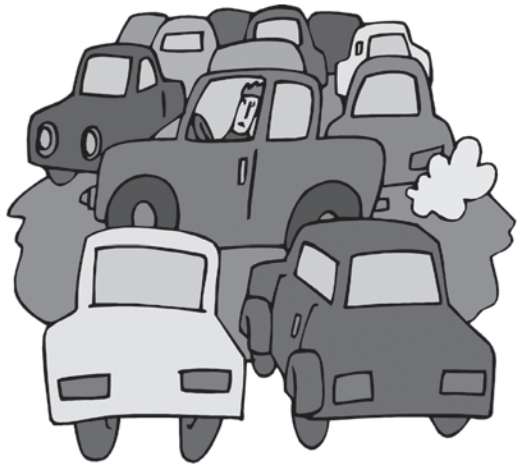
Road Safety Fundamentals



Cornell Local Roads Program

NEW YORK LTAP CENTER

Road Safety Fundamentals

by

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Updated to meet the requirements
of the National MUTCD
and the New York State Supplement
to the National MUTCD

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Preface

The principal author of this manual is James Mearkle, P.E., at the time the Safety Technical Assistance Engineer with the Cornell Local Roads Program and the instructor for the accompanying workshop. From 1992 to 2000, Jim worked in the New York State Department of Transportation's Traffic Engineering and Safety office in Poughkeepsie where he assisted highway designers and construction engineers with a wide variety of capacity, traffic flow, and safety issues.

This workbook, Road Safety Fundamentals, has been prepared and written for the use of local government officials in the State of New York who have responsibility for the operation and management of highway departments. The New York State rules for traffic control are different than the National Manual of Uniform Traffic Control Devices (MUTCD), due to the New York State Supplement to the National MUTCD. Therefore, anyone outside New York State reading this book should be aware of those differences.

Information presented here is intended to guide highway officials. Design issues may require the services of a professional engineer, and legal issues should always be addressed to your municipal attorney or risk manager.

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Introduction

Traffic accidents have a tremendous cost in New York State in terms of lives, injuries, and monetary losses. In 2000, 392,245 accidents were reported in New York State. Of these, 1,338 accidents resulted in 1,444 fatalities, and 292,663 persons were injured in 189,000 accidents. These statistics are even more sobering when you consider these numbers represent real people and their families.

The accident rate on non-state roads is more than twice the rate on state roads. Non-state roads carry 45 percent of all traffic, but 63 percent of all reported crashes occur on these roads. Municipal roads are burdened with more than their share of the crashes.

The state highway system is safer because the agencies that maintain it (New York State Department of Transportation, New York State Thruway Authority, etc.) have larger budgets to make improvements and hire the engineering staffs to design them. Economically, this makes sense, since these roads carry most of the traffic. However, local highway superintendents are hard pressed to maintain their roads, much less make improvements.

This brings us to an important concept: cost effectiveness. Cost effectiveness is a comparison of how much an improvement will cost to how much it will reduce the number or severity of crashes. For example, if $5,000 of guiderail turns a $100,000 injury accident into a $5,000 property damage accident, then it is cost effective. Installing the same guiderail next to a flat field could turn a $100 towing bill into a $5,000 property damage accident.

Since the accidents that occur off of the state system are spread out over 97,000 miles of road, spending a lot of money on the entire local system does not make sense. On existing roads, treating the locations where safety problems occur or are likely to occur is usually more cost effective than upgrading the entire local road network.

LIABILITY

We cannot prevent all accidents. Crashes will occur, and lawsuits may arise from them. A good road safety improvement plan is an effective way to reduce the risk of liability. It can reduce the number of accidents, the loss of lives and the economic costs related to them. Reducing the number of accidents reduces exposure to liability. Safety planning is a good risk management strategy.

Simply put, liability is incurred when one person or organization breaches a duty to someone else who suffers injury or loss because of the breach. The breach may be an improper action, or a failure to act when necessary.

Highway agencies have a duty to keep their highways “reasonably safe.” In highway liability lawsuits, three factors are involved: a defect on the highway right-of-way, the defect was involved in the accident, and the highway agency had prior notice of the defect and an opportunity to do something about it.

Notice means that the highway agency knew of the defect, or should have known about it. *Actual notice* means the agency was informed of the defect, either in writing, or by a police officer. *Constructive notice* means the defect was obvious enough and there long enough that the agency should have been aware of it.

A highway superintendent should also be concerned about “political liability.” Superintendents who rightly or wrongly get reputations for not caring about public welfare may find it more difficult to perform their jobs. If you show responsiveness to public needs, you will get more support from the community.

For in-depth discussions of liability concepts, see the Cornell Local Roads Program (CLRP) publication entitled *Reducing Liability for Local Highway Officials*.

When do you need a professional engineer?

There will be times when you will need the services of a licensed professional engineer (P.E.). State law prohibits practicing engineering without a license. According to the NYS Department of Education which licenses engineers, “You will need a P.E. when the complexity of the design of a project requires the skills of a professional engineer or when the services fall within the legal definition of professional engineering.” You may also need an engineer when a permit is required for your project, and the permitting agency requires certification by a professional engineer.

Qualified immunity

You may wish to use the services of an engineer even in cases not required by law. Using a professional engineer makes the qualified immunity defense easier to use in a lawsuit. The courts will not second-guess a professional engineer if a decision is made in accordance with sound engineering standards, practices, and criteria.

To use the qualified immunity defense successfully, careful record keeping is essential. For a highway defect case, you will need to show details about what was wrong, what was done to correct it, and when the correction was completed. You also need to document which standards were used to reach the decision.

Qualified immunity can be used if a professional engineer is not involved, but the municipality must prove there was adequate professional study and the decision had a reasonable and rational basis. To prove this, careful record keeping is required.

For more information on qualified immunity, see the CLRP publication *Reducing Liability for Local Highway Officials*.

Documentation

The results of decisions you make today may be factors in lawsuits many years from now. Your department could be sued tomorrow because of a decision your predecessor made years before he retired and moved to Tucson. This is why documentation is important.

Good records can prove a disputed case better than memory. Roadway safety items that should be documented include:

- Highway defect notices and how they were addressed
- Road and roadside condition surveys, including ditch depths and slopes
- Records of road patrols and inspections, even if no defects are found
- Sign inventories
- Road work plans

- Traffic studies
- Any time you deviate from a standard practice, it is vital that you record what you did and why. Depending on the nature of the deviation, you may need to have an engineer evaluate the condition.

When no defects are found during a patrol or inspection, be sure to write that down. It makes it harder for the opposition to prove you had constructive notice.

Make sure to include:

- Date and time
- Weather conditions
- Conditions found
- Who, what, where, when, why, and how

The CLRP publication *Reducing Liability for Local Highway Officials* includes sample forms for documenting road inspections.

1 - Road Safety Basics

To reduce traffic accidents, we need to understand what causes them. The highway transportation system can be broken down into three broad categories: the driver; the vehicle; and the road and its environment. Factors that help cause accidents usually fit into one of those categories. Most accidents have at least one contributing factor. Many have several.

Human factors include things like inattention or distraction, fatigue, alcohol use, and vision problems. Vehicle factors may be mechanical failures, bad brakes or tires, or similar problems. Road-related factors can be insufficient sight distance, poor or missing road signs, changes in roadway width, or slippery road surfaces.

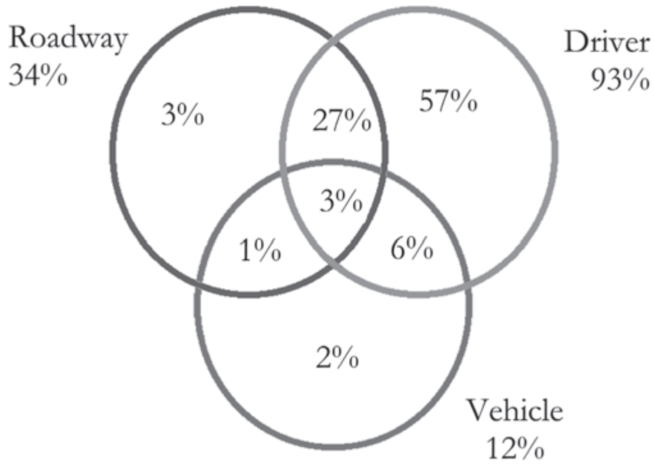

Figure 1 - Accident contributing factors

(Total does not add up to 100 percent due to rounding)

Figure 1 is based on studies of police reports of traffic accidents. The investigating police officer lists factors that contributed to the accident. Driver errors are thought to contribute to most accidents. A road condition is listed as a contributing factor 34 percent of the time, although it may be more. A vehicle defect or malfunction is involved 12 percent of the time.

For highway department officials, the 34 percent of crashes where the road is involved is both a problem and an opportunity. This is where lawsuits come from, but it also means that the highway community has opportunities to prevent more accidents. In most road-related accidents, the investigating officer also lists a driver factor. In other words, something about the road led the driver to make a mistake, or the driver made a mistake, and the road did not allow for recovery from the mistake.

Considering road transportation as a system, we see that there are things we can directly control and things we cannot. Drivers and environmental events like weather are hard to control. If the parts of the system that can be controlled (roads and vehicles) are designed to allow for those we cannot (road users and weather), the system as a whole will work better.

Let's start by looking at factors related to the drivers, roads, and vehicles that make up the highway transportation system.

Figure 2 - Road user types.
Many types of users are on our roads including pedestrians, bicyclists, passenger vehicles, and trucks.

DRIVERS AND OTHER ROAD USERS

Section 152 of the New York State Vehicle and Traffic Law defines traffic as,

> *"Pedestrians, ridden or herded animals, vehicles, bicycles and other conveyances either singly or together while using any highway for purposes of travel."*

While motor vehicles are usually the largest group, others have the right to use the road. How much effort is needed for different user types depends on the amount and types of traffic on a given road. On low-volume rural roads, usually very little extra effort is needed. In built-up areas, sidewalks are often needed for pedestrians. If a road carries large numbers of bicyclists, paved shoulders are a good idea, especially if the road carries high speed or truck traffic. When planning a road project, make note of the types of traffic using the road and consider it when making decisions.

Pedestrians

Normally, decisions on road projects are based on the types of traffic using the road. Pedestrian and bicycle traffic is an exception to this practice. Pedestrians (and bicyclists) will often avoid a road if they feel uncomfortable or unsafe using it. If few people walk along a road, it may mean sidewalks are needed, rather than that there is no demand for them. If there are worn paths alongside the road, or destinations people would want to walk to, then sidewalks will make walking safer and easier. Remember that many pedestrians are children and senior citizens who cannot drive. Sidewalks can dramatically improve their quality of life and improve their safety.

A surprising number of pedestrian accidents happen in rural areas. This is because drivers do not expect them, and highway departments do not allow for them in their design. In rural areas, sidewalks are often not needed. Safety of infrequent pedestrians on rural roadways can be improved by many of the same measures used to improve the safety of motor vehicle drivers, such as sight distance improvements and shoulders.

Expectancy

As drivers gain experience they expect consistency, meaning that things will happen as they have before. For example, most drivers expect that a green light on a traffic signal will lead to a yellow light. Drivers look at an upcoming curve and adjust their speed based on similar looking curves they have driven. This is called expectancy. If a signal changes from green to red, or a curve radius suddenly gets tighter halfway through, the driver’s expectancy is violated, and the driver may react in an erratic or improper way.

Fulfilled expectancy leads to quicker and more correct reactions. Violated expectancies increase driver errors and reaction times. It takes more time to figure out what is going on when something is unexpected, and, if the extra time is not available, accidents may occur. That is why expectancy violations cause problems.

In locations where expectancy is violated, advance warning signs can help reduce the surprise. Oversized or repeated signs help make sure that you get the driver’s attention. For example, stop ahead signs and oversized stop signs can be used at a location where drivers run stop signs.

The driving task

Although most of us take it for granted, driving is a difficult task. The driver must constantly control the vehicle, follow the road, predict the motions of other road users and decide whether an action is needed to avoid them, while navigating to a destination. There are limits to how much information a driver can process at a time. When these limits are exceeded, mistakes happen. It is better to design the road and traffic sign layout so that drivers can take time to make several easy decisions than to force one complex decision in a hurry.

Driving can be modeled as a closed loop, involving information that leads to a decision to perform an action. The results of that action provide more information, starting the process over again (see Figure 3 below).

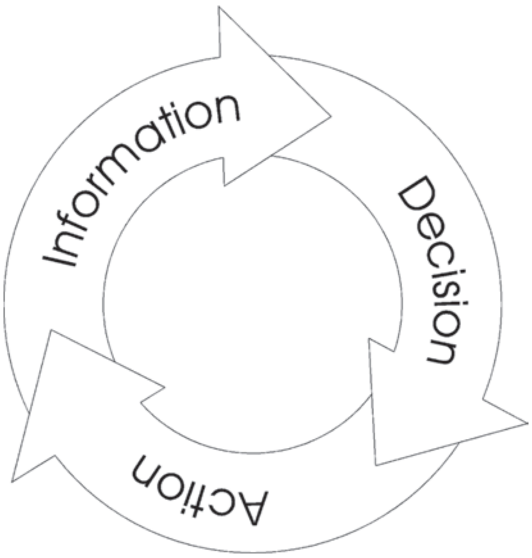

Figure 3 - The driving task

Information

There are two aspects to the information phase: detecting information and recognizing its meaning. We can help drivers with both aspects. Signs are standardized to make them easy to recognize, and the standard color combinations are chosen to be easy to detect. If roads are designed so curves are not just over hillcrests, they will be easier to see. Building curves without decreasing radii will make it easier to judge the sharpness of the curve and choose a safe speed. Expectancy plays a big part. Drivers are more likely to see signs if they are placed where the driver expects them to be.

New drivers and elderly drivers pose special problems. Novice drivers are still learning what information is important, and how to process it. Older drivers often have poorer eyesight, so they may not see the information in the first place. If we can accommodate these two groups, the majority of drivers will be well served.

We can help novice and older drivers by thinking about how we present information to them. The key is providing them with the information they need, without overloading them. Drivers can read three to four familiar words at a glance. Using unfamiliar words, or providing too much information at once, will reduce the chances of drivers finding the information they need.

Drivers gather as much as 90 percent of driving-related information with the eyes. Some aspects of vision that affect driving include acuity, contrast sensitivity, color vision, and size and motion judgment. Five percent of the population has color blindness, and several aspects of vision, including contrast sensitivity and night vision, tend to degrade with age. This is why proper use of visual aids such as traffic control devices is essential, and improper use can be misleading or harmful.

In daylight, drivers use visual cues along the road, like the road edge, tree lines, and fences, to guide them along the road alignment. At night, many of these visual cues are hard to see. We start losing our night vision at age 25, and older drivers need much more light to see than younger drivers.

We can provide visual cues with retroreflective traffic control devices like signs, delineators, and pavement markings. Larger and brighter signs can be read from farther away. These make driving at night easier, especially for older drivers.

Using several related signs can reinforce a message. Using chevron signs on a curve can reinforce a curve warning sign. Another common example is work zone signing. In a typical road work sign series, the first sign is a general warning of road work ahead. The second sign tells drivers what is going on, and the third sign says what they need to do. For example, a flagger-controlled work zone will have a Road Work Ahead sign (something is going on!), a One Lane Road Ahead (what's going on?), and a Flagger Ahead sign (what will I need to do?).

Using several related devices reinforces the message, and, when expectancy is violated, helps reduce the surprise.

Hearing and touch play lesser roles, but they can be used to inform the driver. Examples include warning bells on railroad gates and roadside rumble strips.

Decision

The information gathered in the first phase is combined with experience to reach a decision. To make decisions, attention skills are needed. Drivers need to be able to divide their attention to keep track of several things at once, and ignore what they do not need. These are skills that novice drivers are still learning, and older drivers sometimes find difficult.

We can help them reach the right decision, by spreading information and decision points apart. It is easier to make several simple decisions one after the other, rather than one complex decision in a hurry.

Action

The action phase is when the driver executes the decision. The results of the action provide more information, starting the loop over again.

For a road to be safe, the driver needs time to react. Reaction time is the time it takes for the driver to notice a condition, decide what to do, and to start acting on that decision. People need much more time to react to unexpected situations than they need for expected ones. Also, complex decisions take longer than simple ones. If the driver needs to process more information, it will take longer to react.

Reaction times range from 2.5 seconds for a simple decision like initiating a panic stop to 15 seconds for a complex decision. These times are for below-average drivers in unexpected situations, so they will cover the majority of drivers.

VEHICLES

Highway departments do not control the vehicle aspects that contribute to highway accidents. Other parts of federal and state government have that function. At the highway department level, the types of vehicles that use the road affect many road design decisions. For example, tractor-trailers need more room to turn than passenger cars.

Vehicles are grouped into classes called *design vehicles*. Some common design vehicles are passenger cars, single-unit trucks, buses, and several sizes of tractor-trailers. Select a design vehicle based on the largest vehicle that commonly uses the road. The smallest design vehicle for streets and highways should be the single-unit truck. This class includes fire trucks, maintenance trucks, heating oil trucks, etc. If a significant number of tractor-trailer trucks use the road, a larger design vehicle should be used.

Turning templates can be used to tell whether an intersection layout is wide enough for various design vehicles. A template for a single unit truck with a 30-foot wheelbase (SU-30) is shown in Figure 4. Templates are printed on clear plastic in common engineering scales. The template is placed on the plan sheet. If the lines showing the vehicle wheel paths cross the lines showing the pavement edges, then the intersection is not wide enough for that type of vehicle. The templates show the capabilities of a typical vehicle in that class, given a good driver. It is good practice to allow several feet on either side of the vehicle path as a buffer.

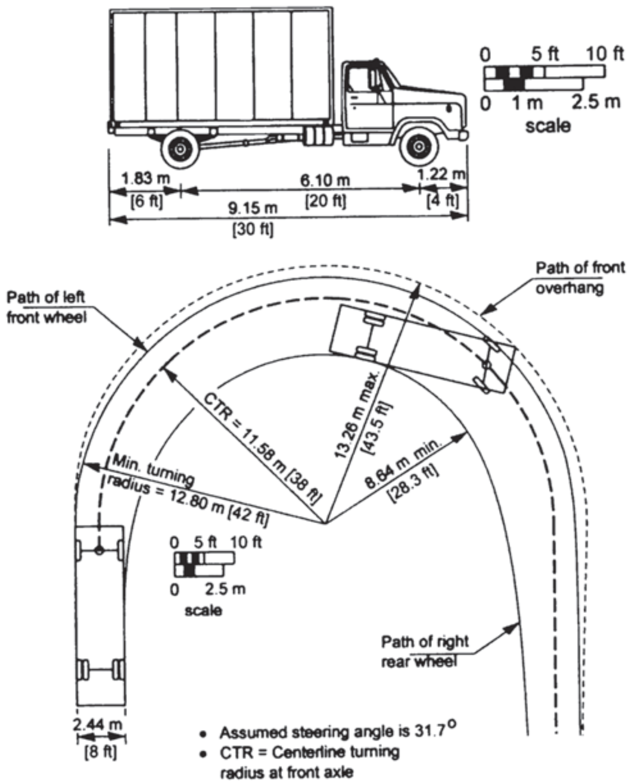

Figure 4 - SU-30 Turning template

Traffic volume

Roads with higher traffic volumes generally should get a higher priority than low-volume roads. More traffic volume means more crashes, since more vehicles and their drivers are exposed to potential hazards. In general, safety improvements are more cost-effective on roads with high traffic volumes, because the chances of accidents are higher. This does not mean that low-volume roads should be ignored. It just means that a treatment that would be appropriate on an arterial may not be cost-effective for low-volume roads.

Traffic volumes are linked to land use. Commercial, industrial, and residential land use generate more traffic than agricultural land.

Accident rates are strongly linked to traffic volume. Traffic volume increases as open land is developed. If your area is developing, then you can expect the number of crashes to increase. Minor problems that have not caused any crashes can become contributing factors to crashes as volumes increase. If “For Sale” signs start appearing on open land in your area, consider them warning signs. Traffic volume studies are discussed on page 18.

Traffic speed

Traffic speed is used in many traffic studies. It affects guiderail length, speed limit determination, and many design values like minimum lane width and curve radius. Ways of measuring traffic speed are discussed on page 18.

Other than continuous enforcement, few methods have been proven to reduce traffic speeds.

Drivers choose a speed they feel is appropriate for the road. Speed limits have little effect on traffic speeds. Speed bumps are not worth the noise they cause, or the damage they can cause to emergency equipment, vehicles, or your plows. "Traffic calming," or making changes to the road to encourage slower speeds, can be effective, but a professional engineer should design it.

ROADS AND THEIR ENVIRONMENT

To design a road to fit the needs, we need to know how it is used. These traffic characteristics include the types of traffic on the road, how many use the road on an average day, and how fast they travel.

