure consistency and avoid misleading motorists (AASHTO, 2001).

Design speed is defined by the AASHTO Green Book as “the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern”. The selected design speed should be consistent with the speed the driver is likely to expect and fit the travel and habits of nearly all drivers. Subject to the constraints of environmental quality, economics, aesthetics, and social impacts, AASHTO recommends higher design speeds to promote safety, mobility and efficiency.

- Road alignment

Road alignment comprises horizontal alignment and vertical alignment (profile), which are among the more significant of the permanent design elements of the roadway. Higher quality in the design of each and of their combination increases usefulness and safety, encourages uniform speed, and improves appearance. The most important points to consider regarding horizontal and vertical alignments are that they should be consistent with the topography, preserve developed properties along the road, and incorporate community values.

Grade, superelevation, radii, and transition lengths are all important elements in road alignment design. The AASHTO Green Book provides guidelines, minimum and maximum recommended values, and equations to use in the roadway design.

One of the essential design elements related to road alignment is sight distance, which is defined as the length of roadway ahead visible to the driver. For safety on highways, the designer should provide sight distance of sufficient length that drivers can control the operation of their vehicles.

The AASHTO Green Book describes three types of sight distance including stopping sight distance, passing sight distance, and decision sight distance. The Green Book provides equations to compute these distances and tabulated values.

**Stopping sight distance** is defined as “the adequate sight distance on a roadway to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path” (AASHTO, 2001). Stopping sight distance is the sum of the distance traversed by the vehicle while driver reacts (brake reaction distance) plus the actual distance needed to stop the vehicle while breaking (braking distance).

**Decision sight distance** is defined by AASHTO (2001) as “the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently”.

Finally, the AASHTO Green Book defines **passing sight distance** for two-lane highways as “the length needed to complete normal passing maneuvers in which the passing driver can determine that there are no potentially conflicting vehicles ahead before beginning the maneuver”.

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Sight distance is dependent on the height of the driver’s eye above the road surface, the specified object height above the road surface, and the height and lateral position of sight obstructions within the driver’s line of sight. For design purposes, the Green Book recommends the height of driver’s eye to be considered 1,080 mm (3.5 ft) for passenger cars, and the height of object 600 mm (2 ft) for stopping sight distance and 1,080 mm (3.5 ft) for passing sight distance.

Some visibility problems can be reduced using additional reinforcement. Visual cues such as lines of trees can help the driver to identify the road layout when the sight distance is poor.

- Cross section

The roadway cross section consists of those geometric features perpendicular to the direction of travel. AASHTO makes a clear distinction between the term traveled way, defined as “the portion of roadway provided for the movement of vehicles exclusive of shoulders”, and the term roadway, which is defined as “the portion of highway, including shoulders, for vehicular use”.

Common cross-section elements include travel lanes, medians, shoulders, and marginal elements such as sidewalks, curbs, gutters and barriers.

The number of lanes needed for a facility is determined by the projected traffic volume at a level of service appropriate for the facility.

The lane width must be sufficient to accommodate the design vehicle, allow for imprecise steering maneuvers, and provide clearance for traffic flow in adjacent lanes. It is dependent on the design vehicle, design speed, volume, the presence or absence of shoulders, horizontal alignment, and the presence of oncoming traffic. The width of travel lanes is limited by the physical dimensions of vehicles to a range between 9 and 12 feet (2.7 and 3.6 meters).

The medians are primarily used to separate opposing directions of traffic on multilane highways, but they also provide a recovery area for out-of-control vehicles, space for barriers and landscape planting. The general range of median width is from 4 feet (1.2 meters), in urban areas, to 80 feet (24 meters) in rural areas.

 Shoulders are the portion of the highway to the right of the actual traveled way and are used for emergency stopping and for lateral support of base and surface courses. Shoulders increase safety and highway capacity and provide a place for non-motorized vehicles and pedestrians when nonexistence of sidewalks. Shoulders are also an important element in the roadway drainage system since they carry surface runoff away from the traveled lanes. Shoulders width varies from as little as 2 feet (0.6 meters) to about 12 feet (3.6 meters) on major highways (FWHA, 1997).