Functional class

Roads are classified based on the role they play in the transportation network:

- Local roads primarily provide access to adjacent land. Through-traffic is usually a small percentage of total traffic.
- Collectors provide access to neighborhoods and carry traffic from local neighborhood road networks to arterials. They also provide access to adjacent properties.
- Arterials carry large amounts of traffic. They usually serve traffic traveling regionally. Intersections are generally at grade, but driveway access to adjacent properties may be restricted.
- Freeways are grade-separated arterials that primarily carry through-traffic. Junctions with other roads occur at interchanges. Driveways are not allowed. Interstate highways are freeways.

A road's functional class is a factor in design decisions. More design effort and money is spent on higher functional classes. For example, lanes on freeways are wider than lanes on local roads. If you are not sure what functional class a road belongs in, ask your NYSDOT Planning office or metropolitan planning organization (MPO) for assistance.

Land use

The way land is used near the road will affect traffic on the road, and the design of the road itself. Common examples are rural roads with light, high-speed traffic and ditches, or urban streets with congested, low-speed traffic, closed drainage, and curbs.

Land use affects the amount and type of traffic the road carries. Roads in agricultural areas should be wide enough for the farm machinery that uses the road. Commercial areas will get more trucks and may need wider streets. Residential neighborhood roads can be designed for slower speeds than rural collector roads.

One pitfall to avoid is classifying a road solely on land use. The amount and type of traffic has to be taken into account. A residential street that services a larger area may need to be classified as a collector or even a minor arterial.

Stopping sight distance

Stopping sight distance is the distance traveled from the instant a driver sees a problem until the vehicle stops. It is the distance taken up by the information, decision, and action phases of driving. In addition to reaction time, it takes time to stop once the brakes are applied. The driver needs to see objects in the road far enough away to come to a controlled stop before hitting them. Table 1 shows stopping sight distance on wet pavement. Because of gravity, braking distances are longer on downhill sections and

shorter on uphill sections. Sometimes, meeting the specified distances is not enough.
The reaction time used to calculate stopping sight distance is two and one half seconds. Where complex decisions or maneuvers are required, longer reaction times are needed. On slippery pavements or unpaved roads, braking distances are likely to be longer.

Table 1 - Stopping sight distance

Stopping sight distance (feet)							
85 percent speed, mph	Downgrades			Level	Upgrades		
	9 percent	6 percent	3 percent		3 percent	6 percent	9 percent
15	85	82	80	80	75	74	73
20	126	120	116	115	109	107	104
25	173	165	158	155	147	143	140
30	227	215	205	200	200	184	179
35	287	271	257	250	237	229	222
40	354	333	315	305	289	278	269
45	427	400	378	360	344	331	320
50	507	474	446	425	405	388	375
55	593	553	520	495	469	450	433
60	686	638	598	570	538	515	495
65	785	728	682	645	612	584	561

Based on the 2001 AASHTO "Green Book," pages 112 and 115.

Stopping sight distance for grades other than those shown in Table 1 can be calculated using this equation:

$$d = 4V + \frac{V^2}{30(0.34 \pm G)}$$

Where d is stopping sight distance, V is the speed in miles per hour, and G is the grade, expressed as a decimal (for example, 8 percent = 0.08). G is added for upgrades, and subtracted for downgrades.

Trucks need more distance to stop than other vehicles, but truck drivers can usually see farther because the seat is higher. On hillcrests, this is usually enough to compensate, but on horizontal curves, sight obstructions are often high enough that truck drivers cannot see over them. When horizontal curves occur on steep downhill sections, the higher driver’s eye height often is not enough to compensate for the longer stopping distances. In these cases, more than the minimum stopping sight distance should be provided.

On low-volume roads, less sight distance may be needed since the chances of a multi-vehicle accident are lower. For roads with less than 400 vehicles per day, see the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <400).

Stopping sight distance is measured using an average eye height of 42 inches and an object height of 24 inches (see Figure 5). On horizontal curves, stopping sight distance is measured along the center of the inside lane, as shown in Figure 6.

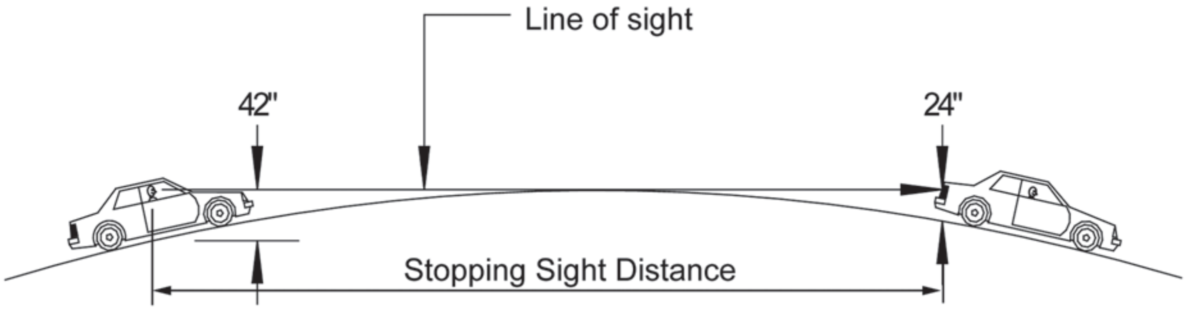

Figure 5 - Measuring stopping sight distance on a crest

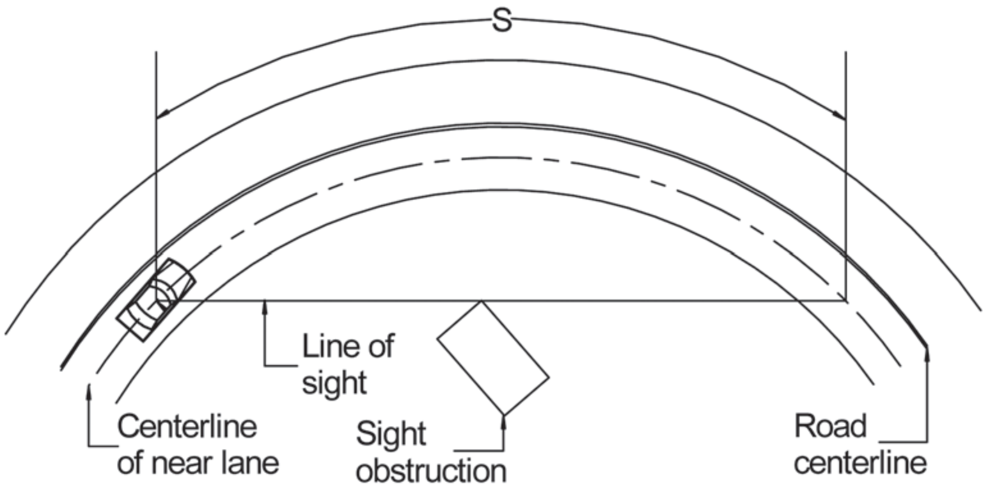

Figure 6 - Measuring stopping sight distance (S) on a horizontal curve

Intersection sight distance

Intersection sight distance is often longer than stopping sight distance. A driver at an intersection needs be able to see far enough to tell whether it is safe to proceed. In addition to traffic speed, the intersection sight distance depends on the maneuver being made (through movement, left or right turn) and the traffic control used at the intersection. Intersection sight distance is discussed in detail in Chapter 6: *Intersections, Driveways, and Railroad Crossings*.

Weather

We cannot control the weather, but we can make allowances for its effects. Road characteristics like good drainage, and skid-resistant road surfaces can reduce the number of poor-weather accidents, while poor drainage or slippery pavement will increase them. The Roadway and Roadside Drainage and Snow and Ice Control manuals published by the CLRP contain more information on weather and roads.

COMBINATION OF FACTORS

Detailed investigations of man-made catastrophes often show a chain of events leading to the incident. It is said that an incident happens when nine things go wrong, and a catastrophe occurs when ten things go wrong. Often breaking a link of the chain of events can prevent an accident.

Figure 1 shows that highway crashes are no different. In most cases where a road condition is involved in an accident, a driver factor also contributes to the crash. For example, a driver with poor night vision has trouble driving at night. Combining poor night vision with old signs could cause an accident. Retroreflective pavement markings and chevron signs in curves could help prevent an accident. Contributing factors in the same class can also combine, such as bleeding pavement on a curve.

OPPORTUNITY COST

You might wonder whether a traffic improvement plan is worth the cost and effort. That time and money could go into making improvements, rather than just planning them. The opportunities you give up when you choose an option are called the opportunity cost. If you choose to spend part of your budget on rebuilding a road, the opportunity cost is everything else you could have done with that money, but chose not to.

Consider the opportunity cost of not planning. What if you put that guiderail in a place it is not needed? Whether you use road safety audits or more traditional accident pattern analysis techniques, proper planning will help you avoid costly mistakes.

Once you have a safety improvement program in place, discuss it with your municipal insurance agent. You might benefit from a loss-control analysis that could result in lower premiums. You could even say that if you have had liability claims, feel you are likely to have future claims, or have to insure against claims, then you can afford to have a safety improvement plan.

2 - Solving Traffic Safety Problems

Because of limited resources, we need to apply the right solution to the right problem on the right road at the right time. This is where problem solving and planning come in.

When improving road safety, the first goal is to stop crashes from happening. That is why the emphasis for roadside improvements is on removing hazards rather than installing guiderail. The second goal is reducing the severity of accidents that do happen. When a roadside hazard cannot be removed or made safer, then guiderail is used to reduce crash severity.

IDENTIFYING AND SOLVING PROBLEMS

A basic method for solving safety problems is:

1. Identify the type of problem and determine contributing factors
2. Select a countermeasure:
   a. Which improvement offers the best results for the least cost?
   b. Will a possible improvement solve the problem, or just move it down the road?
   c. Will a possible improvement cause problems of its own? If so, are they worse than the problem you are trying to solve?
3. Install the countermeasure
4. Evaluate success
5. Return to Step 2 if necessary

You can learn of problems in several ways. Many times, it is a complaint from a citizen. If the complaint comes from a police officer, or it is in writing, you need to do something about it. In legal terminology, you have been given *actual notice* of a potential defect. Investigate the problem and document your decision even if you decide nothing can be or needs to be done.

The complaint may come in the form of a suggested solution, such as a traffic signal request. It is easy to ignore the complaint and deny the request because the person is not a traffic safety expert. Just because a bad solution is offered does not mean there is not a problem. Perhaps the person wants the signal to fix a sight distance problem, and all that is needed is some brush removal. You will not know unless you look. Be sure to document your action.

The best way to avoid constructive notice lawsuits is to find problems before someone else does. As discussed in the liability section, constructive notice means that there was a safety defect in the road that was obvious enough that the highway department should have known about it, but did not. Inspect your roads on a regular basis and after significant events like storms. Also, encourage your employees to report any potential problems they see. More information on road inspections can be found in the CLRP manual *Reducing Liability for Local Highway Officials*.

Emergency service personnel are a good source of information. Police and emergency medical technicians are often called to accident scenes. They may notice accidents tend to happen at certain locations. Remember that a report of a highway defect by a police officer is considered actual notice, even if it is not in writing.

The last way to find problem areas is through a highway safety investigation. These involve conducting a road condition survey and either an accident analysis, a road safety audit, or both.

Figure 7 - Skid marks often indicate problems

In this case, the curve in the road may make the intersection hard to see at night.

INFORMATION GATHERING

The best countermeasure will not work if it is used for the wrong problem. We have to gather the right information to understand the problem to get the best results. Information used in traffic safety studies is usually related to road conditions or traffic characteristics.

Condition diagrams

Condition diagrams are drawings, more or less to scale, that show the locations of curves, traffic control devices, fixed objects, etc. An example of a condition diagram is shown in Figure 8.

If you want to consult with another person, or refer to a manual, a condition diagram can help you to remember details about the location you are investigating. It also provides a record for later use, should another problem crop up nearby.

To prepare a condition diagram, you will need a measuring wheel (or a distance-measuring computer), a clipboard and paper, and a pencil. A tape measure may also be useful to measure offsets and lane widths. Start at a location that will be easy to find again, such as a cross culvert, and set the wheel to zero.

Walk towards the other end, and measure the locations of:

- Intersections and driveways
- Signs
- Fixed objects
- Lane widths

- Curve start and end points
- Crests and low points
- Any other significant feature

When you are done, make a drawing of the road and mark the locations of items you recorded. Remember that this diagram may be subpoenaed in a court case, so have a plan to remedy any defects you find. On the other hand, you could use the diagram to show a missing sign was there on the date of the condition diagram.

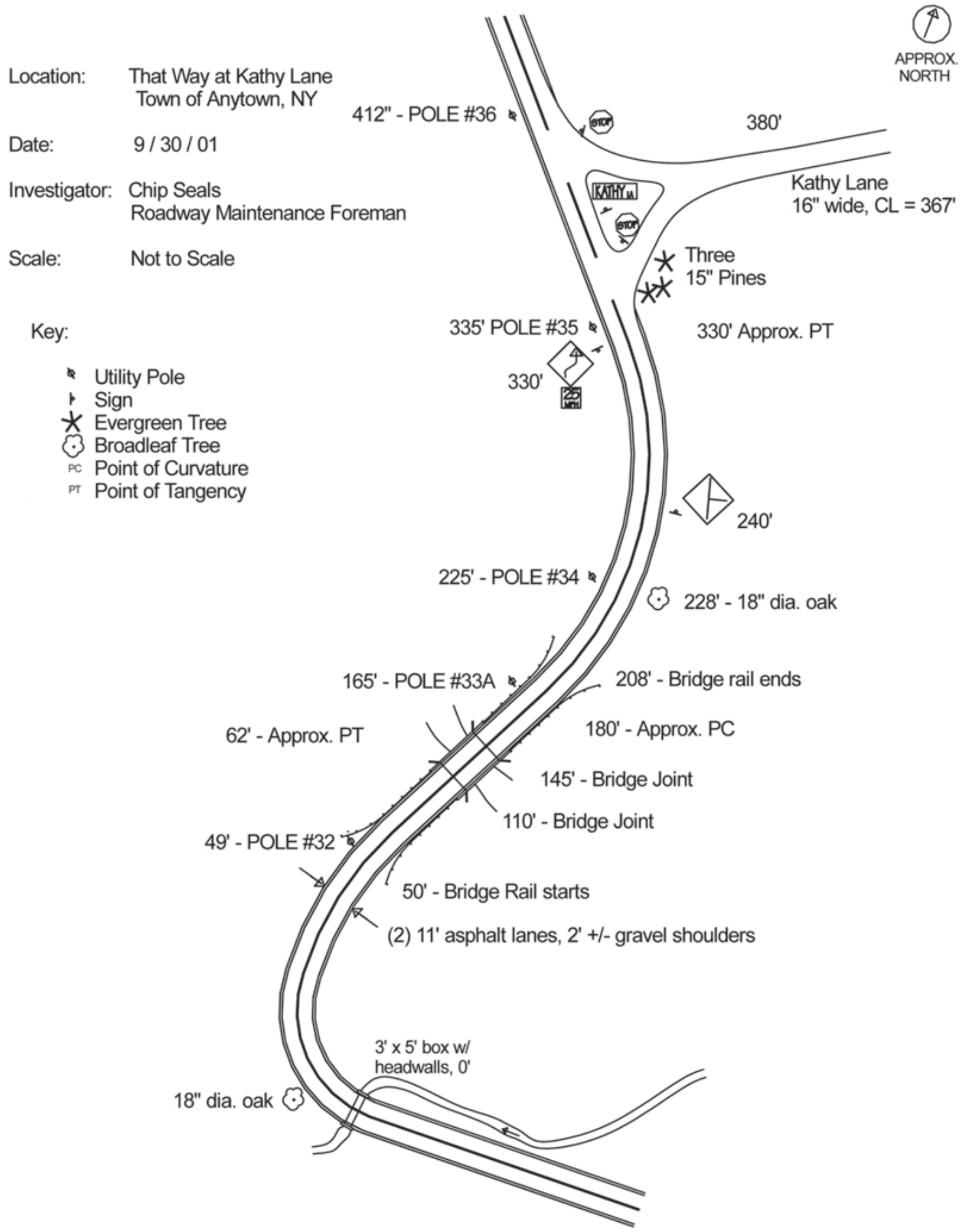

Figure 8 - Sample condition diagram

Traffic volume

The best way to measure traffic volume is with mechanical counters. If counters are not available, the peak hour traffic volume can be used to estimate the average daily traffic. This is easier than standing out on the roadside all day.

Estimating average daily traffic (ADT)

> In rural areas, peak hour traffic is usually about 15 percent of the total daily volume. In urban areas, it is usually about 11 percent. The peak hour often occurs between 4 pm and 6 pm. Divide that period into 15-minute increments, and count the number of cars that go by during each 15-minute increment. The peak hour is the four consecutive 15-minute periods with the highest number of cars. It may be 4:45 to 5:45, for example. Take the total number of cars during that hour and multiply by 7 for rural areas, or 9 for urban areas. That is usually close to the average daily traffic.

Speed studies

The *85th percentile speed* is used when making decisions about everything from curve design to speed limit determination. This is the speed at or below which 85 percent of all drivers drive at a particular location under good weather, visibility, and traffic volume conditions. In other words, 15 percent of traffic exceeds this speed. It assumes that most drivers are reasonably prudent and will not drive too fast for road conditions. The 85th percentile speed is sometimes called the *prevailing speed* or the *running speed*.

The 85th percentile speed can be measured with a police radar or laser speed measurement unit, but they can be costly. Since they will not be used for enforcement, expensive police radars are not needed. Non-enforcement radar units can cost less than $300. If radar is not available, and traffic volumes are moderate, you can follow other cars and note the speed they are driving. This should be done repeatedly to get a good idea of the range of travel speeds on the road.

To get a statistically valid measurement of the 85th percentile speed, the speed of at least 50 cars should be measured, and 100 measurements are desired. More measurements yield more accuracy. On low-volume roads or when using the car-following method, 50 observations may be impractical. You may be forced to make an estimate based on too few observations. Having some data is better than just guessing. For many traffic applications, the 85th percentile speed is rounded up to the nearest five mph, so high accuracy is not always needed.

Road safety studies

There are two main types of road safety studies. In a road safety audit, auditors examine a road, looking for potential trouble spots. Accident analysis uses police accident reports to determine what is causing accidents. They both have strengths and weaknesses, but they complement each other well.

Road safety audits

Over the past few years, a new tool has emerged to improve roadway safety. A road safety audit is a formal examination of an existing road, or a future road or traffic project by an independent team of specialists. The team assesses the safety of a roadway or project, and prepares a report that identifies potential safety problems.

Road safety audits are proactive. The team looks for problems before someone gets hurt. Unlike accident studies, road safety audits can be done at any stage in a road's life. They can be performed in the planning and design stages of a new project. A work zone plan can be audited to solve traffic problems. During construction, the road may be audited to fix problems before the project is completed. Lastly, an audit may be performed on an existing road, to help find and correct safety deficiencies.

The audit report usually gives some indication of the urgency of defects found. A minor defect in a location where a crash is unlikely will be given a low priority. A defect that could result in frequent, severe crashes will be given a high urgency. This helps you focus your resources in a cost-effective way.

Road safety audits do have a few disadvantages. The team may not spot accident patterns that would show up on an accident diagram. Choose team members carefully to avoid biases and make sure the team has the experience needed. An expressway designer may not be a good auditor on a gravel road.

Accident analysis

Accident analysis is a study of police accident reports, looking for common factors in accidents. It has some real advantages. If a lot of similar accidents have been occurring, the answer may be obvious. For example, if more than 40 percent of the accidents happen on wet pavement, look for slippery pavement or bad drainage.

On the other hand, accident analysis has some serious drawbacks. It cannot be done until several years after a project has been completed. Crashes have already happened, and people may have already been hurt. Also, it is only as good as the information in the police officers' reports.

More importantly for local agencies, it does not work as well on low-volume roads. Instead of three years of accident data, ten years or more may be needed before a pattern emerges. Currently, the local accident surveillance system does not precisely locate crashes off the state system that occur between intersections, but changes are planned to improve accuracy and usability of the system.

Other traffic studies

Depending on what information is needed, other types of traffic studies can be performed. Some of these include delay studies, intersection turning counts, or traffic signal studies. The Manual of Transportation Engineering Studies from the Institute of Transportation Engineers has information on many kinds of traffic investigations.

IDENTIFYING CAUSES AND CONTRIBUTING FACTORS

Identifying the cause of an accident pattern is like putting together pieces of a puzzle. Sometimes the cause of an accident pattern will be obvious. Run-off-road accidents on the outside of a curve, or wet pavement accidents are common examples.

Other times, the problem can be subtle. One case involved a nighttime accident pattern at the state line. Until an investigator happened to drive across the state line at night, no one realized that there was no transition from the brightly lit section on the Connecticut side of the line to the unlit New York side. If accidents are occurring during specific conditions such as rain or darkness, a site visit during those conditions can be helpful.

If you have an unusual accident pattern, look carefully at site conditions. One case involved a curve where vehicles were going off the road on the inside of the curve when the road was wet. The road had been repaved starting at the middle of the curve. As vehicles crossed from worn concrete to new asphalt, the sudden increase in traction caused them to veer towards the center of the curve. Had this been a two-way road, there probably would have been a related accident pattern of vehicles sliding off the outside of the curve as they crossed from asphalt to concrete.

To find patterns, look for similarities between accidents. Similarities in types of accidents, weather patterns, or other contributing factors may provide valuable clues to why accidents are occurring.

SELECTING A COUNTERMEASURE

Understanding what factors are contributing to accidents is the key to countermeasure selection. The countermeasure should be targeted at a particular crash type or contributing factor. The goal is to reduce the number and severity of accidents that occur.

There are no cure-alls for safety problems. No countermeasure works for all types of accident patterns. Traffic signals, for example, do not always reduce the number of accidents. They usually reduce the number of right-angle accidents. Rear-end accidents may increase or decrease after a signal is installed. If there have not been many right-angle accidents at an intersection, then an increase in rear-end accidents may be worse than the reduction in right-angle accidents.

NYSDOT and other agencies publish accident reduction factor lists that describe how much of a decrease you can expect after using a given countermeasure. For example, adding arrow signs or chevrons to a bad curve has resulted in 34 percent reductions in run-off-road accidents. Accident reduction factors can be found at *www.dot.state.ny.us/traffic/files/rftab95a.pdf*

Typically, simple and inexpensive solutions are considered first. Realigning a curve can result in a 79 percent reduction in run-off-road accidents, but it is very expensive. Curve and chevron signs are usually tried first. If they do not work well enough, then consider more costly options. This helps make sure the expensive options are saved for where they are really needed.

EVALUATING SUCCESS

After installing a countermeasure, make sure it is working. If you had a history of accidents before the change, compare the accident frequency before the change to the frequency afterwards, and see if it went down. If it did not, look into other countermeasures. You may find unintended consequences. For example, prohibiting left turns at an intersection may increase the number of left turn accidents at the next intersection.

If the number of accidents prior to work was small, observing traffic might be more useful than a before-and-after accident study. If you needed five years of traffic records for the “before” study, you may need at least five years before any conclusions can be made. After installing your countermeasure, watch traffic to see if fewer drivers make erratic maneuvers.

PRIORITIZING WORK

One of the hardest parts of developing a highway safety improvement plan is deciding where to start. At all levels of government from the smallest village up to the Federal Highway Administration (FHWA), the available funds are exceeded by the needs. Like road surface management, drainage, and everything else a highway department does, safety improvements need to be prioritized to make the best use of limited resources.

Could a list of prioritized safety improvements cause problems in a lawsuit? The plaintiff's attorney may argue that the plaintiff encountered a hazard that deserves a higher priority than it received. On the other hand, an ordering of priorities is a legitimate defense, if you have gone through the planning process to set priorities. If you do not prioritize, you will not know where to start, or defects will be fixed in a haphazard way.

Some factors that go into prioritizing safety improvements include:

- Existing safety problems
- Opportunity
- "Bang for the Buck" - how much will you get for your effort and money?
- Available resources - can you afford to spend the personnel time, equipment, and money for the project?
- Opportunity cost - could you solve a more important problem, instead?
- The first three factors tend to be important at the local level.

Existing safety problems

Safety problems should be organized in this order:

- Locations that have had frequent or severe crashes
- Locations where crashes occur occasionally
- Locations where crashes are unlikely

Severity is how bad the accidents are. Probability is how often accidents can be expected to occur in the future, usually based on the accident history of a location. If we combine severity and probability, we can arrive at a priority. Locations with frequent, severe accidents should get the highest priority. Infrequent, minor accident patterns can be given low priority. Infrequent severe accidents and frequent minor accidents are in between.

Table 2 - Priority based on severity and probability

	PROBABILITY		
SEVERITY	Frequent	Occasional	Improbable
Fatal	URGENT	HIGH	MEDIUM
Serious	HIGH	MEDIUM	LOW
Minor	MEDIUM	LOW	LOW

In addition to accident rate, locations where severe accidents occur should get high priority. Severity is a function of speed and the type of accident.

The risk of an injury in a crash increases with the speed squared, and the risk of a fatality is proportional to the speed raised to the fourth power. If the impact speed of a crash is doubled, the fatality risk is sixteen times higher, and the injury risk is four times higher. This is why it is considered when prioritizing safety improvements.

Some accidents are more likely to result in injuries than others. These accidents are often severe:

- Fixed object crashes (27 percent of fatalities in NYS, only 16 percent of crashes)
- Pedestrian accidents (23 percent of fatalities in NYS, only 4 percent of crashes)
- Head-on collisions (8 percent of fatalities in NYS, only 1 percent of crashes)
- Right-angle collisions (16 percent of fatalities in NYS, 16 percent of all crashes)

Opportunity

When planning or doing work, look around for potential problems. This will help prevent constructive notice lawsuits. It is hard to argue that you had no prior notice of a pothole if you cleaned the drain inlet right next to it.

Traffic speeds often increase after pavement work. The number of run-off-road crashes tends to go up after resurfacing, and since they happen at higher speeds, the crashes tend to be more severe. Look for opportunities to address safety during the project. Roadside hazards like too-deep ditches or fixed objects should be addressed along with the pavement. Chapter 5 covers these hazards.

Combining projects can also save time and money. For inexpensive projects like sign installations, driving to the site is a large part of the total cost. If you will be doing other work nearby, that cost is reduced.

Sometimes, working in an area requires you to make upgrades. Sidewalks are one example. Existing sidewalks are allowed to remain, but if you rebuild a sidewalk, you will be required to bring it up to current Americans with Disabilities Act (ADA) standards. Improvements may also be required if you rebuild the road next to the sidewalk.

"Bang for the buck"

It may seem heartless at first, but it often comes down to available money and resources. Economists and highway engineers use benefit/cost ratios to determine priorities. On one side of the equation are the benefits of the project. On the other are the improvement costs. Safety projects are intended to reduce the number or severity of accidents. These cost reductions are compared to the costs, such as design, installation, and maintenance.

Sometimes, a safety improvement will have accident costs of its own. A guiderail six feet away from the edge of the road will probably be hit more often than a tree that is twelve feet away, but collisions with a properly designed rail will be less severe than tree collisions.

An improvement will be cost effective if:

Reduction in crash frequency		Installation cost
Reduction in crash severity		Maintenance costs
+ <u>Reduced liability costs</u>		+ <u>Cost of more frequent, but less severe, crashes</u>
Total benefits	>	Total costs

Economists include various factors involving interest rates and inflation. These factors are used to compare the cost of an improvement today with an accident it prevents many years from now.

When you consider the costs of traffic accidents, it is easy to see that effective improvements can pay for themselves quickly. These costs are based on NYSDOT calculations:

Table 3 - Cost per accident

Accident severity	Average cost per accident
Property damage only	$5,000
Injury accident	$100,000
Fatality accident	$3,600,000

Putting it all together

With so many factors, prioritizing projects is not simple. Do you address the location with a high accident rate, or the one where you will be chip-sealing this summer? Let's say we have two accident problems we wish to treat, but we can only afford to do one of them. One is a curve that has had ten run-off-road accidents in the last year. The other is an intersection with ten right-angle accidents in the same year.

Using NYSDOT's accident reduction factors, arrow signs on curves reduce run-off-road accidents by 34 percent, and oversized stop signs reduce intersection accidents by 19 percent. The curve signs will probably reduce the run-off-road accidents to six or seven per year. The oversized stop signs will probably reduce the intersection accidents to eight per year.

We also need to look at accident severity. If there are no fixed objects on the outside of the curve, the right-angle accidents are probably more severe, so the accidents prevented by the oversized stop signs may be more serious.

If you will be installing street name signs because of 911, it will be a good opportunity to install oversized stop signs, since you will be doing sign work on the corners anyway.

When you prioritize safety work, document the rationale behind it. If you do not, it is hard to prove that your plan was well considered. Courts have accepted a legitimate ordering of priorities as a defense against liability claims. Documentation makes it easier to prove the priorities were legitimately ordered.

3 - Traffic Control Devices

Traffic control devices are your main means of communicating with drivers. They include signs, traffic signals, pavement markings, delineators, and work zone devices.

New York State's official regulation for the use of traffic control devices is a combination of the *National Manual of Uniform Traffic Control Devices* (National MUTCD) and the *New York State Supplement to the National MUTCD* (NYS Supplment). Taken together, they are commonly referred to as 'the MUTCD.' The NYS Supplement is published as *Volume 17B of the Official Compilation of Codes, Rules, and Regulations of the State of New York* (NYCRR).

The MUTCD describes all approved traffic control devices and their proper use. The MUTCD has ten chapters, called 'Parts', as follows:

- General Provisions
- Signs
- Marking
- Highway Traffic Signals
- Traffic Control Devices for Low-Volume Roads
- Temporary Traffic Control
- Traffic Control for School Areas
- Traffic Control for Highway-Rail Grade Crossing
- Traffic Control for Bicycle Facilities
- Traffic Control for Highway-Light Rail Transit Grade Crossing

The design of each device is described as well as how, when, where, and why to use it.

The MUTCD is required to be consistent with national standards, so national uniformity is promoted. Drivers who see a particular traffic control device should expect the same conditions and be prepared to take the same action whether they are on a town road in the Finger Lakes Region or on an expressway in Missouri. The MUTCD must be followed on all public roads in New York State. Nationwide consistency is the goal of uniform traffic control devices.

To foster this uniformity, the New York State Vehicle and Traffic Law (Section 1680 (c)) prohibits municipalities from purchasing or fabricating signs that do not conform to the current MUTCD or its amendments. Signs that are on hand, in place, or on order when a revision to the MUTCD is adopted, and that no longer conform, must be replaced as prescribed in the MUTCD. New York State adopted the National MUTCD with a NYS Supplement in September 2007.

To purchase Volume 17B of the NYCRR, contact West Group at 1-800-328-4880, or visit their website at *www.westgroup.com/store*. The National MUTCD, the New York State Supplement (NYCRR 17B), and other New York State Department of Transportation (NYSDOT) traffic control documents are available online at: *www.nysdot.gov/portal/page/portal/divisions/operating/oom/transportation-systems/traffic-operations-section/mutcd*

SHALL, SHOULD, AND MAY

Many parts of the MUTCD use the terms “shall,” “should,” or “may.” These words have specific meanings as follows:

> SHALL - A mandatory condition. Requirements having “shall” stipulations are mandatory. No discretion in following them is allowed.
>
> SHOULD - An advisory condition. Where “should” is used, it is recommended, and normally is to be followed, but is not mandatory. Deviation from such provision is permissible if, and to the extent, there is justifiable cause to do so. The reasons for any deviation should be documented and filed for future reference.
>
> MAY - A permissive condition. No requirement for design or application is intended.

PRINCIPLES OF TRAFFIC CONTROL DEVICES

For a traffic control device to be effective, it should meet these basic principles:

- Fulfill a need
- Command attention
- Convey a clear, simple meaning
- Command respect
- Give adequate time for response

If a traffic control device does not meet these basic needs, it may be ignored, misunderstood, overlooked, or otherwise not meet the need it is meant to fulfill.

PRIMACY

Primacy is the relative importance of the information on a sign, based on what would happen if a driver did not see it. This is used when two signs are supposed to be installed near the same place. The most important sign should get the most visible location, and other signs should be fit in around it. In order of importance, signs fall into these categories:

1. Warning signs and vital regulatory signs. Vital regulatory signs are Stop, Bridge Closed, and other signs that could have catastrophic effects if they are missing.
2. Other regulatory signs, such as speed limits or parking regulations.
3. Guide signs and route markers.

If a parking sign is supposed to be installed in front of an intersection warning sign, the warning sign would have primacy. The warning sign should be placed in the best position for visibility, and the parking sign should be moved to a location where it will not block a driver’s view of the warning sign. This may mean that the locations of other parking signs will have to be adjusted, since parking signs are supposed to be 200 feet or less apart.

SIGNS

Sign types

Regulatory Signs inform road users of traffic regulations and laws. They are used to control vehicle and pedestrian movements. They include stop signs, parking signs, speed limits, etc. Many regulations cannot be enforced unless the proper signs are in place. Regulatory signs can be used to remind drivers of statutory rules, but statutory rules do not need signs to be enforceable. For example, it is illegal to park a vehicle in front of a fire hydrant whether or not a sign prohibits it. To prohibit parking where it would otherwise be legal, "no parking" regulations and signs are required.

Use of traffic regulations is covered in the Vehicle and Traffic Law. To learn what authority your municipality has, see the following sections:

Cities and Villages	Article 39
Counties	Article 40
Towns	Article 41

Most regulatory signs are rectangles taller than they are wide. Exceptions include stop and yield signs. White, black, and red are most commonly used for regulatory signs.

If properly used and enforced, regulatory signs can promote smooth, orderly traffic flow. When they are not used correctly, they can often cause more problems than they solve. For example, unneeded stop signs cause unnecessary air and noise pollution. Drivers often disobey regulations they perceive to be unneeded. These drivers may develop a habit of disobeying traffic regulations, whether or not they are needed. Other roadway users may expect them to obey the regulation, and act accordingly. For example, a pedestrian may cross a street, expecting an approaching driver to stop at the stop sign. A serious injury could occur if the driver does not stop.

Figure 9 - Common regulatory signs

Warning signs are used to tell road users there is a need for caution because of a condition on or near the roadway. Warning signs are especially helpful to drivers who are not familiar with the road. Warning signs should only be used where needed, because overuse tends to cause disrespect for all warning signs, and reduces their effectiveness.

After you determine that a warning sign is needed, next consider whether the hazard can be removed. If is impossible or not cost effective to remove the hazard, then a warning sign should be installed. If you will remove the hazard eventually, a sign should be used to warn traffic of the condition until it is removed.

Warning signs are usually diamond-shaped, with black text or symbols on a yellow background. Road work warning signs should have orange backgrounds. An exception is the railroad crossing sign (W10-1). It is always round, and it always has a yellow background, even if used in a work zone.

Certain warning signs may have fluorescent yellow-green backgrounds. These include pedestrian, handicapped, bicyclist, and school signs. The use of fluorescent yellow green is currently optional on these signs. A change in the National MUTCD may require yellow-green signs to be used for school signs in the future.

Figure 10 - Common warning signs

Guide and information signs help drivers reach their destinations. They include route markers, destination signs, and information signs. They have green, blue, or brown backgrounds and white legends. Guide signs used in work zones should be orange with black legends.

Their role in traffic safety is to help drivers navigate to their destinations. By giving information to drivers when they need it, we can reduce the numbers of erratic maneuvers by drivers who suddenly realize they are going the wrong way.

Figure 11 - Common guide signs

Placement

Proper location of each sign is essential to obtain maximum visibility and effectiveness. The location of a sign must be compatible with the layout of the highway. Deviation from the MUTCD should be justified by an engineering study. If a sign is placed in a location other than what is shown in the MUTCD, document and file the reasons for this placement for future reference. Section 2A of the MUTCD provides general guidance on sign placement, and the section for each sign gives specific instructions for that sign.

All sign locations should be carefully checked to ensure that nothing obstructs the motorist's view of the sign and that nighttime visibility will be adequate. Avoid placing signs in dips, beyond hillcrests, or at other places where motorists would not see them soon enough to safely react. Make sure a new sign will not block the view of an existing sign. Always consider the possibility of a sign being obscured by parked trucks or summer foliage, or being a hazard to pedestrians.

Ground-mounted signs should be located on the right side of the roadway facing approaching traffic, unless another location is required or permitted. Signs in any other position should be considered supplementary to those in the usual location.

Lateral placement

Where conditions permit, signs on roads without curbs should have a lateral clearance of at least twelve feet from the edge of the travel lane to the near edge of the sign, or six feet from the edge of the shoulder, if the shoulder is more than six feet wide. When there is something in the way, or the sign will not be visible, signs shall be located as far from the travel lane as possible.

On curbed roads, the edge of the sign should be two feet or more from the face of the curb. The sign should be farther from the curb, if possible, to minimize the chance that it will be struck by vehicles. This is especially true on corners where trucks turn frequently. Take care to make sure the sign and signpost will not block a sidewalk.

Longitudinal placement and advance posting distance

The distance along the road from a sign to the condition, regulation, or action to which it refers is the longitudinal placement. Placement of signs along the highway depends on the type of sign, the nature of the message, and, for many signs, the prevailing speed.

The placement of signs in relation to each other is affected by sign type and highway characteristics. Signs should be erected individually, except when signs supplement each other. Signs should be at least 200 feet apart where possible. Signs at intersections and in built-up areas often cannot meet this spacing. On high-speed roads, longer spacing should be provided when possible.

Signs requiring decisions by the motorist should be sufficiently separated to provide adequate response time. Motorists react best when they are only required to make one decision at a time.

Where physical conditions limit visibility, the sign location should be adjusted. For example, a ground-mounted sign placed immediately beyond an overpass may not be very visible. Improve the sign's visibility and effectiveness by placing it before or well past the overpass. Guide signs can usually be placed beyond the overpass, but the distance between a warning sign and the condition it warns about should not be shortened. The reason for adjusted locations should be documented and filed for future reference.

Advance posting distance for warning signs is determined by the prevailing approach speed and the action required responding to the condition. These factors govern the travel distance needed for the driver to understand and react to the sign message, and perform any necessary action.

For purposes of determining advance posting distance, except in work zones, each warning sign is in one of three conditions. The MUTCD has tables that show where the sign should be placed for Condition A and B (see Table 4).

Condition A relates to locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical applications are Merge and Right Lane Ends signs.

Specific warning signs are used when drivers should be prepared to stop. Stop Ahead and School Crossing signs are examples of these, and are treated as a Condition B with an advisory speed of 0 (zero) mph.

Slippery when wet (W8-5), Traffic circle (W2-6), Soft shoulder (W8-4) are a few warning signs that may not have obvious associated advisory speeds. The previous NYS MUTCD used an advisory speed of 15 mph less than posted or 85th percentile speed for these types of warnings (Condition B signs).

More information on sign placement can be found in the MUTCD, the *Traffic Sign Handbook for Local Roads* or the Cornell Local Roads Program workbook *Traffic Signs and Pavement Markings*.

Height

There are several height criteria when installing signs. The MUTCD prescribes the minimum height of signs for visibility. In urban areas or other locations where other vehicles may block a driver’s view, signs should be seven feet above the edge of the roadway. In rural areas, five feet is enough. If the sign has a supplementary panel, the height of the bottom of the supplementary panel may be six feet above the roadway on urban areas and four feet in rural areas.

Another criterion is related to crash safety. Crash testing has determined that a sign is much less likely to come through the windshield of a car that hits the post, if the top of the sign is nine feet or more above the ground.

In sidewalks or other pedestrian areas, the bottom of the sign should be high enough that pedestrians are not likely to hit their heads on the sign panel.

The MUTCD does not specify the maximum height of signs. Sometimes, it is useful to place the sign higher than normal, so that it can be seen over a crest in the road, for example.

Size

The standard size for signs on two-lane roads is shown in the MUTCD. Other permitted sizes are shown for low volume and other types of roadways. Where standard size signs have not had the desired effect, larger signs may be used for added emphasis. First, check to make sure the existing sign meets the basic considerations listed above.

A person with 20/30 vision can read a standard highway sign 30 to 40 feet away for each inch of letter height. Symbol signs are often legible from a much longer distance, but they are sometimes harder to understand.

Table 4 - Guidelines for advance placement of warning signs (Table 2C-4 from the NYS Supplement to the National MUTCD)

Posted or 85th-Percentile Speed (mph)	Advance Placement Distance (ft)[1]																
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition[4]															
		0[3]	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
20	410	115	110	105	90	75	-	-	-	-	-	-	-	-	-	-	-
25	515	155	160	150	135	120	95	-	-	-	-	-	-	-	-	-	-
30	620	200	205	195	185	165	140	110	-	-	-	-	-	-	-	-	-
35	720	250	255	245	235	215	190	160	130	-	-	-	-	-	-	-	-
40	825	305	320	310	295	280	255	225	190	150	-	-	-	-	-	-	-
45	930	360	380	370	360	340	315	285	255	210	165	-	-	-	-	-	-
50	1030	425	455	450	435	415	390	360	330	285	240	185	-	-	-	-	-
55	1135	495	530	520	505	490	460	435	400	355	315	255	205	-	-	-	-
60	1280	570	605	595	585	565	540	510	475	435	390	335	280	220	-	-	-
65	1365	645	670	690	675	660	630	605	570	525	485	425	375	315	240	-	-
70	1445	730	785	775	765	745	720	690	660	615	570	515	460	400	325	260	-
75	1545	820	880	870	855	840	810	785	750	705	660	605	550	495	420	350	275

Notes:

1 The distances have not been modified to account for sign legibility.

2 Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are taken from the 2001 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E.