Curbs are primarily used in low-speed urban and suburban environments and serve a variety of functions including drainage control, roadway edge delineation, right-of-way reduction, aesthetics, and delineation of pedestrian walkways. Curbs configurations include vertical and sloping curbs. Sloping curbs are low with flat sloping faces to allow vehicles to cross them when the need arises. Vertical curbs are
intended to discourage vehicles from leaving the roadway and protect pedestrians on the sidewalk. Vertical curbs should not be used along high-speed roadways.

Sidewalks and pedestrian paths must ensure the safe and efficient accommodation of pedestrians along the road. Sidewalks can either be located next to a planted strip, usually grass or plants, or flush with the roadside edge, if curbing is provided. Typically, sidewalks in residential areas vary in width from 1.2 to 2.4 m (4 to 8 ft). The wider the sidewalk, the more room there is for street furniture, trees, utilities, and pedestrians. However, when considering the placement of fixed objects inside the sidewalk, it is important to keep the pathway as unobstructed as possible. For example, utility poles should be placed to the sides and not in the center of the sidewalk (FWHA, 1997).

Figure 3-2 illustrates various cross-section elements discussed in this section.

![Figure 3-2 Urban Highway Cross-Section Design Features and Terms (FHWA, 1997).](image)

- Intersections

Intersections may possibly be the most critical elements of the urban highway system. The efficiency, safety, speed, cost of operation, and capacity of the highway system mostly depend on the design of its intersections. AASHTO (2001) defines intersection as “the general area where two or more highways join or cross, including the roadways and roadside facilities for traffic movements within the area”.

Intersection design can vary widely in terms of size, shape, number of travel lanes, and number of turn lanes. Each roadway radiating from an intersection is called a "leg." Most intersections have four legs, which is recommended by AASHTO
as the maximum number for safety and capacity reasons. The basic intersection types include the three-leg intersection or T intersection, the four-leg intersection, the multileg intersection, and the modern roundabout.

A wide range of design elements should be considered in the intersection design to ensure operational quality and safety. The alignment before and through the intersection must promote driver awareness, operate well under frequent braking, and be easy to drive. Crossing roadways should intersect at 90 degrees, if possible, and at no less than 75 degrees to avoid visibility issues. Wherever possible, provide separate lanes or space left for left turns is a practice to enhance intersection safety. This is certainly the single most effective treatment that applies to urban and suburban streets (ITE, 1999).

The design of intersections should also incorporate provisions for intersection sight distance. The driver of a vehicle approaching or departing from an intersection should have an unobstructed view of the intersection, including any traffic devices, and sufficient length along the intersecting highway to permit to anticipate and avoid potential collisions. These unobstructed views form triangular areas known as sight triangles. These areas should be clear of obstructions that might block a driver’s view of conflicting vehicles or pedestrians.

The two types of sight triangles are approach sight triangles and departure sight triangles. Both types are illustrated in Figure 3-3 below.

FIGURE 3-3 Approach and Departure Sight Triangles (ASSHTO, 2001).
The triangular area for approach sight triangles should be large enough that drivers can see approaching vehicles and pedestrians in a sufficient time to slow down or stop. Departure sight triangles should provide sight distance sufficient for a stopped driver on a minor road to depart from the intersection and enter or cross the major road.

To determine whether an object is a sight obstruction, both the horizontal and vertical alignment must be considered, as well as the height and position of the object. For passenger vehicles, it is assumed that the driver’s eye height is 1,080 mm (3.5 ft) and the height of an approaching vehicle is 1,330 mm (4.35 ft). Obstructions within sight triangles could be buildings, vehicles, hedges, trees, bushes, walls, fences, etc.