3 Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are taken from the 2001 AASHTO Policy, Stopping Sight Distance, Exhibit 3-1.

4 Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distances are determined by providing a 2.5 second PIEV time and a vehicle deceleration rate of 10 ft/second^2.

Retroreflectivity

Permanent traffic control devices shall be retroreflective so that they have essentially the same appearance day and night. Materials used for signs should provide nighttime visibility comparable to daytime visibility. Black portions of a sign face need not be reflectorized.

Often, washing a sign with a soft sponge and mild soap can restore retroreflectivity by removing dirt.

SIGNPOSTS

Signposts are one of the lesser hazards in terms of annual fatalities in New York State, but one that highway departments have direct control over.

One problem with signs is they must be close to the road to be visible. This conflicts with the clear roadside area that allows drivers who lose control to return safely to the roadway. To solve this problem, various types of breakaway post systems have been developed. These break away in a controlled manner when hit, allowing a vehicle to safely pass over or under the sign. Many times, the base post is undamaged and reusable, reducing the labor needed to repair the sign.

For breakaway signposts to work properly, the top of the stub must be less than four inches above the ground. There have been cases where high stubs have damaged fuel tanks and caused fires. Non-breakaway posts can actually cause a vehicle to roll over.

During your sign inventory inspection, check base-post heights in areas where erosion could occur. If enough soil washes away, a post that was installed correctly may become too high.

Figure 12 - Properly (left) and improperly (right) installed signposts

The post on the left has breakaway hardware, and the base post is less than four inches above ground level. On the right, the upper post is in front of the base post, and the base post is too high. This post will not break away as intended.

PAVEMENT MARKINGS

Pavement markings are used to guide and regulate traffic. They can improve the safety of a highway, and inform the driver without diverting attention from the roadway. This workbook only covers the basics of pavement markings. Consult the MUTCD for more details.

Pavement markings are useful for guiding traffic through sharp or multiple curves, delineating road width reductions and marking no-passing zones. They are especially useful in addressing run-off-road and crossover accident problems.

Pavement markings are required on roads with three or more lanes. They are recommended on:

- Two-way roadways 16 feet or more in width with prevailing speed over 35 mph
- Major through-highways
- Roads carrying significant traffic volumes
- One-way roads more than twenty feet wide

The MUTCD recommends pavement markings on rural roads that carry more than 3000 vehicles per day, and urban roads that carry more than 4000 vehicles per day. It requires them on urban roads that carry more than 6000 vehicles per day.

Pavement markings fall into three categories: long lines like center and edge lines, transverse lines such as stop lines and crosswalks, and special markings such as words and symbols.

Pavement markings must be reapplied as needed to maintain good visibility. Failure to do so can result in a liability risk to the municipality. Once the decision has been made to use pavement markings, maintenance must be continued to avoid the risk of liability, unless a formal engineering study shows the money is better spent elsewhere. The findings of the study should be documented and filed for future reference.

The effectiveness of pavement markings decreases as the markings wear. New markings provide much better guidance than worn ones, especially at night. The nighttime reflectivity of pavement markings is often lost before wear is apparent during daylight.

DELINEATORS

Reflective roadside delineators are used to guide traffic during darkness. Inclement weather affects delineators less than pavement markings, and delineators do not have to be replaced as often since traffic does not continually drive on them.

Delineators may be used along the whole road, or just where needed in curves or intersections. White delineators are used on both sides of two-way roads, and on the right side of one-way roads. Yellow delineators are used on the left side of one-way roads, and in the median of divided roads.

Delineators are normally placed between two and six feet past the edge of the shoulder or curb. They are mounted four feet above the roadway edge on lightweight posts. Normal spacing is 200 feet apart, but they should be spaced closer together on curves. Spacing on curves can be looked up in the MUTCD, or calculated with the formula 3 x R -50, where R is the curve radius in feet.

TRAFFIC CONTROL DEVICE MAINTENANCE

Installing a traffic control device means accepting a responsibility to maintain it. If the sign or pavement marking deteriorates to the point it no longer functions as it is meant to, it is a liability risk. Worn pavement markings and faded signs are of use to no one except lawyers.

Repairs should be prioritized based on the primacy of the sign, and its condition. Important signs, and signs in poor condition should be higher on the priority list.

If a device is no longer needed, it should be removed. This could be due to changing traffic patterns, changes to laws or ordinances, or perhaps it was ineffective to begin with. Removing a traffic control device requires careful consideration. Why is the device no longer needed? Is there something else you could install instead? Record the details, and keep them for future use. You may find yourself defending your action in the future.

Inventory

A complete inventory is one of the most useful tools for effectively maintaining your traffic control devices. It will help you plan and budget your maintenance efforts, and makes replacing missing signs easier. The initial inventory can be labor-intensive, but once it is done, it is easy to maintain, and worth the effort.

Inventories may be kept on a paper system such as index cards or a binder, or using computer software. The method you use should be flexible enough to add new signs and delete signs that are removed. Documentation of repairs is also useful.

Computer inventory systems also allow you to add information on sign condition, and, based on the condition and the primacy of the sign, prioritize repairs.

Figure 13 - Sign in poor condition

Important signs in poor condition, such as this stop sign, should get the highest priority for repair or replacement.

4 - Roadways

Figure 14 - The safety of a road is affected by its character and condition

APPROPRIATE STANDARDS

Many references can be used as road design standards. Examples include NYSDOT's *Highway Design Manual* or *A Policy on Geometric Design of Highways and Streets*, published by the American Association of State Highway and Transportation Officials (AASHTO). Although they contain information on local roads, they are largely written for designers of collectors, arterials, and freeways.

If the road carries less than 400 vehicles per day, the AASHTO book *Geometric Design Guidelines for Very Low-Volume Local Roads* may be used. The *Guidelines for Rural Town and County Roads*, by the Local Roads Research and Coordination Council, is also intended for low-volume roads. It is available from the Cornell Local Roads Program. The key is choosing the standard most appropriate for your roads and using it consistently.

It is important to remember that standards are not a replacement for good judgment. Meeting all the standards does not necessarily mean a road will be safe, and not meeting them does not always mean it will be unsafe. However, if judgment leads you to deviate from a standard, documentation is essential. Depending on the degree and type of deviation, the documented advice of a professional engineer may be warranted.

CONSISTENCY

Many traffic accidents occur at places where the road character changes. Transitions from straight to curved alignments, reductions in width, and borders between rural and built up areas are examples of character changes where accidents can happen.

Where possible, try to maintain a constant road width and character. Where a change in road character is unavoidable, use signs and pavement markings to warn drivers about the change and guide them through it. When possible, changes should be in locations where they can be seen. For example, curves should be located before hillcrests, not just over them.

Figure 15   Change in character

Accidents tend to happen at places where the road character changes.
Narrow points, like bridges, are one example.

CROSS SECTIONS

The cross section of a road is what you would see if you removed a slice across it and looked at it end-on. From a safety standpoint, we are interested in cross slopes, lane widths, shoulders or curbs, and roadside slopes. The last item is covered in Chapter 5.

Cross slopes

Cross slope refers to the slope of the road from side to side. Except in curves, the road should be higher in the middle than the edges to shed water. This is called the crown of the road.

Normal cross slope for paved roads is ¼ inch vertically per foot laterally (2 percent). Gravel roads should have a steeper cross slope, ⅜ to ½ inch per foot. Cross slopes that are too steep can be difficult to drive on in winter weather.

Lane widths

The lane width needed for a given road depends on the functional class of the road, and the amount and speed of traffic it carries.

For most roads, lanes should be between 10 and 12 feet wide. Twelve-foot lanes are standard for high-speed arterials. Collectors often get by with 11-foot lanes. Local roads can often operate safely with lanes 10 feet wide, unless they carry an unusually large number of trucks. For low-volume roads, nine-foot lanes can be acceptable. For more information, see one of the references listed under *Appropriate Standards* on page 35.

On curbed roads, an additional two feet of width is often added to the lane next to the curb. This helps keep vehicles from hitting the curb, or shying away from it towards the next lane. On roads with light traffic, it can provide room for bicyclists. On higher volume roads, more room should be provided for bicyclists, mail delivery, etc.

Widening narrow roads can result in big safety improvements. It can reduce the number of head-on, sideswipe, and run-off-road accidents. It also gives more room for trucks, agricultural equipment, and bicyclists. It is relatively expensive, so it is best used where there are safety or operational problems that it can help. It is easier to justify the cost if the road carries more than 1000 vehicles per day. Widening at intersections or tight radius curves, rather than the entire road, can be more cost-effective. See *Safety widening for curves*, page 40. For new roads and major reconstruction projects, the cost of wider lanes is often more reasonable.

Shoulders

On low-volume roads, shoulders are often unneeded. As traffic volumes and speeds increase, however, their value becomes greater. Some of the benefits of shoulders include:

- Allowing for driver error and providing space to make evasive maneuvers
- Increasing sight distance for through vehicles and for vehicles entering the roadway
- Providing structural support to the pavement
- Moving water farther from the travel lanes, reducing damage to the base and sub-grade, as well as reducing hydroplaning, splash, and spray
- Providing space for maintenance operations, portable maintenance signs, and snow storage
- Reducing conflicts between motor vehicles and bicyclists and pedestrians
- Making pedestrians more visible to motorists
- Allowing for easier turning from travel lanes to side roads
- Providing more room for turning trucks and providing space for off-tracking of truck rear wheels in curves
- Providing space for disabled vehicles, mail delivery, and bus stops

Shoulders can be graded, stabilized, or paved. On rural roads, consider providing two-foot wide shoulders. If a shoulder is intended to be used by pedestrians or bicyclists, it should be paved and four feet or more wide. Wider shoulders are used on higher volume and higher speed roads. See the NYS *Highway Design Manual* or AASHTO *'Green Book'* for more information.

Shoulders usually have a cross slope of ¾ inch per foot (six percent). If a shoulder is meant to substitute for a sidewalk, the cross slope should be ¼ inch per foot (two percent). On the outside of banked curves, reduce the shoulder cross slope to keep the difference between the lane cross slope and shoulder cross slope less than one inch per foot (eight percent). Differences more than eight percent can cause stability or control problems when a vehicle drifts onto the shoulder. For example, if a road in a curve is banked at four percent, the slope of the outside shoulder should be reduced from six to four percent or flatter.

Parking

In built-up areas, on-street parking can contribute to a lot of accidents, but removing parking will often anger local business owners and residents. In built-up areas like village and hamlet centers, replacing on-street parking with municipal lots can reduce accidents.

Angle parking is especially troublesome because drivers have difficulty seeing approaching traffic while backing out of a parking space. It should be limited to parking lots and avoided on roadways.

Parallel parking has fewer problems but still needs to be managed in developed areas. Parking should be prohibited near curves or other places where a vehicle cannot be seen while parking or leaving the parking area. Parking should also be prohibited in places where parked vehicles will cause visibility problems, such as near intersections or mid-block crosswalks.

Remember that ordinances or regulations are required to prohibit parking, except where it is already prohibited by the Vehicle and Traffic Law.

Curbs

Curbs have many uses. They can be used to channel storm water into drain inlets, or to control access to driveways. They can separate sidewalks from the rest of the road. Curbs should not be used on high-speed roads. They can vault a vehicle over a guiderail, or cause rollover accidents.

Non-mountable curb has a nearly vertical face. It is used to discourage drivers from leaving the roadway, but it will not prevent a vehicle from leaving the roadway intentionally, or through loss of control.

Mountable curb has a sloped face that still discourages drivers from leaving the roadway, but allows vehicles to drive over it at a slow speed.

The approach ends of curbs should start at ground level and gradually slope up to full height to reduce damage to snowplows and car tires.

SIDEWALKS

Sidewalks are used to provide a safe place to walk. They should be provided in built-up areas where walking is common. On slow and medium speed roads, sidewalks are usually used with curbs. Remember that curbs will not protect pedestrians from vehicles. A buffer space or planting strip between the sidewalk and the curb will provide a little more safety and comfort for pedestrians. This also provides room for snow storage. Since curbs should not be used on high-speed roads, a wide planting strip should be used to separate the street from the sidewalk.

Sidewalk layout is set by the *Americans with Disabilities Act Accessibility Guidelines*. Sidewalks should be at least five feet wide. They may be four feet wide, if an area five-foot square is provided every 200 feet. This allows wheelchair users, stroller pushers and others to pass each other. Sidewalks should have cross slopes of ¼ inch per foot. This allows water to drain off the surface, and is not steep enough to cause problems for wheelchair users.

Where curbs are used with sidewalks, ramps are required to allow wheelchair users to cross streets. Detectable surfaces are required on ramps so that blind pedestrians can tell where the sidewalk ends and the intersection begins.

The FHWA book *Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide* has more information on sidewalk and curb ramp design, as does Chapter 18 of the New York State *Highway Design Manual*. The responsibility for maintaining sidewalks is spelled out in the Highway Law.

ROAD SURFACE

A road surface management plan will add to your safety plan. Slippery pavements play a part in wet weather accidents. Slippery pavement is often caused by polished aggregate or bleeding asphalt. If more than about 40 percent of accident reports cite wet pavement, look for drainage or slippery pavement problems. Poor drainage, in addition to weakening the pavement, can contribute to accidents by causing hydroplaning. Rough roads decrease traction, and potholes and bumps can damage safety-related equipment like suspensions and tires. If severe enough, they can also cause loss-of-control accidents.

Loose dirt or gravel on the road surface can cause skidding or damage windshields. Loose gravel can be loose aggregate from the road itself. This can be reduced on chip sealed roads by using the right proportions and types of stone and emulsion, and by brushing loose aggregate after the emulsion sets. It could also be tracked onto the road from intersecting gravel roads or driveways. A paved apron on the first ten feet of an unpaved road or driveway can reduce tracking, and a thick bed of gravel can be used to clean tires at construction entrances.

CURVES

Curves are often locations of safety problems. Problem curves can usually be successfully treated with curve warning signs, road delineators, chevron signs, pavement edge lines and centerlines, or some combination of the above. More expensive measures like realignment can be used, but the less expensive ones should be considered first.

Some problems on curves to look out for:

- Sight distance problems caused by obstructions on the inside of the curve
- Fixed objects, especially on the outside of the curve. Don’t neglect the inside of the curve. Run-off-road accidents to the inside are less common, but they do happen
- Unexpected curves at the end of long straight sections
- Curves that get tighter (increasing sharpness or decreasing radius)
- Curves hidden by hillcrests

Delineating curves

The safety of problem curves can be improved with traffic control devices. The most common method is providing advance warning with a curve sign. Other methods work by giving more visual cues to drivers. These include post-mounted delineators, chevron or arrow signs, and pavement markings. These are especially helpful at night.

Delineating curves helps when evidence shows that drivers are having difficulty staying in their lane. The evidence could be skid marks, or a history of repeated, run-off-road, or crossover (head-on and opposite direction sideswipe) accidents.

Safety widening for curves

Widening the roadway or adding shoulders gives a second chance to drivers that find trouble in the curve.

Widening the travel lanes provides more margin of error for drivers, and allows trucks to go around the curve without having the back wheels encroach on the other lane or the shoulder. It is often more cost-effective than widening the entire roadway. As shown in Table 5 below, the width that should be added is a function of the curve radius and the speed of traffic. This table is for roads 20 feet wide.

The values in the table are the width added to accommodate single unit trucks on 20-foot roadways. If tractor-trailers are frequent enough to control design, see the NYS Highway Design Manual or AASHTO "Green Book." Usually, widening is not used unless the added width is at least two feet.

Table 5 - Safety widening for curves (feet)

	Approach speed (mph)						
Radius (feet)	30	35	40	45	50	55	60
1200						2.0	2.1
1000					2.0	2.2	2.4
900				2.0	2.2	2.4	
800			2.0	2.2	2.4	2.6	
700		2.0	2.2	2.4	2.6		
600	2.1	2.3	2.5	2.7	2.9		
500	2.4	2.6	2.8	3.0			
450	2.5	2.7	2.9				
400	2.8	3.0	3.3				
350	3.0	3.3	3.5				
300	3.3	3.3					
250	3.9						
200	4.6						

Source: NYS HDM, AASHTO

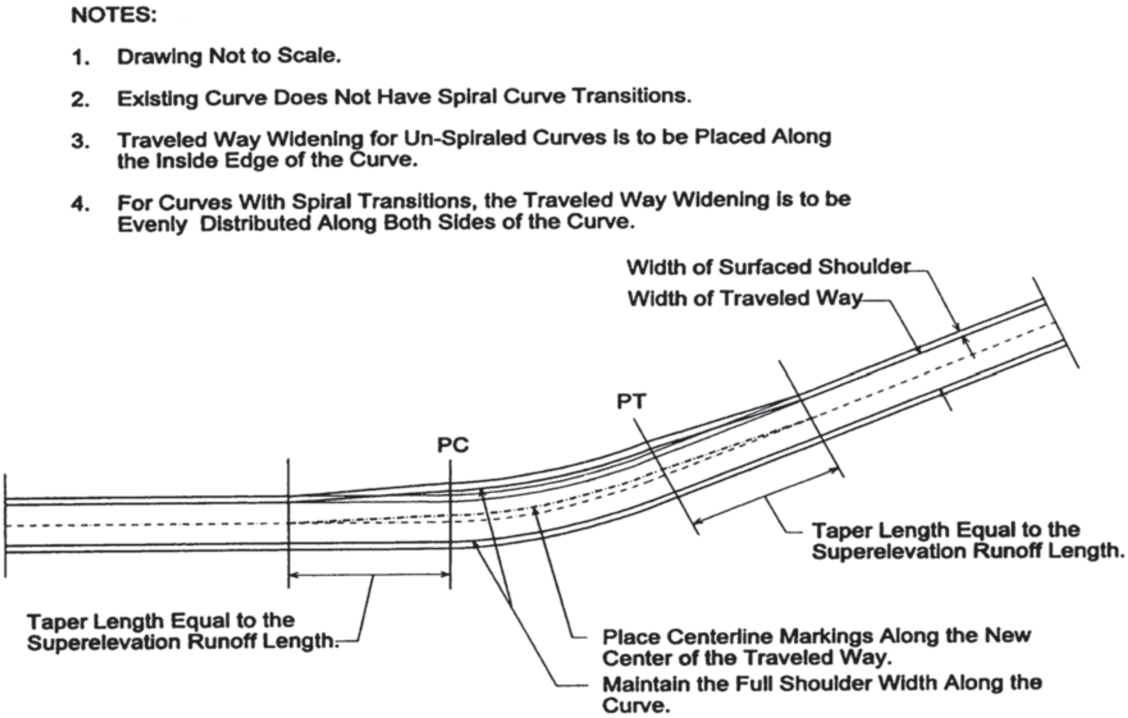

Figure 16 - Curve widening

Superelevation

By banking a curve so that the inside of the curve is downhill, gravity will pull the vehicle towards the inside of the curve. Combined with its forward motion, this helps the vehicle go around the curve.

The amount of banking used on a curve depends on the curve's radius and the prevailing speed of the road. Higher speed roads need more banking. Since there are so many possible combinations of radius and speed, tables have been developed for superelevation rates. These can be found in the NYS *Highway Design Manual* or the AASHTO "*Green Book*."

There is a practical limit in northern states like New York, because a steeply banked curve is hard to drive on during winter weather. Usually, curves are not banked more than six percent in rural areas and not more than four percent in urban areas.

Things to watch for when superelevating curves:

Transitions are needed to change the cross slope from normal crown to a banked curve. Making this transition too abruptly will result in bumps at the beginning and end of the curve. These bumps can be severe enough to startle the driver or cause loss of control. The transition length varies from 90 to 165 feet, depending on the speed and amount of banking. When only a short distance separates two curves in opposite directions, it can be difficult to provide enough transition length.

When banking is added to a curve with existing guiderail, the height of guiderail may need to be changed. Guiderail may not work properly if the rail section is too low or too high above the road. You may have to reset or replace the guiderail to use superelevation. Allowable guiderail heights are shown in Table 7, page 57.

Another problem with superelevation is the difference in slope between the travel lane and the shoulder. This is called the "rollover rate." If it is more than eight percent, it can destabilize vehicles that go onto the shoulder and cause an accident. For example, if a curve is banked at four percent, the cross slope of the shoulder on the high side should be reduced from the normal six percent to four percent or flatter.