- **Auxiliary lanes**

  An auxiliary lane is defined by AASHTO as “the portion of the roadway adjoining the traveled way for speed change, turning, storage for turning, weaving, truck climbing, and other purposes supplementary to through-traffic movement”. According to these guidelines, an auxiliary lane may be provided to comply with the concept of lane balance, to comply capacity needs, to accommodate speed changes and maneuvering of entering and leaving traffic. The width of an auxiliary lane should be equal to the through lanes and when they are placed along freeways, shoulders 2.4 to 3.6 m (8 to 12 ft) wide are desirable (ASSHTO, 2001).

- **Clear zones and crash barriers**

  The clear zone is defined by AASHTO as “the unobstructed, relatively flat area provided beyond the edge of the traveled way for the recovery of errant vehicles”. The width of the clear zone is influenced by several factors, the most important of which are traffic volume, design speed of the highway, and slope of the embankments.

  The AASHTO “Roadside Design Guide” is a primary reference for determining clear zone widths for freeways, rural arterials, and high speed rural collectors. For low speed rural collectors and rural local roads, the AASHTO Green Book suggests providing a minimum clear zone width of 2.0 to 3.0 m (7 to 10 ft) (47). For urban arterials, collectors, and local streets with curbs, space for clear zones is typically restricted. A minimum offset distance of 500 mm (18 inches) should be provided beyond the face of the curb, with wider offsets provided where practical (ASSHTO, 2001).

  In some situations, effective design demands that objects be placed in the clear zone such as signs and illumination supports. In these cases, a breakaway support must be provided. These devices incorporate frangible or weakened sections to allow for controlled breakage when truck by a vehicle (ITE, 1999).

  Where fixed objects, natural or constructed, cannot be eliminated from the roadside, safety dictates that crash barriers be provided as a means of shielding these objects. A correct use of crash barriers is an important component in roadway design to prevent crashes and improve safety. A wide variety of crash barriers is available,
including both longitudinal barriers such as guardrails and medians, and crash cushions, such as impact attenuators, which primarily serve to decelerate vehicles to a complete stop.

The purpose of crash barriers is to minimize the severity of potential crashes involving vehicles running off the traveled way where the consequences of errant vehicles striking the barrier are less severe than leaving the roadway. However, traffic barriers are themselves obstacles and present some degree of crash risk, therefore its use should consider both aspects. An in-depth discussion of these factors as well as guidance on the selection of a particular barrier design is presented in the AASHTO “Roadside Design Guide”.

- **Bridges and culverts**

  The geometric guidelines provided by the AASHTO Green Book related to bridges deal primarily with the width of the bridge deck and its relationship to approach roads. Bridges are portions of the continuous roadway and should be designed maintaining the cross-section dimensions. Particularly on urban collectors, ASSHTO indicates that the clear width should be the same as the curb-to-curb width of the approach roadway.

  For evident safety reasons, barriers should be provided along the bridge. Bridge railings need to be designed ensuring that, in case of impact, the vehicle is safely redirected, without penetration or vaulting over the railing.

- **Pavement**

  The selection of the pavement type is based on the traffic volume and composition, soil characteristics, weather, availability of materials, energy conservation, and the overall maintenance and cost. The AASHTO “Guide for Design of Pavement Structures” provides extensive guidance for structural design of pavements.

  Important pavement characteristics that could be considered safety related are the ability of the surface to retain its shape and dimensions, to drain, and to retain adequate skid resistance.

- **Lighting**

  Adequate lighting of a highway or street may improve safety and operation comfort. There is evidence that in urban and suburban areas, with significant pedestrian activity and intersections, appropriate illumination would enhance visibility and therefore safety. The ASSHTO “Informational Guide for Roadway Lighting” is specially intended to assist in the selection of roadway sections for which fixed-source lighting may be warranted and to present design guide values for correct illumination.
3.3.1.2 Traffic Control Devices

Traffic control devices are the communication elements of the roadway, which must provide the driver with a message in a clear, unambiguous, and uniform way. They include pavement markings, signs, traffic signals, and object markers. The Manual on Uniform Traffic Control Devices (MUTCD) defines traffic control devices as “all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction”.

The MUTCD (2001) is an official manual that contains the basic principles on the design and use of traffic control devices with the purpose of promoting highway safety and efficiency. The MUTCD defines five requirements for a traffic control device to be effective:

- Fulfill a need;
- Command attention;
- Convey a clear, simple meaning;
- Command respect from road users; and
- Give adequate time for proper response.

• Signs

The MUTCD describes three general categories of signs including regulatory signs, warning signs, and guide signs. Regulatory signs convey information about a specific traffic regulation with which drivers must comply, warning signs give notice of a situation that might not be readily apparent, and guide signs assist drivers in selecting appropriate routes to their desired destination (McShane et al., 1998).

Following the MUTCD guidelines, regulatory and warning signs should be used conservatively. These signs lose their effectiveness if used to excess. Contrarily, guide signs should be used frequently to keep users informed promoting safe and efficient operations.

Regarding to location, MUTCD recommends to place signs on the right side of the roadway to be easily recognized by users and sufficiently far apart for the required decisions to be made safely. The manual also requires signs to be placed outside the clear zone or otherwise mounted on a breakaway or yielding support. Signs should also be located so that they optimize nighttime visibility, do not obscure each other, and are not hidden from the view.

• Traffic signals

The MUTCD (2001) defines traffic control signal as “any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed”. Traffic includes pedestrians, bicycles, vehicles, streetcars, and other conveyances using the roadway with travel purposes.

Traffic signals must attract the attention of every road user, including older ones, fatigued or distracted, or those not expecting a signal, under a wide range of
conditions including day and night, adverse weather, and visually complex surroundings. For all these reasons, standards for traffic signals are very important and the selection and use of them should be based on an engineering study of roadway, pedestrian, bicyclist, and other conditions.

The MUTCD provides eight traffic signal warrants to conduct a complete analysis to determine if the installation of a traffic control signal is justified at a particular location. This manual also provides guidance concerning features of traffic signals including signal timing; pedestrian control features; preemption and priority controls; coordination of traffic signals; and the different signal indications, lenses, and faces.

- Markings and delineation

Traffic markings are the most frequently used traffic control device. Major marking types include longitudinal markings, such as lines separating traffic and curb markings; transverse markings, such as crosswalks stop lines and parking markings; and object markers and delineators. These elements can be used alone or as a supplement of other traffic control devices such as signs, signals, or other markings.

Markings have visibility and durability limitations. Material characteristics, traffic volumes, weather, and location affect marking durability. Snow, debris, and water reduce the visibility of pavement markings. Reflectorized paint and small reflectors affixed to the pavement are commonly used to minimize this issue. Audible and tactile features such as bars or differential surface profiles may help the road user to identify delineation on the roadway.

3.3.1.3 Roadway Activity

- Pedestrians and cyclists

Every user of the roadway must be considered in the road survey. To ensure safety of all users, safe and comfortable space for bicycling and walking should be provided along the roadway.

Wide shoulders, bike lanes, or parallel paths provide a way for bicyclist to travel outside the vehicle travel lane increasing bicycle safety. Appropriate sidewalks and crossing points for pedestrians should be provided along the roadway, especially in urban and suburban areas. Children, sometimes harder to see because they are shorter, and older pedestrians, which often require more time to cross and to react, also warrant special consideration (ITE, 1999).

Appropriate signs, signal phases and pavement markings should be used to enhance the safety of both bicycle and pedestrian traffic.

- Parking and public transport

The existence of parking lanes along the roadway creates additional side friction for vehicles in the adjacent lane and disruption due to vehicles entering and leaving from the parking spaces to the traveled lane, thereby affecting the overall
safety and efficiency of the roadway (McShane et al., 1998). Vehicles parked are hazards to passing vehicles or bicycles from opening doors, obstructions that hide pedestrians, and obstructions that block visibility at intersections and access points.

The presence of public transport, and especially the existence of stops along the roadway, influences the overall flow of vehicles and therefore the safety of the roadway. Bus stops must be located ensuring safety for both vehicles and other users (Austroads, 2002).