Realignment

If less expensive methods fail, realigning the curve usually works. The design and construction costs will be high, since a professional engineer should design the new alignment, and right-of-way takings will probably be involved. A cost-effectiveness study is definitely worthwhile before starting a realignment project.

VERTICAL CURVES

Changes in grade are connected with vertical curves. Curves at the tops of hills are called crest curves, and curves in valleys are called sag curves. Crest curves occur where a steep climb becomes less steep, or a gentle downgrade becomes steeper. Sag curves occur where a steep downhill grade becomes less steep, or a gentle upgrade becomes steeper. A sharp crest vertical curve can block the visibility of other vehicles, objects in the roadway, intersections, and curves.

Cutting down a crest vertical curve usually requires full depth reconstruction, and may require right-of-way takings because of roadside cuts. Instead, signs that warn of road conditions on the far side of the crest can be used. These include Stop Ahead, Intersection Ahead, or Curve Ahead signs. Most signs can be moved to locations before the crest so they can be seen in time. Signs that cannot be moved, like stop signs or curve warning chevrons, can be mounted higher above the ground to make them visible over the top of the crest.

Sag vertical curves can cause problems at night, if headlights do not shine up high enough to illuminate the roadway ahead. This is not usually a large problem, since the lights of other vehicles should make them visible. If sag vertical curves cause problems at night, overhead lighting can help.

PAVEMENT EDGE DROP-OFFS

A drop-off at the edge of the pavement can cause accidents if a driver goes off the road. A substantial steering angle is needed to get the tires to climb back up the drop-off. Once the car is back on the pavement, this steering angle can send it careening into oncoming traffic or off the left side of the road.

The chance of a driver losing control depends on the height and the shape of the drop-off. Vertical drop-offs are more likely to cause a loss of control than sloped or rounded ones. Vertical drop-offs more than three inches high are considered hazardous to motor vehicles. Lower shoulder drop-offs can cause bicyclists to fall toward the travel lane.

The effects of pavement edge drop-offs can be reduced in several ways. Use a paved or stabilized shoulder where traffic continually wears away gravel or grass shoulders. In curves, the back wheels of trucks will often wear an unpaved shoulder away, creating a drop-off. Safety widening can prevent this. Building the pavement edge with a one-on-one slope reduces the steering angle needed to return to the pavement.

Figure 17 - Edge drop-off

Soft or loose shoulders can cause a similar effect, because of the sudden increase in traction when tires leave the shoulder and return to the pavement. Stabilizing or paving the shoulder can prevent this.

As an interim measure, W4-11 “Soft Shoulder” or W4-12 “Low Shoulder” signs should be installed until the condition can be repaired.

5 - Improving Roadside Safety

After collisions between motor vehicles, single vehicle collisions with roadside hazards cause the most fatalities in New York State. Roadside hazards include fixed objects such as trees and dangerous slopes.

Several strategies can be used to help reduce run-off-road accident problems:

- Help drivers stay on the road, using methods such as delineation and superelevated (banked) curves
- When drivers go off the road, prevent accidents by removing hazards or relocating them to a place they are less likely to get hit
- When accidents do happen, reduce the severity by making hazards traversable or breakaway, or shielding them with guiderail

This chapter discusses the latter two approaches. For more information on delineation and banked curves, see Chapter 3, *Traffic Control Devices*, and Chapter 4, *Roadways*.

DO YOU NEED GUIDERAIL?

When should guiderail be installed? You could install it everywhere there is a potential hazard along the side of the road, but that would be expensive. Or, you could install it in locations where run-off-road accidents have occurred. That means people may already have been hurt, and you may already be facing a lawsuit. A compromise is needed, so that guiderail will be installed where it will make a meaningful improvement to public safety without wasting public money.

The decision to install guiderail requires serious consideration. It is important to realize that guiderail can be a hazard in itself. In 1999, there were 121 fatal collisions with guiderail in New York State. Guiderail is meant to protect traffic from hazardous objects or slopes. It is better to remove hazards than install guiderail. If hitting the guiderail would be worse than hitting the hazard, then the guiderail should not be installed. Remember that the guiderail will probably be hit more often, since it will be closer to the road than the object it shields.

Installing guiderail means acknowledging a responsibility to maintain it. If you cannot make a commitment to inspect guiderails and promptly repair damage from crashes or corrosion, then consider other remedies instead.

A primary method used to determine whether guiderail should be installed is cost-effectiveness. If the costs (installation, maintenance, and costs of crashes with the rail) are higher than the benefits of guiderail (reduced crash severity), guiderail is usually not warranted.

So, do you need guiderail, or is a different treatment more appropriate? This chapter should help you answer this question.

CLEAR AREAS AND CLEAR ZONES

The *clear area* is the area alongside the road that is free from fixed objects or dangerous slopes. This area should be free from unyielding objects such as utility and light poles, trees or boulders. The ground should be relatively flat and gently graded. Rounded changes in slope will help a driver regain control of the vehicle and return to the roadway.

While the clear area is a description of the roadside, the *clear zone* is a commitment. On construction projects, highway agencies will declare that they will maintain a certain width of the roadside free from fixed objects or hazardous slopes.

The desired clear zone width depends on the nature of the road. It is based on factors like the amount of traffic on the road, the prevailing speed, the slope of the roadside, and the curvature of the road. On new roads, the desired clear zone width should be provided where possible. For more information on desired clear zone widths, see the AASHTO *Roadside Design Guide*, Chapter 10 of the New York State *Highway Design Manual*, or the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <400)*.

On curbed roads, obstructions such as utility poles or fire hydrants should be at least 1.5 feet from the face of the curb. Curbs will not prevent a car from leaving the road, so more than 1.5 feet should be provided behind the curb where possible. At medium to high speeds, the curb will tend to cause loss of control of a vehicle that hits it. Rather than keeping the vehicle away from the sidewalk, hitting the curb can make it turn towards the sidewalk. Because curbing will not protect pedestrians, a buffer area should be provided between the sidewalk and the curb.

On rural roads, traffic speeds are generally higher, so wider clear zones should be provided. The clear zone should be wider where the roadside slopes down and away from the edge of the road, and on the outsides of curves. Do not neglect the insides of curves. Vehicles do go off the road on the inside of curves, and fixed objects on the inside of curves can restrict sight distance.

For rural local roads, clear zones of seven to ten feet from the edge of the traveled way are desirable. For low-volume roads (ADT < 400), clear widths wider than seven feet are usually not cost-effective. On collectors and arterials, consult the AASHTO *Roadside Design Guide* or Chapter 10 of the New York State *Highway Design Manual*.

Existing clear area width

On existing roads, the desired clear zone width is often difficult to achieve because of right-of-way or terrain constraints, but improvements should be made where they are needed. Focus your efforts on locations where run-off-road crashes have occurred. The NYSDOT regional offices can supply municipalities with accident summary reports. Usually, three years of crash data are used, but on low-volume roads, five to ten years of crash data will probably be needed before problem areas become apparent.

After the existing problems have been treated, concentrate on areas that are likely places for accidents to happen. These locations include curves, downhill sections, and locations where the road character changes, such as reductions in width.

Types of run-off-road hazards

Run-off-road hazards generally fall into one of three types: roadside objects, roadside hazards, and slopes.

Roadside objects include fixed objects, and objects that may penetrate the passenger compartment. *Fixed objects* are relatively small unyielding obstacles such as utility poles, trees and boulders. Common fixed objects include:

- Culvert headwalls and bridge parapets
- Massive mailboxes or multiple single mailboxes close together
- Trees four inches or more in diameter, or smaller trees less than seven feet apart
- Cross culverts three feet or more across
- Parallel culverts (driveway or crossroad pipes) two feet or more across
- Other objects more than four inches high

Groups of mailboxes on a horizontal board are hazards because the board is at the same height as most windshields. When hit, it breaks free from the support posts and enters the car at about head height. This can cause severe, often fatal injuries.

Roadside hazards, such as rock cuts and guiderail, extend along the road for a significant distance.

Slopes are hazardous if they could cause a vehicle to roll over or launch it into the air. Side slopes are parallel to the road, such as ditch slopes or embankments. Transverse slopes are at an angle to the road, and include creek beds and embankments for other roads, driveways, or railroads.

Side slopes are split into three categories, depending on how steep they are:

- *Recoverable* slopes are flatter than one-vertically-on-four-horizontally. A driver has a good chance to regain control and return to the roadway.
- *Non-recoverable* slopes are between one-on-four and one-on-three. A vehicle on a non-recoverable slope will probably stay upright, but the slope is too steep to return to the roadway. The vehicle will end up at the bottom of the slope.
- *Critical* slopes are steeper than one-on-three. They should be avoided or shielded, since they increase the chances of a severe rollover crash.

Except for new construction or full reconstruction of a road, one-on-two slopes less than five feet high can be retained without guiderail. On the other hand, not much fill material is needed to flatten a low, steep slope to one-on-three, if right-of-way or adjacent landowners allow.

Transverse slopes are often found where side roads, driveways, and drainage channels intersect the highway. On high speed roads, these slopes should be gentle, so that they do not ramp an errant vehicle into the air.

TREATMENT OF ROADSIDE HAZARDS

When considering what to do with a hazard that reduces the available clear zone distance, ask these questions:

- Is the potential hazard dangerous?
- Can you remove the hazard?
- Can you relocate it to a place where it is less likely to be hit?
- Can you reduce the severity if the hazard is hit?
- If the hazard cannot be removed, relocated, or modified, will guiderail make the road safer?
- Would delineation guide drivers around the hazard?

Is the potential hazard dangerous?

If something on the roadside is a hazard, you should consider doing something about it.

- Is there an unyielding object in the clear zone?
- Is there an object in the clear zone that may enter the passenger compartment if struck?
- Is there a critical slope near the road?
- Is there an unyielding object at or near the bottom of a non-recoverable slope?

Look at the clear area for that stretch of road. If the obstacle or slope in question is closer to traffic than everything else nearby, then fixing it may improve the safety of the road. On the other hand, removing one tree from a 3,000-foot long woodlot will not make a big difference.

Can you remove the hazard?

The best option is to eliminate the hazard. For example, cutting a tree stump down to ground level will allow a vehicle to pass over it safely.

Can you relocate it to a place where it is less likely to be hit?

Moving an object farther from the road, or from the outside of a curve to the inside can reduce the chances that the hazard will be hit. Cross culverts can be extended to move the culvert end out of the clear zone, and utility poles can be moved farther from traffic. Extending culvert pipes can sometimes reduce the amount of water they can carry, so make sure you aren’t exchanging one problem for another. If the new pipe will be 50 feet or more long, get expert advice.

Can you reduce the severity if the hazard is hit?

If you cannot remove or relocate the hazard, try to reduce the severity of an impact. There are three main ways to do this:

- Signposts, light and utility poles can be installed on breakaway bases that reduce impact forces. Hardware has been developed that breaks in a controlled manner under impact, allowing the vehicle to pass under or over it.

- Drainage features can be made traversable, so that errant vehicles can drive over them. Grates can be placed over culvert ends to allow the vehicle to drive over the opening rather than falling into it (and also improving safety for your mower operators). Using traversable ditch foreslopes and backslopes can make ditches safer for an errant vehicle.
- Crash cushions and impact attenuators can be used to soften the impact with solid objects. These are rarely used on local roads, because the initial and maintenance costs are high.

Figure 18 - Culvert safety end section

The bars on this cross-culvert end section allow vehicles to drive over it rather than falling in. Photo courtesy of J & J Drainage Products.

Will guiderail make the road safer?

Remember that guiderail can cause injuries when struck. Guiderail should only be used where a collision with the hazard would be worse than striking the guiderail.

If a potential hazard intrudes into the clear zone and it cannot reasonably be removed, relocated, or modified to be crashworthy, consider providing guiderail. If it is a 'fatal at any speed' hazard (body of water, large propane tank, etc.) and it is reasonable to assume that an errant vehicle could reach it, provide a strong barrier system to shield it such as heavy post blocked-out corrugated or box beam.

Would delineation guide drivers around the hazard?

Signs, pavement markings, and post-mounted delineators are used to delineate, or outline, the edge of the road or mark hazardous conditions. Delineation helps guide prudent drivers around obstacles, although it does not help drivers who have lost control of their vehicles. Examples include chevrons on curves and object markers at narrow bridges.

If the hazard cannot be removed, moved, modified, or shielded with guiderail, then signs and delineation should be used to warn drivers that it is there. Delineation is especially helpful if accident records show frequent nighttime run-off-road accidents.

Delineation can be used instead of guiderail if hitting the guiderail would be more severe than hitting the object. It can also be used to make guiderail more visible. This is especially helpful when brown “rustic” rail is used.

Delineation can be a low-cost interim measure if guiderail installation is warranted, but will be delayed by budget, time, or personnel constraints. Just make sure the interim measure does not become a permanent one if guiderail is truly needed.

Is the treatment feasible and cost-effective?

This is probably the hardest question to answer. There is a point where the cost of an improvement is more than the accident cost savings that can be expected from it. Since guiderail needs a clear deflection zone behind it, it may be impossible to install guiderail without narrowing the road. On low-volume roads, the deflection distance of some guiderail systems exceed the desirable clear zone width.

GUIDERAIL

If you have concluded that guiderail is needed, the next step is designing it. There are several types of guiderail to choose from, and it is important to understand the advantages and disadvantages of each type to choose the one best for your needs.

Consider having a professional engineer design safety hardware like guiderail. This makes the qualified immunity defense more effective in court (see page 2).

Roadside hardware is tested to make sure it is safe and effective. The tests used are covered in National Cooperative Highway Research Program (NCHRP) *Report 350*. A 4,400-pound pickup truck is used to test the strength of the system, and an 1,800-pound passenger car is used to make sure that the system will not cause unacceptable injuries. NCHRP 350-compliant hardware is required on National Highway System roads, and a good idea elsewhere. A list of compliant hardware can be found at *safety.fhwa.dot.gov/programs/roadside_hardware.htm*

Slopes

When a vehicle goes off the top of an embankment, it will often become airborne. With the exception of cable, guiderail should either be installed at the top of the embankment, or twelve feet beyond the change in slope. Cable guiderail can be used on slopes as steep as one-on-six. If guiderail other than cable has to be installed on a fill slope, it must be at least 12 feet past the breakpoint (where the slope gets steeper). If guiderail is installed past the breakpoint but less than 12 feet past it, vehicles will probably go over the rail.

Guiderail and curb

When a vehicle hits a curb, it will usually bounce upwards. Even at moderate speeds, it can bounce high enough to vault the vehicle over the guiderail. Curb should not be used with guiderail if possible. If you need to place a guiderail behind curb, see Section 10.2.2.4 of the NYSDOT *Highway Design Manual*.

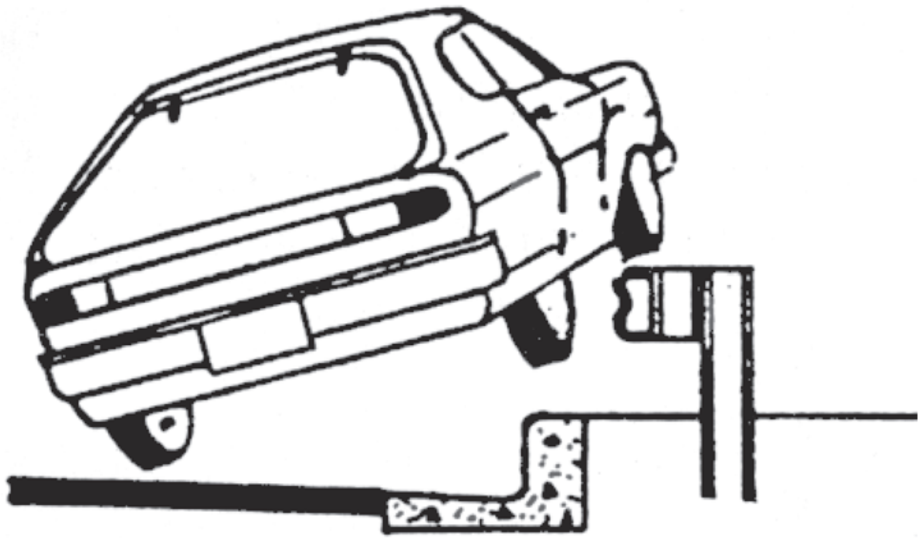

Figure 19 - Car vaulting over guide rail after hitting a curb

Deflection distance

Guiderails are generally classified as flexible, semi-rigid, or rigid. The class is based on the *deflection distance* of the rail. Deflection distance is the amount the rail can be expected to bend under impact.

Table 6 - Guiderail deflection distance

Rail class	Rail type	Post spacing	Deflection distance
Flexible	Cable	4’ 0”	7’
		8’ 0”	8’
		12’ 0”	10’
	Light post corrugated	4’ 2”	5’
		6’ 3”	6’
		12’ 6”	8’
Semi-rigid	Box beam	3’ 0”	4’
		6’ 0”	5’
	Heavy post, blocked-out corrugated	3’ 1.5”	2’
		6’ 3”	4’

Figure 20 - Insufficient deflection distance

As shown in Table 8, this guiderail will deflect up to 6 feet when hit. It will not prevent traffic from hitting the trees.

Flexible systems

Flexible guiderail systems include cable guiderail and weak-post corrugated (w-beam) guiderail. They tend to be forgiving when hit. They will deflect considerably under the impact, which reduces the impact forces on the vehicle occupants. On the other hand, they have some limitations.

When flexible systems are hit, the impact forces are resisted by tension in the rail. To resist the pulling force, large concrete anchors are embedded in the ground. Shovel and boxing glove end sections lack these anchors. So, not only are they hazards in themselves, they reduce the effectiveness of the rest of the guiderail.

Cable guiderail is the least expensive, but it requires a lot of maintenance. It loses effectiveness if cable tension is not maintained. After it is hit by a vehicle (or a wing plow), the whole length of the rail is ineffective until repair work is done. It should not be used unless a commitment can be made to maintain and repair it, especially on high-speed or high-volume roads. On the other hand, the cables are not always damaged by the crash. Often, only the posts and tension springs need to be replaced.

Cable rail deflects up to ten feet in a collision. Since it is a relatively soft system, vehicle occupants are less likely to get injured. On the other hand, this requires a lot of clear area behind the rail. On low-volume roads, if you have enough deflection distance for cable guiderail, you may not need guiderail.

Weak post corrugated guiderail is also inexpensive, but more expensive than cable. Impact damage tends to be more localized than a similar impact with cable guiderail.

At speeds over 42 miles-per-hour, light trucks (pickups and SUVs) tend to go over or through it, and vehicles can be vaulted into the air or flipped by the turndown end section. (A new design is being developed that will redirect light trucks.)

Corrugated guiderail can act as a snow fence and cause significant snow drifting on the road.

Semi-rigid systems

Semi-rigid systems include box beam and heavy post blocked-out guiderail. They deflect less than flexible systems. This means they are more likely to cause an injury in a crash, but they can be used when the hazard is closer to the road. Semi-rigid guiderail can also be set back from the road, reducing the chances of crashes. They are also more durable, and often remain serviceable after minor impacts.

Box beam guiderail is a six-inch square steel tube mounted on light posts. It gets its rigidity from the stiffness of this tube. The tube acts as a beam, spreading the impact force over several posts. Because of the way it works, it needs to be at least 125 feet long to function properly.

Box beam is the most expensive of the commonly used rails. Concrete barriers and the fancy wood-faced rails are more expensive.

Because of the stiffness of the rail, it cannot be curved in the field. Shop-curved sections are needed when the radius is less than 725 feet. This increases initial cost, repair cost, and repair time.

Heavy post blocked out (HPBO) corrugated guiderail uses the same corrugated rail sections as light post corrugated rail, but they are mounted on heavier posts. Blocks are used to hold the rail away from the post, because the posts are rigid enough that vehicles can snag on them. This could cause high impact forces or roll the vehicle over, increasing the chance of injury. Do not use heavy posts without the blocks. Plastic or wood blocks should be used because recent testing has shown that the thinner web sections of traditional steel blocks tend to collapse under impact and allow the vehicle to snag on the post.

HPBO corrugated guiderail can often take multiple impacts before losing effectiveness. Its rigidity increases risk to vehicle occupants. This decrease in safety may be offset by the added safety due to its durability. HPBO corrugated guiderail costs more than flexible systems (but less than box beam).

Rigid systems are concrete barriers. Their expense usually keeps them from being used on local roads, so they will not be discussed here.

Barrier length

Guiderail has to be long enough to protect traffic from the hazard it shields. The basic rules are simple, but design gets complicated quickly when curves, hills, and other common features are present. For this reason, we recommend having a professional engineer design rail installations.

Avoid short gaps. If another run of guiderail starts less than two-hundred feet away, combine the two rails into one longer rail. On two-way roads, the trailing end of the guiderail run has to be long enough to protect traffic that goes off the left side of the road.