- Heavy vehicles, emergency vehicles, and slow-moving vehicles

The composition of the traffic is a characteristic to consider when analyzing the safety of a roadway. Heavy vehicles are large vehicles that need more room to maneuver, especially at intersections. The existence of shoulders and spacious lanes facilitate the movement of maintenance vehicles, emergency vehicles, and slow moving vehicles (Austroads, 2002).

3.3.1.4 Environmental Considerations

- Weather

As it has been previously noted, adverse weather affects design features such as visibility, and consequently affects roadway safety. In the road survey, the effects of rain, fog, ice, and wind on design features must be checked.

- Animals

Animals could be a hazard on the roadway. If animals, due to migratory routes in surrounding areas or other reasons, are a frequent risk for road users, appropriate measures should be taken such as fencing or signing.

3.3.2 Checklists

The purpose of road safety review checklists is to assess in identifying any potential safety issues. Many of the elements considered in the checklists may not be relevant to the roadway being review or others may seem repetitive. It is important to keep in mind that checklists are a means to an end, not an end in themselves (Austroads, 2002).

A successful review is not achieved by simply completing the checklist. The topics listed are intended to cover the more common elements; they are not exhaustive and engineers should use their skills and judgement about safety of any feature to ultimate accomplish the review. Checklists do not substitute knowledge and experience but they may help to not overlook something important.

This document provides a complete checklist for assisting in the road safety review. The checklist has been proposed keeping the same four major areas described in the road survey section, which include geometric design elements, traffic control devices, roadway activity, and environmental considerations. The road safety review
checklist is in Appendix A of this document and is based on the checklists provided by the Austroads’ Road Safety Audit Guidelines (Austroads, 2002).

### 3.3.3 Speed Data

Speed-related information is an important element to consider in roadway evaluating as it relates to safety, time, comfort and economics. Speed studies are conducted to establish the speed distribution of a traffic stream at a specific location. The data obtained from these studies are used to determine vehicle speed percentiles and speed variance, factors extremely useful in making speed-related decisions.

Speed data can be gathered using a variety of techniques. This document discusses three methods to conduct speed studies including the stopwatch method, the radar meter method, and the automatic traffic recorder method (CTRE, 2002). These methods are described later in this section ordered from least expensive to most expensive.

#### 3.3.3.1 Speed Data Collection

- **Stopwatch Method**

  The stopwatch method to collect speed data is quick, inexpensive and useful for a small sample size over relatively a short period of time. The procedure is based on recording the elapsed time it takes a vehicle to travel through a known length of roadway, providing sufficient data to compute vehicle speed.

  The first step is to choose an appropriate study length of roadway carefully. Recommended values range from 100 to 250 feet (30.5 to 76.2 meters), depending on the traffic stream average speed. The length needs to be long enough for reliable observer reaction times. For average speeds between 25 and 40 mph (40 and 64.4 km/h), the speed study length should be approximately 175 feet (53.3 meters) (CTRE, 2002). Figure 3-4 illustrates a typical layout for conducting a stopwatch speed study.

![FIGURE 3-4 Example Stopwatch Speed Study Layout (CTRE, 2002).](image-url)
Reference points, such as colored vertical posts, should be used to delineate the selected length. The observer should be situated at a preferential location, often higher than the study area, in order to guarantee good sight of the segment and facilitate the surveillance.

The observer starts the stopwatch as the front wheels of the vehicle cross a mark at the beginning of the selected length and the watch stops when the vehicle’s front wheels reach the reference line at the end of the segment. The length of the study segment divided by the time recorded equals the speed at which the vehicle travels.

- Radar Meter Method

A radar meter is an electronic device that directly measures speeds. Radar can be hand-held, mounted in a vehicle or mounted on a tripod. Figure 3-5 shows an example of a hand-held radar meter.

![Radar Meter (CTRE, 2002).](image)

A radar meter requires line-of-sight to measure speed and is easily operated by one person. They are effective at measuring distances from 200 ft up to two miles (CTRE, 2002).

Choosing a proper location at the study area for the radar meter is crucial since the unit should be hidden from the view of motorists. If drivers notice that a radar unit is operating in the vicinity, they will typically slow down affecting the results. Additionally, the distance to the target vehicle decreases precision and the angle to the centerline also affects the accuracy of the data obtained. The least precise position is found when the radar meter is aimed at a 90-degree angle to the roadway centerline (CTRE, 2002). Figure 3-6 exemplifies a typical layout for conducting a radar meter speed study.
Automatic Traffic Recorder Method

The automatic traffic recorder method is used for longer periods of data collection than the other two methods explained. The most used system is by pneumatic road tubes placed across the road and connected to traffic data recorders located at the side. The road tubes send an air pulse to the recorder each time an axle of a vehicle hits the tube.

JAMAR technologies Inc. (U.S.) and MetroCount (Australia) are companies that provide all the necessary equipment to conduct traffic surveys using pneumatic road tubes and traffic recorders. Figure 3-7 presents an automatic counter-classifier recorder provided by JAMAR Technologies, Inc.

The traffic data recorders are capable of storing large amount of individual or binned vehicle data that are later downloaded from the recorder to a computer. Collected data could be analyzed in a variety of way including volume, speed, vehicle classification and vehicle gaps.
Different road tube layouts could be used depending on the type of data that need to be collected. Figure 3-8 illustrates a road tube layout to collect data for bi-directional traffic with the JAMAR traffic data recorder.

![Diagram of road tube layout](image)

**FIGURE 3-8 Example Pneumatic Road Tubes Speed Study Layout (Jamar Technologies Inc.).**

The A and C tubes should be spaced eight feet apart, as should the B and D tubes. The tube A should be spaced six inches from the D tube. Ensuring that vehicles strike the short tube first, this configuration provides lane separation. This layout is used to collect volumes, speed, classification, and gap data.

An alternative to the pneumatic road tubes is the use of magnetic systems. The Hi-Star is a traffic counter patented by Nu-metrics, Inc. that records data using a magnetic sensor. The traffic counter is placed in the middle of the traffic flow lane sheltered with a protective cover fixed to the pavement.

To download and manipulate the collected data, the companies provide proprietary traffic data analysis softwares. Traxpro is the software offered by JAMAR Technologies Inc. Once the data are in the appropriate format, they could be analyzed.

3.3.3.2 Speed Data Analysis

The first task in the analysis is to validate the data. The speed study must be conducted considering only free-flow speeds. A free-flowing vehicle is one whose driver has the ability to choose a speed of travel without influence from other traffic, conspicuous police presence, or environmental factors. Heavy traffic situations, nearby emergency vehicles, the presence of enforcement, and vehicle maneuvers such as braking, accelerating or decelerating influence the free flow speed of traffic and thereby are situations that must be excluded from the sample (TRB, 1998).

A field observer could monitor these conditions and select a valid sample. However, most automatic devices used to record traffic data are unable to detect these
interfering factors and therefore data from automatic traffic recorders underestimate the free-flow speed of traffic.

The speed data obtained by automatic methods should be filtered to procure the best free-flow sample possible. When headway data are available, all vehicles presenting a gap of less than four seconds in the same lane must be excluded from the sample (TRB, 1998).

In most cases, speed distributions tend to be normal. Normal distributions are represented by a bell-shaped curve, strong central tendency and decreasing probability of extreme values.

Speed distributions are presented in several standard formats. A useful way to display the data is by frequency distribution tables and curves, and by cumulative frequency distribution curves.

A frequency distribution table shows the total number of vehicles observed for the selected speed groups. A speed group could include one single speed value (for example, 33 mph) or a range (for example, from 32 to 34 mph). The frequency distribution curve plots points that represent each speed group versus the percent of vehicles in the group and the cumulative frequency distribution curve plots the speed group versus the cumulative percent of vehicles. The cumulative percent frequency is defined as the percentage of vehicles traveling at or below the given speed (McShane et al., 1998).

Various descriptive statistics can be computed from the speed data. The statistics used describe two important characteristics of the distribution: tendency and dispersion. Measures of tendency describe specific points of the distribution and include the average speed, the median speed or 50th percentile speed, the mode, the 85th and 95th percentile speeds and the pace. Measures of dispersion define the extent to which data spreads around the center and include the standard deviation and the percent of vehicles within the pace (McShane et al., 1998). These descriptive statistics are presented in Table 3-2.