For bodies of water, large stands of trees, or steep embankments that cannot easily be bypassed, the rail should be long enough that if a vehicle gets behind it will be able to come to a safe stop before reaching the hazard.

Terminals

Guiderail terminals have two main functions. First, they anchor the ends of the rail to resist the tension in the rail when the rail is struck. Second, they must also be crashworthy. Modern terminals used on high-speed roads are designed to absorb the impact and bring the vehicle to a controlled stop.

Many early terminal designs were severe hazards. These include the shovel ends and boxing gloves. If hit end-on, they would often puncture the vehicle and enter the passenger compartment, with severe results. They also do not anchor the rail very well, so the rail cannot withstand side impacts nearly as well as a properly anchored rail. The common practice of burying the end of the rail without an anchor reduces the impaling problem, but weakens the rail.

The best way to terminate a guiderail is to anchor it in a backslope. This can be difficult if the guiderail has to cross a ditch to get to it. The height from the bottom of the ditch to the rail must not exceed the limits in Table 7 (page 57). Vehicles that enter ditches tend to follow the ditch. The ditch will lead the vehicle into the guiderail, and, if it is too high, the rail may hit the windshield instead of the bumper.

TRANSITIONS

Transitions from one type of guiderail to another, or from guiderail to bridge rail have to be made carefully. Avoid sudden changes in stiffness or lack of continuity. Standard designs for transitions are available from NYSDOT.

PRIORITIZING ROADSIDE IMPROVEMENTS

To efficiently use funds and personnel, roadside improvements should be prioritized, based on the probability of a crash and the severity of a crash if one should occur. When setting priorities for roadside improvements, consider the probability of an accident occurring at that location, and the likely severity if a crash does occur.

Several factors affect the probability of an accident occurring. These include:

- Accident history
- Prevailing speed along the road
- Amount of traffic on the road
- Position of the hazard

Recurring run-off-road accidents at a location are a good indicator that there will be more. On higher volume roads, accident records show if accidents are already occurring there. Accident records are not as useful on lower volume roads. This is because crashes do not occur as often, and it may take many years of data for a pattern to become visible. A higher-than-expected pattern of similar crashes at the same location is called a *cluster*. Finding and correcting the cause of the cluster can improve safety.

Higher speed roads should receive a higher priority. At high speeds, drivers have less time to react and avoid a crash than at lower speeds. Vehicles that drive off the road will travel farther before coming to a stop, so a fixed object a given distance from the road is more likely to be hit on a high-speed road than on a low-speed road.

Higher volume roads should receive a higher priority, since crashes tend to happen more frequently on higher volume roads.

The position of the hazard is important because objects that are closer to the road are more likely to get hit. Also, improvements should be made where run-off-road crashes tend to happen. These include areas on the outside of curves and on downgrades.

The severity of crashes depends on the speed at impact, and the nature of the object that gets struck. More severe hazards should get higher priority than less severe ones. Accident severity increases sharply with speed. High-speed accidents are much more likely to be fatal than low speed accidents.

Some hazards can be fatal at any speed, such as propane tanks and other hazardous materials, cliffs and high, steep embankments, and bodies of water deeper than one foot (if the vehicle lands on its roof, the water need not be very deep to drown an incapacitated crash victim).

Other objects can be fatal at low speeds. These include spearing hazards like “boxing glove” or “dovetail” guiderail ends. Some objects, like horizontal boards holding multiple mailboxes, can penetrate through the windshield and cause fatal head injuries.

Massive objects that do not move can be lethal. Most run-off-road fatalities are in this category. Examples include overpass abutments and concrete or masonry walls, trees more than four inches in diameter, and embankments more than a few feet high and steeper than one-on-three.

MAINTENANCE

Good maintenance is as crucial to safety as good roadside design. A roadside barrier will not function if it is badly corroded or damaged by crashes. Equally important, roadside safety improvements should be maintainable. This section presents some tips for maintaining roadsides.

Roadside Maintenance

Roadside clear areas need to be managed to prevent tree growth. They should be mowed once a year, unless more is needed for drainage or sight distance reasons. Also, the areas behind guiderails need to be mowed to prevent trees from growing in the deflection zone (see Table 6, page 51).

Be careful when cleaning ditches. Do not make the ditch deeper than it needs to be, and keep the foreslope and backslope as gentle as possible. Rounded changes in slope help keep vehicles from becoming airborne or unstable, and make it easier for the driver to regain control.

Encroachments by adjacent landowners can be a serious cause for concern. Dangerous mailboxes, landscape boulders, or planters can create serious hazards to the public. If they are in the right-of-way, the municipality can force the landowner to remove them, or remove them with municipal forces and bill the landowner. If they are on an adjacent property, consult with your municipal attorney before acting.

Figure 21 - Poor rail type transition

The flexible cable will deflect enough to direct a vehicle into the unyielding bridge rail.

Guiderail maintenance

Damaged guiderail may not function as designed. In addition to crash damage, corrosion of steel posts and rails, and rot in wood posts can reduce the strength of the system.

Periodic guiderail condition inventories will help catch guiderail problems before they get out of hand. They should be supplemented with regular patrols looking for problems in general. Things to look for include:

- Crash damage
- Insufficient deflection distance (see Table 6, page 51)
- Too high or too low (see Table 7, page 57)
- Rail too short
  - Does not protect traffic from the hazard
  - Box beam under 125 feet long
- Discontinuities
- Poor transition from one type to another (sudden change in stiffness). See Fig. 21, above.
- Rail behind curbs
- Obsolete and nonstandard rail types, such as:
  - Cobbled-up, non-standard rail
  - Rail mounted on concrete posts
  - External-splice box beam
  - Four-strand cable

- Obsolete end sections
  - Boxing gloves and dovetails
  - No end section
- Condition of rails and posts
  - Rust
  - Rot in wooden posts
  - Loose bolts
  - Cable tension

Table 7 - Acceptable heights for guiderail

Barrier type	Normal Height (inches)	Acceptable Heights[1,5]	
		Max. inches	Min. inches
Cable[2]	27	30	24
W-beam (weak post)[3]	30	33	27
W-beam (heavy post)[3]	27	30	24
Box beam[3]	27	30	24
Concrete (NJ shape)[4]	32	32	30

Notes:

1. Height is normally measured from the ground directly below the barrier. Measure from the pavement surface if curb is present within 12 inches (300 mm) of the railing.
2. Measured at the center of the top cable at the mounting point.
3. Measured at the top of rail at a post.
4. Measured at the top of the barrier.
5. Measured after resurfacing, when applicable.

When repairing guiderail, keep in mind the questions for treating roadside hazards. If you can remove the need for the rail and the rail itself, you can make the road safer and there will be one less guiderail for you to maintain. When removing a guiderail, consider getting the written concurrence of a professional engineer to help protect you from any future lawsuits.

An advantage of using standard guiderail types is its parts will be available for a long time, making repairs easier. If not, you may be forced to upgrade it to current standards. Rail that is too high or too low can be removed and reset at the proper height, if it is otherwise in good condition.

DITCHES

Drainage is an essential part of a road. Without proper drainage, the road will quickly deteriorate. This can become a safety problem in itself. In rural areas, ditches are often used to carry water away from the roadbed. When ditch slopes become too steep, ditches become safety problems.

To be effective, ditches need to be deep enough to handle the water that flows through them. Sometimes, this conflicts with safety. The foreslope can be steep enough to cause a rollover accident. If the vehicle stays upright, the collision with the backslope could be severe enough to cause injuries. If the front bumper digs into the backslope, a car can be spun around in a very violent manner.

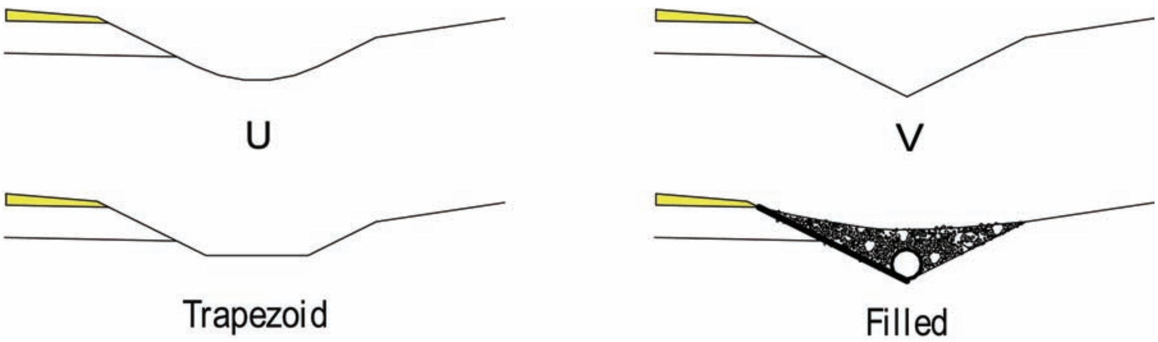

Figure 22 - Ditch types

Flat-bottomed ditches and U-shaped ditches can be effective and safe. The bottom reduces the chance of a collision with the back slope, and these ditches are hydraulically efficient. V-ditches are easy to construct, but hard to maintain. They are prone to erosion, which causes silt problems downstream, and makes the ditch less safe for vehicles that enter it.

If a ditch with gentle foreslopes and backslopes cannot be built within the right-of-way, a filled ditch with an underdrain could be used. This can also be used to provide room for a shoulder where one is needed when right-of-way is not available.

Figure 23 (page 59) shows preferred cross sections for ditches. Ditches that fall in the shaded area are considered reasonably safe.

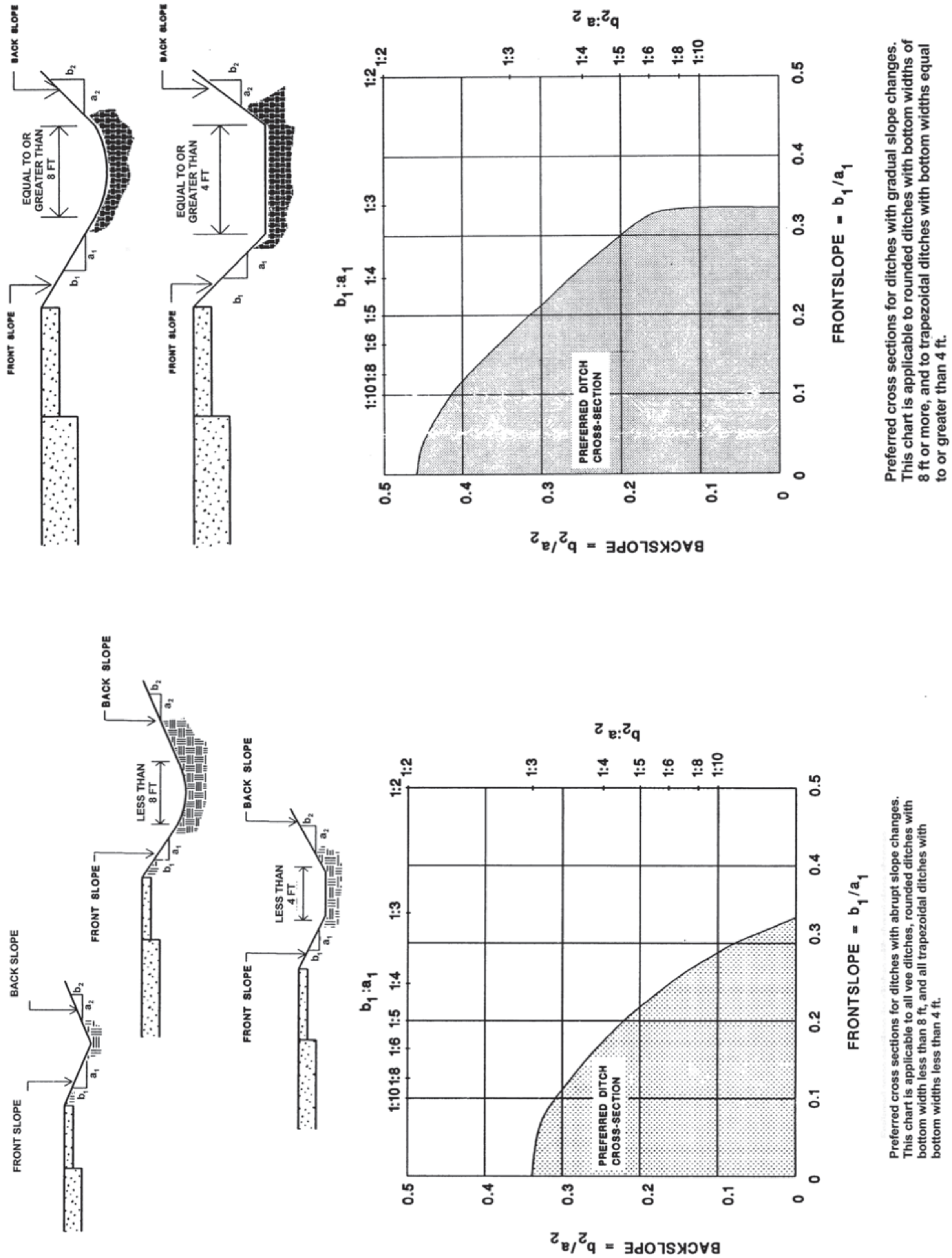

Figure 23 - Preferred ditch sections

6 - Intersections, Railroad Grade Crossings and Driveways

Conflicting traffic flows are inherent problems at intersections, driveways, and railroad crossings. Intersections are the second most common place for fatal accidents, after single vehicle roadside crashes. The severity of railroad crossing crashes raises the importance of grade crossing safety.

INTERSECTIONS

Intersections are often safety trouble spots because they are places where vehicle paths cross. This increases the likelihood of a collision. Often, poor intersection layout contributes to safety problems. These problems may not show up at low volumes. If your area is developing, intersections that have been relatively safe may start to have problems.

Intersections can be classified by how many roads enter the intersection. There are three-leg or T-intersections, four-leg intersections, and multi-leg (five or more leg) intersections.

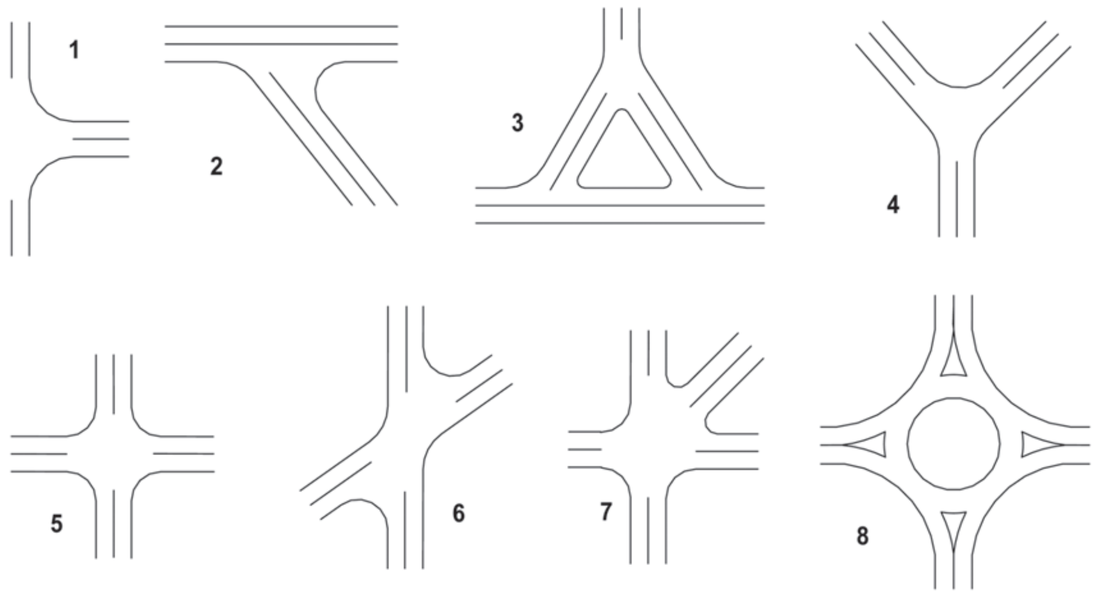

Figure 24 - Intersection types

1. T-intersection	*2. Skewed-T*	*3. Channelized-Y*	*4. Y-intersection*
5. Four-leg	*6. Skewed four-leg*	*7. Multi-leg*	*8. Roundabout*

Channelized-Y, skewed, and multi-leg intersections often have safety or operational problems.

Three-leg or T-intersections are often safer than four-way intersections because there are fewer conflict points where accidents take place. If a new road is being built across from a three-leg intersection, it should be at least three hundred feet from the existing intersection. If that is not possible, it should be built directly across from the existing intersection, turning it into a four-leg intersection. If opposite approaches to an intersection do not line up, the intersection is offset. Depending on the direction of the offset, this can cause safety problems, or disrupt traffic flow. Intersections less than 30 feet apart are considered one intersection for traffic control purposes.

Intersections with five or more legs often create problems because it is hard for drivers to watch that many conflicting traffic flows all at once. Sometimes, one of the legs can be relocated, turning a five-leg intersection into a four-leg intersection with a nearby T- intersection. This may be cost effective if safety or delay problems are occurring.

If the intersecting roads meet at an angle other than 90 degrees, the intersection is called *skewed*. This can cause problems. First, drivers will have to look over their shoulders to see approaching traffic. This can be difficult for older and disabled drivers. Second, it increases distance across the intersection, and therefore the time it takes for cross-traffic to clear the intersection.

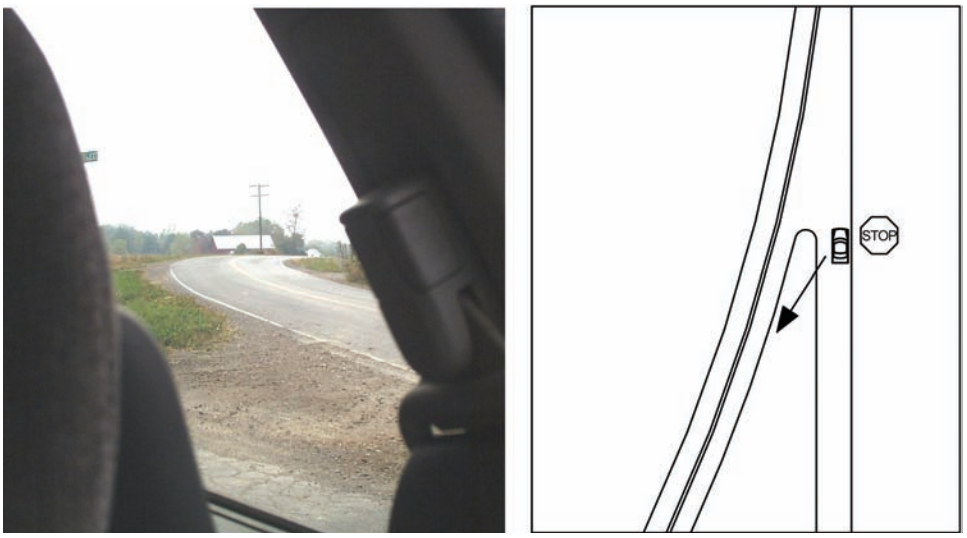

Figure 25 - Skewed intersection

To see oncoming traffic at this intersection, drivers must twist around and look out the car's rear side window. This is difficult for older drivers and persons who have had neck or back injuries. The photograph was taken at the location shown on the drawing, looking in the direction of the arrow.

To avoid these problems, intersections should be built so that the corner angle is between 75 and 105 degrees. Merging traffic flows are an exception. They should meet at 1 to 3 degrees.
The idea is that drivers should be able to see conflicting traffic through a front side window or the mirrors. Intersection angles between 3 and 75 degrees do not permit this. This is a problem with many channelized right turn lanes. Existing intersections can be rebuilt to reduce the skew to less than 75 degrees.

Many older three-leg intersections have a triangular island in the middle. These are called *channelized-Y intersections*. They often have high accident rates. The corner angles are part of the problem, since a channelized-Y intersection is essentially three skewed intersections. Drivers have difficulty turning to see conflicting traffic. Channelized-Y intersections can often be rebuilt as T-intersections or roundabouts within the existing right-of-way.

Right-turn roadways are added to increase the traffic capacity of an intersection. This is not the same as a channelized Y. If properly designed, turn roadways can add capacity and work safely. Like any other intersection, the skew angle should be less than 60 degrees.

Corner radius is a good example of a balancing act inherent in roadway design. A larger radius can reduce rear-end collisions with right-turning vehicles because it allows the turning vehicle to get out of the way of following vehicles more quickly. On the other hand, wide open intersections with very large corner radii create problems. Large corner radii increase the distance pedestrians need to cross. This increases their exposure to traffic. It can also be difficult to place stop signs where they can be seen, and the intersection layout does not guide drivers to where they should go.