**TABLE 3-2 Statistics Used to Describe the Distribution**

<table>
<thead>
<tr>
<th>TENDENCY</th>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average speed</td>
<td>( \overline{S} = \frac{\sum S_i}{N} )</td>
<td>The sum of all individual speed divided by the total</td>
</tr>
<tr>
<td>The median speed or 50th percentile speed</td>
<td>( P_{50} )</td>
<td>The speed at or below the 50 percent of vehicles travel</td>
</tr>
<tr>
<td>The Mode</td>
<td>( M )</td>
<td>The most frequent speed</td>
</tr>
<tr>
<td>The 85th percentile speed</td>
<td>$P_{85}$</td>
<td>The speed at or below the 85 percent of vehicles travel</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>The 95th percentile speed</td>
<td>$P_{95}$</td>
<td>The speed at or below the 95 percent of vehicles travel</td>
</tr>
<tr>
<td>The pace</td>
<td>$P$</td>
<td>The 10 mph increment in speed in which the highest percentage of drivers were observed</td>
</tr>
</tbody>
</table>

**DISPERSION**

<table>
<thead>
<tr>
<th>The standard deviation</th>
<th>$s = \sqrt{\frac{\sum (S_i - \bar{S})^2}{N-1}}$</th>
<th>The average of the difference between the individual speeds and the average speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent vehicles within the pace</td>
<td>$p$</td>
<td>The actual percentage of vehicles traveling within the 10 mph range of the pace</td>
</tr>
</tbody>
</table>

If the speed distribution is assumed to be normal, precision and confidence intervals could be added to the analysis of the speed sample. Standard errors and confidence intervals could be determined for the analyzed statistic values. Normal distributions are symmetric and for this reason present identical average speed, median speed, and mode.

### 3.4 FINAL REPORT

The final report summarizes the results of the office review and the field review. The main task of the road safety review report is to identify the aspects of the roadway that may involve hazard and to make recommendations about corrective actions. The report should be concise, giving clear identification of the problems and recommendations, and illustrative, each problem identified should be referenced on a location plan.

A review report must include a summary of the procedure, findings and recommendations, and a concluding formal statement.

The summary of procedure should contain background information and a description of the main steps followed in the road safety review process. The background information consists of the main characteristics of the roadway including name, location, length, classification, etc; the review team members names as well as their affiliations and qualifications; and a list of documents used during the review. The process description explains the tasks accomplished in the review process in general terms, what has been completed in the office review and the field review.

The findings and recommendations part consists in a series of findings about all the safety deficiencies which were identified, with recommendations after each finding. It is recommended to use a table format to present these results. Review
findings should identify what is potentially dangerous or what could lead to crashes. Recommendations should be appropriate for the type of road and location. A review recommendation should indicate the direction on which a solution should be sought, rather than specifying the solution. This would be the most substantial part of the report (Austroads, 2002).

Each finding in the road safety review should be categorized into a level of risk. The assignment of a level of risk could help identify the severity of the issue and the urgency of the solution. Table 3-3 offers a scale of level of risk and its suggested treatment approach. This is not a scientific system and professional judgment should be used.

TABLE 3-3 Level of Risk (Austroads, 2002)

<table>
<thead>
<tr>
<th>LEVEL OF RISK</th>
<th>SUGGESTED TREATMENT APPROACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerable</td>
<td>Must be corrected</td>
</tr>
<tr>
<td>High</td>
<td>Should be corrected or the risk significantly reduced, even if the treatment cost is high</td>
</tr>
<tr>
<td>Medium</td>
<td>Should be corrected or the risk significantly reduced, if the treatment cost is moderate, but not high</td>
</tr>
<tr>
<td>Low</td>
<td>Should be corrected or the risk reduced, if the treatment cost is low</td>
</tr>
</tbody>
</table>

A concluding formal statement, signed by all review team members, should be included advising they have undertaken the road safety review.