In general, the radius should be large enough for the most common type of heavy vehicle that uses the intersection. Thirty feet is usually enough for school buses and straight trucks.

Tractor-trailers need more. In rural areas, more can be beneficial. In areas where pedestrians are common, larger radii should only be used where needed for large trucks.

Intersection Sight Distance

As a driver approaches an intersection, several different types of sight distance come into play:

- Stopping sight distance to the intersection (see page 13)
- Approach sight triangle to the intersecting road
- Intersection sight distance

Drivers on through-roads approaching intersections need to see far enough ahead to stop safely if a vehicle on the side road makes an unsafe move. This is called *stopping sight distance* and is discussed in Chapter 2.

The sight triangle affects the traffic control used at the intersection. If traffic on the side road can see traffic on the main road from far enough away, yield signs can be used instead of stop signs. Section 211.2 of *Volume 17B* covers how to choose between stop signs and yield signs.

Drivers stopped at an intersection need to see far enough to tell if there is a large enough gap in traffic to safely pull out into the intersection. This is called intersection sight distance. The amount needed depends on the type of intersection control and the maneuver being made.

Two-way stop control: use Tables 8, 9, and 10.

All-way stop control: a driver on one leg needs to be able to see the first stopped vehicles on the other legs of the intersection.

Traffic control signals: use Table 10 for left-turning traffic at traffic signals, unless left turns are only allowed during a left green arrow. Otherwise, a driver on one leg needs to be able to see the first stopped vehicles on the other legs of the intersection.

Table 8 - Sight distance for left turns and crossing maneuvers

	Sight distance along major road for left turns or to cross major road (feet)			
	30 mph	40 mph	50 mph	60 mph
Passenger cars	325	450	560	660
Single-unit trucks	425	560	710	840
Tractor-trailers	510	680	850	1000

Table 9 - Intersection sight distance for right turns for two-way stop control

	Sight distance along major road for right turn (feet)			
	30 mph	40 mph	50 mph	60 mph
Passenger cars	300	390	480	580
Single-unit trucks	380	510	620	760
Tractor-trailers	475	620	775	925

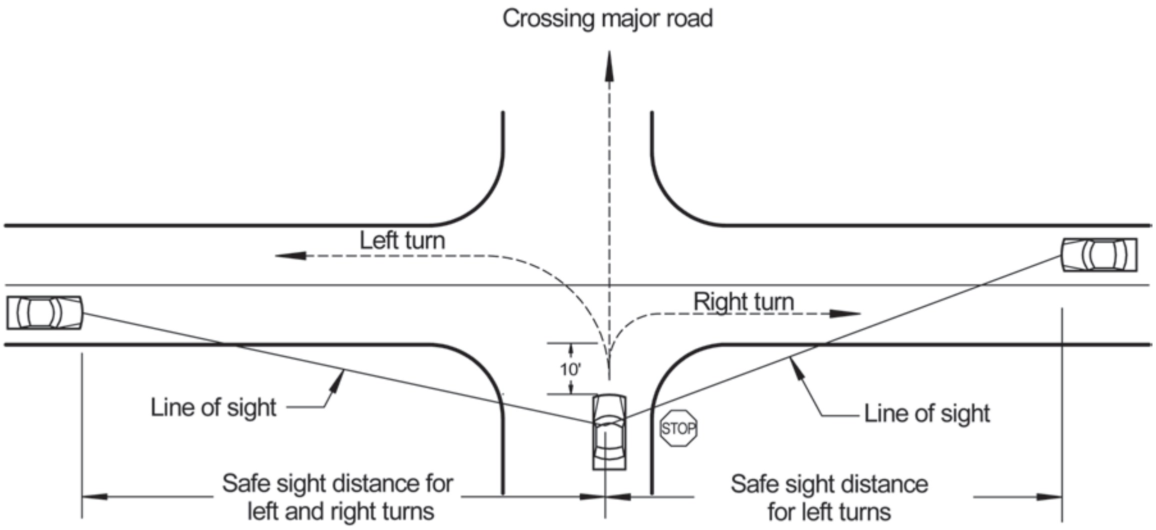

Figure 26 - Sight distance at intersections

Table 10 - Sight distance needed for left turns off the major road

	Sight distance needed for left turns off the major road (feet)			
	30 mph	40 mph	50 mph	60 mph
Passenger cars	245	325	405	490
Single-unit trucks	290	385	480	580
Tractor-trailers	335	445	555	670

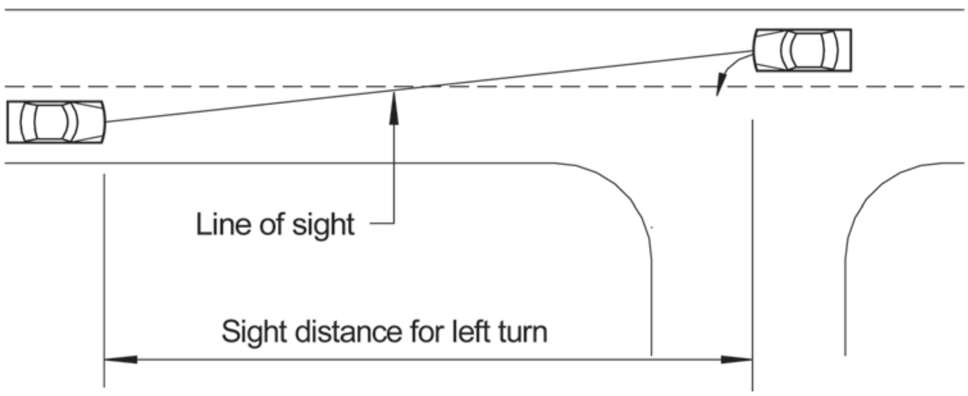

Figure 27 - Sight distance needed for left turns off the major road

INTERSECTION CONTROL TYPE

Because vehicles cross paths at intersections, some form of traffic control is usually used to assign right-of-way.

No control

Where sight distance is good and volumes are very low, uncontrolled intersections may be a viable choice. They may even be safer than stop-controlled intersections at low volumes. Drivers may be more likely to run a stop sign if they know that the chances of a vehicle coming the other way are small. They are more cautious if they know that the other driver does not have to stop. On the other hand, since uncontrolled intersections are becoming less common, drivers may assume that, since they do not have a stop sign, the other driver must have one. If accidents are occurring, drivers cannot see vehicles on other approaches to the intersection, or if total volumes exceed about 150 vehicles per hour, traffic control should be provided.

Yield control

If volumes are more than 150 vehicles per hour, uncontrolled intersections may not work well. If sight distances are good, yield signs can be used. Yield signs do not require traffic to stop unless it is necessary to yield to another vehicle, and therefore cause less delay than stop signs. Often, drivers need only adjust their speed to yield to another vehicle, not come to a complete stop. The yield signs should be installed on the minor road. The MUTCD specifically prohibits all-way yield control.

If sight distance is not good enough for a yield-controlled intersection to operate safely, stop control should be used. *The Traffic Sign Handbook for Local Roads*, available from the Cornell Local Roads Program, covers how to choose between stop signs and yield signs.

Stop control

Stop control may be necessary because of sight-distance restrictions, traffic volumes on the intersecting street, or unusual conditions at the intersection. They can improve safety by assigning right-of-way and reducing the number of right-angle collisions at an intersection, at the expense of some disadvantages.

Stop signs cause substantial inconvenience and delay to motorists. Excessive use of stop signs can lead to disregard for them. Many drivers will run a stop sign, or only come to a rolling stop. Stop signs should not be used for speed control. There is some evidence that frequent stop signs may actually increase traffic speed between the signs, as drivers try to make up the time lost. Stop signs may also increase the number of rear-end accidents on roads with high traffic volumes.

Stop-controlled intersections are divided into two-way stop control, and all-way stop control. In two-way stop control, traffic on the main street does not stop. All-way stop controlled intersections work best when all the approaches carry similar amounts of traffic.

Two-way stop control

Two-way stop control is used on minor roads that intersect roads with more traffic. Normally, the road at an intersection that carries less traffic will be controlled by a stop sign.

- Install two-way stop control so the highway with the heavier traffic volume is given right-of-way.
- If sight distance is good, yield signs may be as safe with less delay. See the MUTCD for more details.
- Use stop signs at intersections with restricted sight distance.
- Periodically check to make sure traffic patterns have not changed.
- If an intersection does not meet the MUTCD warrants, do not use all-way stop control without a compelling reason.
- The higher speed traffic should be given right-of-way.
- The highway appearing to be the major road should be given right-of-way.
- Some intersections have unusual geometry, unexpected traffic conflicts, or both. A careful study should be conducted before a determination is made.
- Resist the temptation to use stop signs for speed control.

All-way stop control

All-way stop intersections are becoming increasingly common as communities try to react to increasing traffic. Unfortunately, they are not always the most effective tools for the task.

All-way stop control works best when amounts of traffic on each approach to the intersection are roughly even. See the MUTCD for warrants and other information on all-way stop controlled intersections. Multi-way stop control may be warranted for the following:

- As a temporary measure until a needed signal can be installed.
- At a location where five or more right-angle or turning accidents happened in twelve months.
- Where there is enough traffic to meet criteria in the MUTCD. These criteria are:
  - Average delay to side road traffic exceeding 30 seconds per vehicle for at least one hour.

- At least 2,400 vehicles using the intersection in any eight hour period, with at least 1,600 vehicles coming off the side roads during the same period.
- At least 1,680 vehicles total and 1,120 on the side road, if the prevailing traffic speed on the main road is over 40 mph.

All-way stop control may work if intersection sight distance is too poor for two-way stop control. Otherwise, the disadvantages of all-way stop control are likely to outweigh the advantages, unless the intersection meets one or more of the warrants. One researcher has calculated the user costs of a typical all-way stop intersection at $210,000 per year. This includes fuel, brake wear, delay, and other costs. If the intersection does not meet the warrants listed above, the benefit to the public is unlikely to exceed the cost.

Traffic signals and roundabouts

When traffic volumes are too high for stop control, traffic signals or modern roundabouts can be used. These can be expensive to install and maintain. Experienced, licensed engineers should design them.

Traffic signals work best when most of the traffic is on the main road, with light traffic on the side road and small traffic volumes turning left off the main road. The MUTCD contains eight warrants for traffic signals. Meeting one of the warrants does not require the installation of a traffic signal. If none of the warrants are met, signals often cause more problems than they solve. Also, remember to budget money for maintenance and power usage when considering a traffic signal.

Unlike the traffic circles of the first half of the last century, modern roundabouts are safe and efficient. They are designed to operate at 15 to 25 mph, unlike traffic circles, which often operate at 35 to 45 mph. Roundabouts work well when traffic volumes are close to even, or when left turn movements are heavy. They can eliminate head-on collisions and turn right-angle crashes into glancing fender benders. Single-lane roundabouts are often a good alternative to all-way stop control. Multilane roundabouts can replace traffic signals, but they are especially tricky to design. Small changes in design can have large effects on safety and capacity. This should be left to professional engineers with multilane roundabout experience.

Figure 28 - Roundabout on Long Island

STREET NAME SIGNS

Street name signs play an important role in helping drivers reach their destination. Street names for both intersecting roads should be posted at each intersection. They are normally placed on the far right and near left corners for traffic on the major road.

While four-inch high letters have been used for many years, six-inch letters are readable from farther away, and should be used on high-speed roads. The MUTCD now considers six-inch letters standard on street name signs. Four-inch letters are still allowed on low volume roads or streets with speed limits of 30 mph or less.

PEDESTRIAN CROSSWALKS

Pedestrian crosswalks have special significance in traffic safety because pedestrians are the most vulnerable road users. This is especially true when pedestrians are children or senior citizens. Children do not develop distance judgment skills until around age nine, and their peripheral vision is not as good as adults. Older walkers do not walk as fast, and vision may not be as good.

Crosswalk markings by themselves do not improve pedestrian safety. In fact, on high-volume roads (12,000 vehicles or more per day) an unmarked crossing may be safer than a marked one. It may be that pedestrians in a marked crosswalk feel more secure are less alert than pedestrians in an unmarked crossing. The crosswalk should be used to show pedestrians the best place to cross, and other devices, such as pedestrian crossing signs or curb extensions, should be used to alert drivers.

Locating crosswalks is a compromise between keeping the crossing distance short, and putting it where pedestrians will use it. Pedestrians do not like to go out of their way and often take a direct route. Crosswalks should be perpendicular to the road to keep the crossing distance short.

Curb extensions and medians are effective at improving pedestrian safety. Curb extensions or "bulb outs" are places where the sidewalk is extended into the shoulder or parking lane. This moves pedestrians out to where they are more visible to traffic, and reduces the distance they have to cross. Medians allow pedestrians to cross the street in two stages, rather than having to deal with traffic from both directions at once. For pedestrians, raised medians are best, as long as they do not impede handicapped pedestrians. Consider how curb extensions and medians will affect drainage and winter maintenance before installing them, and make sure curb extensions will not force cyclists into motor vehicle traffic.

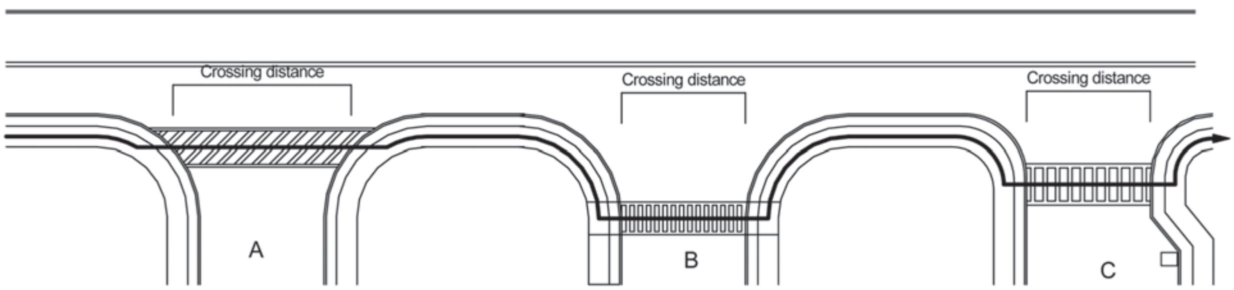

Figure 29 - Crosswalk placement

Figure 29 shows some things to consider when placing crosswalks. At intersection A, the crosswalk is on a direct path for pedestrians, but its placement lengthens the crossing distance. At intersection B, the crosswalk is shorter, but it is out of the direct path, so pedestrians are unlikely to walk in the crosswalk. It also reduces the visibility of pedestrians who do use the crosswalk to drivers turning off of the main road. By reducing the corner radius, intersection C achieves a balance between crossing distance and directness. The curb extension on the right side also helps reduce the crossing distance, and increases visibility of pedestrians about to enter the crosswalk.

RAILROAD CROSSINGS

Various signals, signs, and pavement markings are used to convey traffic control messages at railroad crossings. The uniform application of standard devices is essential. To ensure the safe operation of a traffic control system at a railroad highway grade crossing, it is important that each traffic control device look the same, have the same meaning, and be applied in the same manner, regardless of which highway agency or railroad company installs or maintains it.

Local government is responsible for only the W10-1 advance warning signs and, if appropriate, pavement markings. Railroad crossing devices such as flashing signal lights, automatic gates, and crossbuck signs are the responsibility of the railroad owner. If the need for additional protection becomes evident, notify the NYSDOT Regional Director in writing.

Railroad crossing pavement markings provide additional warning of railroad grade crossings. Railroad crossing pavement markings are required at railroad grade crossings when one or more of the following conditions are present:

- Crossings with railroad crossing gates or signals
- Crossings if the prevailing highway approach speed is 40 mph or higher

- Other locations where significant conflicts could occur between trains and motor vehicles
- Many railroad crossing accidents happen at night. Except for the locomotive, train cars are often unlit and sometimes dark. This makes trains at uncontrolled crossings hard to see. Some low-cost measures to prevent night crossing accidents include:
- Make sure W10-1 railroad advance warning signs and R15-1 crossbucks are in place and reflective sheeting is in good condition
- Install reflective material on back of railroad crossbucks and their posts. As the train goes by, the reflective material flashes through gaps in between train cars.
- Overhead lighting makes trains more visible at night. One or more lights should be installed on each side of the crossing.
- Crossing signals with flashing lights and gates can be installed. If you think a railroad crossing signal may be needed, write a letter to your NYSDOT Regional Director.

DRIVEWAYS

Driveways present an often overlooked potential for accidents. Traffic entering the road from a driveway faces the same conflicts as traffic at an intersection. Therefore, the design and location of a driveway can affect the safety of the road.

Access management

Because accident rates and congestion increase as the number of driveways goes up, more and more communities are turning to access management to maintain the safety and capacity of their roads. By requiring subdivision lots to share driveways, the number of entrances can be reduced. This improves the safety and traffic flow on the road.

Access management primarily applies to arterials and collectors because they carry a large amount of traffic. Land access is the main role of local roads, so it does not make sense to be overly restrictive.

The NYSDOT Corridor Management Group was formed to assist municipalities making access management plans. They can be contacted at (518) 457-3429.

Permits

Landowners should be required to obtain a highway work or building permit for construction within the right-of-way of a public road, including driveways (State law requires this on state highways). The permit review and inspection process can minimize the safety and operational effects on the road, and make sure it is built correctly with no damage to the roadway. It allows the municipality to make sure hazardous headwalls are not built within the right-of-way.

The municipality should require driveways to meet minimum geometry standards. The NYSDOT booklet *Policy and Standards for Entrances to State Highways* may be a good starting point to develop your own policy.

Poorly designed driveways should be brought up to current standards under these circumstances:

- The property is redeveloped
- The municipal planning board decrees a change of use
- The municipality should upgrade nonstandard driveways during construction projects

An existing nonstandard driveway can be ‘grandfathered’ unless the accident history shows it to be unsafe. Forcing alterations to existing driveways is a good way to become unpopular with the natives. Business owners tend to be especially sensitive to changes that they think may make it more difficult for customers or deliveries. Proper driveway design helps prevent this.

Driveway design

The frequency of accidents on a road has been shown to increase as more driveways are built. Minor commercial and residential lots should be limited to one driveway for this reason.

Driveways should be perpendicular to the street. Angled driveways cause difficulties for older drivers and others with restricted neck movement. Older drivers are becoming an increasing portion of the population. Acceptable angles range from 75 to 105 degrees.

Twelve feet in width is usually sufficient for residential driveways. Minor commercial driveways are normally 24 feet wide, but can range from 22 to 30 feet. The corner radius needs to be sufficient for the vehicles using the driveway. See Figures 30 and 31 for typical residential and minor commercial driveway designs. See *Policy and Standards for Entrances to State Highways* for more details.

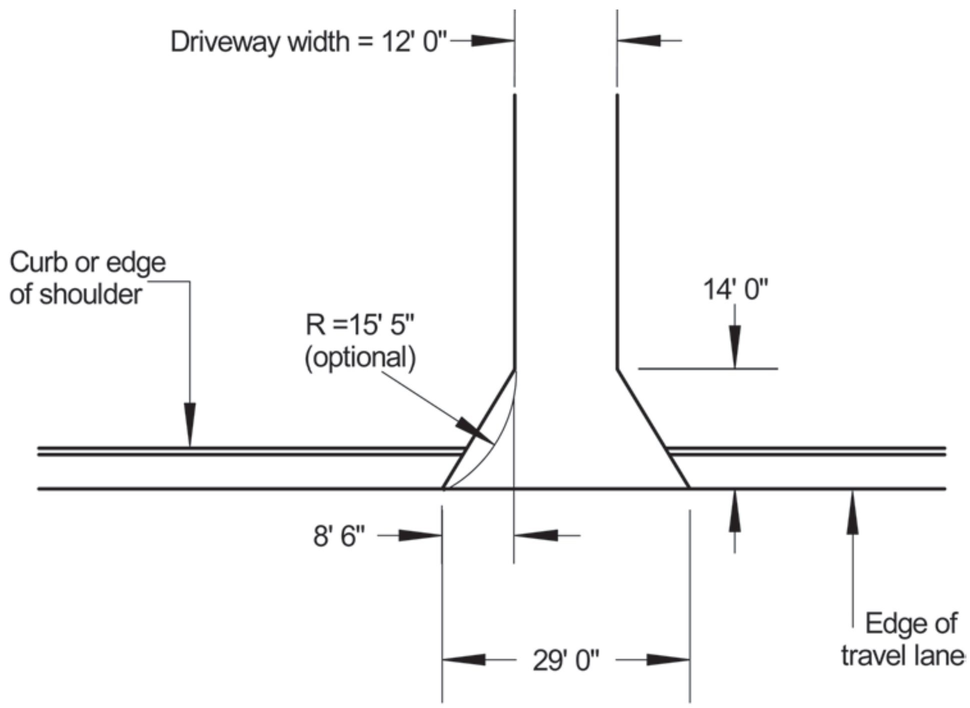

Figure 30 - Typical residential driveway design

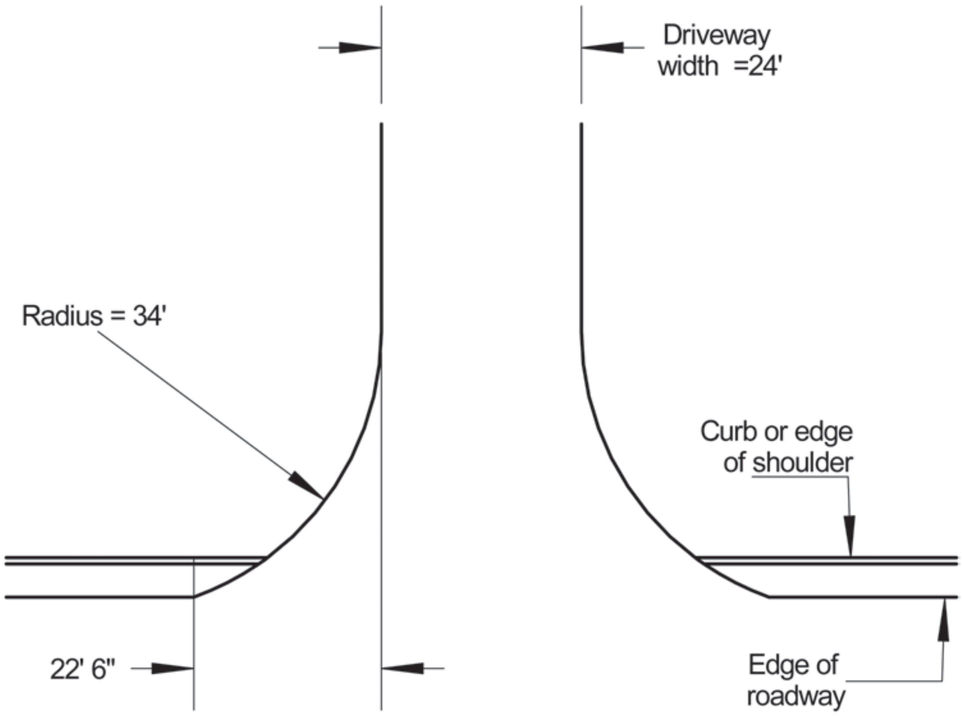

Figure 31 - Typical minor commercial driveway design

Sight distance

Sight distance for driveways is similar to sight distance for intersections. Three types of sight distance are important in driveway design. The minimum allowable sight distance approaching the driveway should be stopping sight distance (Table 1, page 12). This allows drivers approaching the driveway to see a vehicle exiting the driveway in time to stop and avoid a collision. Preferably, drivers turning out of a driveway or making a left turn into it should be able to see oncoming traffic from far enough away to make the turn safely. Tables 8, 9 and 10 (Page 64) show the amount of sight distance needed for these maneuvers.

Often a building lot will be in a location with less than desirable sight distance. In this case, the driveway should be placed at the location along the lot's frontage with the best sight distance. This is a good requirement to have in the municipal building code. Planning boards should require that all parcels have safe driveway locations when property is subdivided.

LIGHTING

Intersection lighting can improve the safety of intersections and railroad crossings that are prone to nighttime accidents. Lighting should be considered if the number of nighttime accidents at an unlit intersection is more than one third of the daytime accidents in the same period.

Lighting can reduce the number of nighttime accidents by 50 percent, and reduce nighttime railroad crossing accidents by 60 percent. Lighting is also effective at reducing collisions with pedestrians.

When considering lighting, budget for electrical costs and bulb changing. New technologies will increase the power efficiency and bulb life.

Appendix A - Glossary

AASHTO - American Association of State Highway and Transportation Officials. An association of transportation departments in the 50 states, the District of Columbia, and Puerto Rico.

ADT - *Average Daily Traffic*. The number of vehicles that use a road on an average day. AADT is "Annualized Average Daily Traffic." AADT corrects for seasonal changes in traffic volumes to provide a year-round average.

Clear area - The area available to a vehicle that goes off the road. It is the area free of obstacles or dangerous slopes. It gives drivers an opportunity to recover control before hitting anything. See also Clear zone.

Clear zone - The distance from the edge of the road to the nearest roadside hazards. More clear zone width is desired on high-speed or high-volume roads. If the road is on top of a fill slope, more should be provided. If the roadside slopes upwards, less clear zone is needed. Wider clear zones are desired on the outside of curves.

- *Desired clear zone width* - The width recommended in national standards, based on speed, volume, curvature, and roadside slopes.
- *Design clear zone width* - What you actually decide to provide when designing a road project, considering cost, ROW, etc. It also represents a commitment to maintain a clear area at least this wide.

Corner angle - the included angle between two roadways, or a road and a driveway. It should be between 75 and 105 degrees. Angles close to 90 degrees are safest.

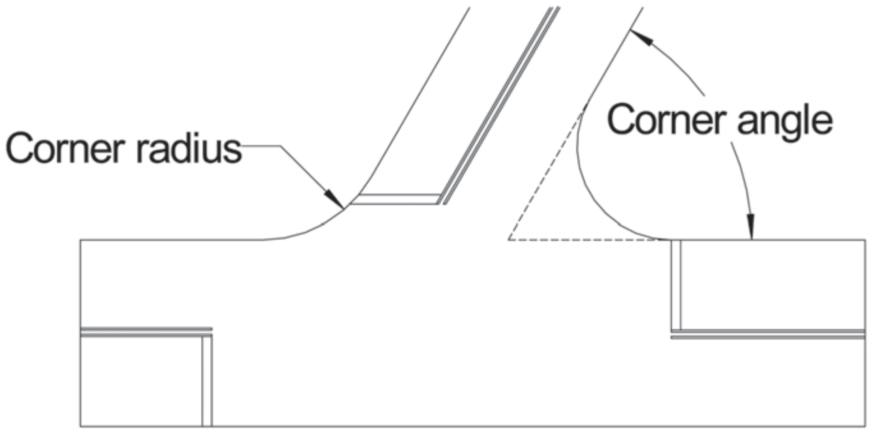

Figure 32 - Corner angle and radius

Critical slope - A slope parallel to the road steeper than one on three. There is a good chance that a vehicle on a critical slope will roll over. Critical slopes higher than five feet should be either shielded with guide rail, or fill should be added to make the slope traversable or recoverable.

Expectancy - What drivers expect the road ahead of them to be like, based on the road they have just driven, and all of their lifelong driving experience. Violations of expectancy often cause driver error.

Fixed object - A roadside object that is massive enough to injure vehicle occupants, such as trees, utility poles, boulders, etc**.**

Functional class - A way of characterizing roads based on the role they play in the transportation network:

- *Local roads* primarily provide access to adjacent land. Through traffic is usually a small percentage of total traffic.
- *Collectors* provide access to neighborhoods and carry traffic from local neighborhood road networks to arterials. They also provide access to adjacent properties.
- *Arterials* carry large amounts of traffic. They usually serve traffic traveling regionally. Intersections are generally at grade, but driveway access to adjacent properties may be restricted.
- *Freeways* primarily carry through traffic. Junctions with other roads occur at interchanges. Driveways are not allowed. Interstate highways are freeways.

Geometry or Geometrics - Collective term for alignment, lane widths, curve radius, etc.

Low-volume road - A road with an *ADT* of less than 400 vehicles per day.

Opportunity cost - The other choices you give up when selecting one alternative over others. In other words, what you could have done instead.

Retroreflective - a property of material that reflects light back roughly in the direction it comes from, rather than the equal and opposite angle. It is used on traffic control devices to reflect the light from vehicle headlights back to the driver's eyes.

Roadside hazard - Conditions near the road that present a danger to vehicles that leave the road. Common types include:

- Fixed objects like trees, buildings, or guiderail
- Spearing hazards that could enter the passenger compartment
- Slopes steep enough to launch a vehicle into the air or to roll it over

Road safety audit - a formal examination of an existing road, or a future road or traffic project by an independent team of trained specialists. The team assesses the safety of a roadway project and prepares a report that identifies potential safety problems.

Recoverable slope - A slope parallel to the road that is flatter than one on four. If the clear zone is wide enough, a driver on a critical slope may be able to regain control and return to the roadway.

Superelevation - 'Banking' of a curve

Traffic study - An investigation that gathers information on traffic flow or safety, and uses it to solve a traffic problem. The information gathered, techniques used, and decisions made during traffic studies should be documented for future use.

Traversable slope - A slope steeper than a recoverable slope, but not as steep as critical slope. A vehicle on a traversable slope probably will not overturn, but it is unlikely that the driver will be able to return to the road. The vehicle will probably continue down to the bottom of the slope.

Appendix B - References

A Policy on the Geometric Design of Highways and Streets, (the AASHTO *'Green Book'*) American Association of State Highway and Transportation Officials (AASHTO), 2001.

Accident Mitigation Guide for Congested Rural Two-Lane Highways, National Cooperative Highway Research Project (NCHRP) Report 440, Transportation Research Board (TRB), Washington DC.

Americans with Disabilities Act Accessibility Guidelines, Architectural and Transportation Barriers Compliance Board, (*'The Access Board'*), 1998. Access their website at: *www.access-board.gov/adaag/html/adaag.htm*

Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide, FHWA, 2001.

Engineering Study Guide for Evaluating Intersection Improvements, NCHRP Study 457, TRB. Available on their website at: *http://trb.org/trb/publications/nchrp/esg.pdf*

Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <400), AASHTO, 2001.

Guidelines for Rural Town and County Roads, Local Roads Research and Coordination Council (1992)

Highway Safety Design and Operations Guide, AASHTO, 1997.

Manual on Uniform Traffic Control Devices, FHWA: *http://mutcd.fhwa.dot.gov*

NYS Highway Design Manual (HDM). This manual is written by NYSDOT and sets design policy for state highway projects in New York. It is overkill for most local road systems, but does include a lot of useful information. Chapters of special interest include:

Chapter 2: Design Criteria
Chapter 10: Roadside Design, (revised in 2002)
Chapter 18: Pedestrians and Bicyclists
Chapter 24: Traffic Calming

The *Highway Design Manual* can be purchased from NYSDOT: (518) 457-2124, or downloaded from their website: *www.dot.state.ny.us/cmb/consult/hdmfiles/hdm.html*

Policy and Standards for Entrances to State Highways, NYSDOT Traffic Engineering and Safety Division, 1998.

Reducing Liability for Local Highway Officials, Cornell Local Roads Program (CLRP).

Roadside Design Guide, AASHTO, 2002.

Roadway and Roadside Drainage, CLRP.

Roadway Safety Guide, Roadway Safety Foundation (2001).

Snow and Ice Control Operations for Local Highway Officials, CLRP.

Traffic Control Device Handbook, Institute of Transportation Engineers (ITE).

Traffic Sign Handbook for Local Roads, 3rd Edition, CLRP 2008.

Volume 17B of the Official Codes, Rules and Regulations of New York State, (the New York State Supplement to the National MUTCD). Available from West Group: (800) 344-5009.

Appendix C - Road Safety Review List

This is a list of things to look for when performing road safety investigations or inspections. It is not meant to be a checklist, and it is not all-inclusive. Just because a condition is not on this list does not mean the road is safe. Judgment is required.

Roadsides

- Are roadsides free of fixed objects or other hazards that could be removed?
- Are roadsides free of fixed objects or other hazards that could be relocated to places they would not be a hazard?
- Are roadsides free of fixed objects or other hazards that could be made traversable, breakaway, or otherwise made safer to hit?
- Are the clear zones free of nonconforming and/or dangerous obstructions that are not properly shielded?
- Are clear zones free of hazardous or non-traversable side slopes without safety barriers?
- Are guiderails free of corrosion and crash damage?
- Are guiderails free of nonstandard installations?
- Are drainage features within the clear zone traversable?

Road surface and pavement condition

- Is the pavement free of defects that may cause loss of steering control or other safety problems (e.g., frost heaves, pot holes, etc.)?
- Are changes in surface type (pavement begins, changes type or ends) free of poor transitions?
- Does the pavement have adequate skid resistance, particularly on curves, steep grades, and approaches to intersections? (Look for polished aggregate or bleeding asphalt)
- Is the pavement free of areas where ponding or sheet flow of water may cause hydroplaning or other safety problems?
- Is the pavement free of loose soil or gravel that may cause safety problems?
- Are pavement edges free of drop-offs more than three inches high?
- Are shoulders firm and free of loose material?

Road surface - pavement markings

- Is the road free of locations with pavement marking safety deficiencies?
- Is the road free of pavement markings that are not effective for the conditions present?
- Is the road free of pavement markings that are worn?
- Is the road free of old pavement markings that affect the safety of the roadway?

Road surface - unpaved roads

- Is the road surface free of defects that could result in safety problems (e.g., loss of steering control)?
- Is the road surface free of areas where ponding or sheet flow of water occurs resulting in safety problems?
- Is the road surface free of loose gravel or fines that may cause safety problems (control, visibility, etc.)?
- Are changes in surface type (e.g., pavement ends or begins) free of drop-offs or poor transitions?

Signing and delineation

- Is the road free of locations where signing is needed to improve safety?
- Are existing signs in places where they are easily seen and catch attention?
- Are existing signs adequately reflective at night?
- Is the road free of locations with improper signing, which may cause safety problems?
- Is the road free of unnecessary signing, which may cause safety problems?
- Are signs effective for existing conditions?
- Can signs be read at a safe distance?
- Are signs in locations where they do not impair safe sight distance?
- Is the road free of locations with improper or unsuitable delineation (post delineators, chevrons, object markers)?

Intersections and approaches

- Are intersections free of sight restrictions that could result in safety problems?
- Are intersections free of abrupt changes in elevation or surface condition?
- Are advance warning signs (stop ahead, yield ahead, traffic circle ahead or signal ahead) installed when intersection traffic control cannot be seen a safe distance ahead of the intersection?
- On through roads, are intersection warning signs installed when the intersection cannot be seen a safe distance ahead of the intersection?

Other road users

- Are travel paths and crossing points for pedestrians and cyclists properly signed and/or marked?
- If sidewalks are needed, are they present?
- If sidewalks are present, are they free from tripping hazards?
- If sidewalks are present, are curb ramps provided for handicapped users? Are tactile surfaces provided to warn blind pedestrians of intersections?
- Are bus stops safely located with adequate clearance and visibility from the traffic lane?
- Is appropriate advance signing provided for bus stops and refuge areas?

Consistency

- Is the road section free of inconsistencies that could result in safety problems?
- Are narrow bridges, lane drops, and other reductions in width properly marked?

Railroad crossings

- Are railroad crossing (R10-1 crossbucks and W5-14 railroad crossing ahead) signs used on each approach at railroad crossings?
- If appropriate, are railroad signals and/or pavement markings present and in good condition?
- Are railroad crossings free of vegetation and other obstructions that have the potential to restrict sight distance?
- Are roadway approach grades to railroad crossings flat enough to prevent vehicle snagging (especially lowboy trailers)?

Accident history

- Are roadsides free of accident debris or crash damage to trees, guiderail, etc.?
- Are the pavement and roadsides free of skid marks that indicate close calls?
- Do police accident reports show a repeated pattern of similar accidents, or accidents with similar contributing factors?

Appendix D - Symptoms and Countermeasures

This is a list of potential countermeasures to common accident problems. It is not intended to be an all-inclusive list, and not all suggested countermeasures will work in all locations.

Safety Symptom	Possible Causes	Potential Countermeasures
Pedestrian collisions	Crossing street	Pedestrian crossing signs
		Pedestrian crossing signs and crosswalks
		Curb extensions
	School children	Crossing guards
		Bussing
	Walking along streets	Install sidewalks
		Install shoulders (rural)
Disabled access issues	Mobility handicapped pedestrians using street instead of sidewalk	Install or upgrade curb ramps Repair sidewalks
	Blind pedestrians not detecting intersections	Install tactile warning surfaces (required by law on new curb ramps, adhesive tactile warning surfaces are available for existing ramps)
Head-on collisions	Poor passing sight distance	No passing zones
	Traffic inadvertently crosses centerline	Centerline pavement markings Curve delineation
Rear-end collisions	Poor sight distance on approach to intersections	Stop ahead or yield ahead sign
		Driveway sign assembly
	Driveway traffic	Turn restrictions (may move problem to next intersection)
		Adopt & enforce driveway geometry standards and access management plan
		Two-way left turn lane
	Left turn traffic waiting in through lane to turn	Turn restrictions (may move problem to next intersection)
		Left turn lanes
	Poor pavement friction	See *skidding* or *wet weather* in this table
	Poor signal timing	Check signal timing for insufficient green or yellow time

Continued on next page.

Safety Symptom	**Possible Causes**	**Potential Countermeasures**
Run-off-road collisions	General	Improve clear zone
		Fill pavement edge drop-off or stabilize shoulders
	Sharp or unexpected curves	Curve warning signs
		Chevrons, arrow signs and/or post-mounted delineators
		Superelevate curve
	Fixed objects and critical slopes	Procedure for treatment of roadside hazards
		Reshape ditches and side slopes
Right-angle collisions	Inappropriate intersection control	Check intersection control, see *Volume 17B*
	Visibility of traffic controls	Check location of stop or yield sign, or signal heads, move if needed
		Install oversized stop or yield sign
		Add stop or yield sign on near left corner
		Add stop ahead or yield ahead sign
	Visibility of the intersection when approaching it	Intersection ahead sign
		Double arrow sign across from stem of T
		Remove vegetation
	Visibility of conflicting traffic when at the intersection	Cut back embankments
		Realign skewed intersection closer to 90°
		Enact corner clearance ordinance (see Appendix E)
	Traffic volumes	All-way stop, see Section 6.3.3.2
		Traffic signal, see Section 6.3.4
		Modern roundabout, see Section 6.3.4
Opposite direction sideswipe collisions	Traffic inadvertently crosses centerline	Curve delineation
		Centerline pavement markings
Nighttime collisions	Old traffic control devices	Check reflectivity of signs and pavement markings, replace as needed
	Poor visibility due to darkness	Delineate road alignment using pavement markings, curve signs, and/or post-mounted delineators
		Street lighting

Continued on next page.

Safety Symptom	**Possible Causes**	**Potential Countermeasures**
Skidding or wet weather accidents	Polished pavement	Surface-treat or overlay, mill & fill, reclaim pavement, etc. Use high-friction aggregate
		Diamond grind if Portland concrete
	Bleeding pavement	Reclaim or mill and replace pavement
	Gravel or dirt on road	Driveway aprons
		Gravel tire cleaning beds
		Swales between cut slope and road to divert rainwater
	Insufficient or excessive cross slope	Correct cross slope
	Poor drainage	Improve drainage
Opposing left turn collisions	Poor sight distance	Prohibit left turns (may move problem to next intersection)
		Improve sight distance
	Poor signal timing	Retime signal, add left turn phase

Appendix E - Sample Legislation

Corner clearance ordinances

These ordinances are used to make sure adequate sight distances are provided at intersections. The first one is probably easier to enforce. The second probably has more flexibility.

Example 1

1) § 1. Corner lot clear areas

   a) On any corner lots, no structure, fence or planting is permitted within a “clear area” defined as:

      i) A horizontal, triangular area described by the following three (3) points:

         (1) Point A: the intersection of the two (2) street right-of-way lines.

         (2) Point B: a point on one (1) of the right-of-way lines twenty (20) feet from the intersection of the right-of-way lines.

         (3) Point C: a point on the other right-of-way line twenty (20) feet from the intersection of the right-of-way lines.

   b) And, within this triangle: a vertical area beginning two and one-half (2½) feet above the ground and extending to ten (10) feet above the ground.

      i) Any fence or planting that extends into the clear area must be made to conform within ninety (90) days from the effective date of this chapter.

2) § 2. Driveway clear areas

   a) On any lot no structures, fence, or planting is permitted within a driveway clear area, defined as:

      i) A horizontal, triangular area described by the following three (3) points:

         (1) Point A: the intersection of the center of the driveway and the street right-of-way line.

         (2) Point B: a point on the driveway ten (10) feet from this intersection.

         (3) Point C: a point on the street right-of-way line ten (10) feet from this intersection.

   b) And, within this triangle: a vertical area beginning two and one-half (2½) feet above the ground and extending to ten (10) feet above the ground.

      i) Any fence or planting that extends into the clear area must be made to conform within ninety (90) days from the effective date of this chapter.

Example 2:

Required sight distance - Intersections shall be so planned and graded that a clear view exists across the corner property from a vehicle 75 feet from the center of the intersection on one street to another vehicle the same distance from the intersection on the other street and 100 feet in the case of a major street. A corresponding sight distance shall be observed on curves on all major streets, and up to this line of sight, the subdivider shall permit no obstruction to view.