Chapter 17—Road Networks

17.1. INTRODUCTION

Chapter 17 presents Crash Modification Factors (CMFs) applicable to planning, design, operations, education, and enforcement-related decisions that are applied holistically to a road network. From the federal level to the state and local levels, planning, engineering, and policy decisions affect the physical road network. This in turn has an impact on the mode, route, and trip choices that users make. As the pattern of trips on the network changes, the collective safety effects on the network will change. The information presented in this chapter is used to identify effects on expected average crash frequency resulting from treatments applied to road networks.

The Part D—Introduction and Applications Guidance section provides more information about the processes used to determine the information presented in this chapter.

Chapter 17 is organized into the following sections:

- Definition, Application, and Organization of CMFs (Section 17.2);
- Crash Effects of Network Planning and Design Approaches/Elements (Section 17.3);
- Crash Effects of Network Traffic Control and Operational Elements (Section 17.4);
- Crash Effects of Road-Use Culture Network Considerations and Treatments (Section 17.5); and
- Conclusion (Section 17.6).

Appendix 17A presents the crash effects of treatments for which CMFs are not currently known.

17.2. DEFINITION, APPLICATION, AND ORGANIZATION OF CMFs

CMFs quantify the change in expected average crash frequency (crash effect) at a site caused by implementing a particular treatment (also known as a countermeasure, intervention, action, or alternative), design modification, or change in operations. CMFs are used to estimate the potential change in expected crash frequency or crash severity plus or minus a standard error due to implementing a particular action. The application of CMFs involves evaluating the expected average crash frequency with or without a particular treatment, or estimating it with one treatment versus a different treatment.

Specifically, the CMFs presented in this chapter can be used in conjunction with activities in Chapter 6—Select Countermeasuresand Chapter 7—Economic Appraisal. Some Part D CMFs are included in Part C for use in the predictive method. Other Part D CMFs are not presented in Part C but can be used in the methods to estimate change in crash frequency described in Section C.7. Section 3.5.3, Crash Modification Factors provides a comprehensive discussion of CMFs including: an introduction to CMFs, how to interpret and apply CMFs, and applying the standard error associated with CMFs.

In all Part D chapters, the treatments are organized into one of the following categories:

1. CMF is available;

2. Sufficient information is available to present a potential trend in crashes or user behavior but not to provide a CMF; and

3. Quantitative information is not available.

Treatments with CMFs (Category 1 above) are typically estimated for three crash severities: fatal, injury, and non-injury. In Part D, fatal and injury are generally combined and noted as injury. Where distinct CMFs are available for fatal and injury severities, they are presented separately. Non-injury severity is also known as property-damage-only severity.

Treatments for which CMFs are not presented (Categories 2 and 3 above) indicate that quantitative information currently available did not meet the criteria for inclusion in the HSM. The absence of a CMF indicates additional research is needed to reach a level of statistical reliability and stability to meet the criteria set forth within the HSM. Treatments for which CMFs are not presented are discussed in Appendix 17A.

17.3. Crash Effects of Network Planning and Design Approaches/Elements

17.3.1. Background and Availability of CMFs

This section presents general background information about the crash effects of network planning and design approaches/elements. Planning decisions include a range of issues that may affect the expected average crash frequency on the road network. Examples of planning decisions that affect network safety include:

- The travel frequencies and travel distances in the course of people's daily activities;
- The travel mode used (train, subway, bus, car, bicycle, or walking);
- The period of greatest travel demand (throughout the day, week, and year);
- The facility type used (whether people travel on a freeway or an arterial road);
- The number of high-traffic volume or low-traffic volume intersections that road users must pass through;
- The distance between access points;
- The need for children to cross roads on their way to school; and
- The operating speeds implied by the local residential road network (e.g., straight wide roadways, narrow curved roads, or cul-de-sacs).

Similar to planning decisions, design and operational decisions vary in their impact on the network. Decisions to widen a shoulder or to provide a turn lane may have little effect on travel patterns over the network as a whole. Other design and operational decisions may affect a wider part of the network. For example, one-way street systems appear to affect a relatively limited area but may have crash implications for other streets in the road network due to changes in traffic patterns.

Network design elements include treatments and broader design concepts intended to achieve uniformity and similarities across a roadway network. Self-explaining roads and transportation safety planning (TSP) are two examples of design principles that are applied across a network to achieve geometric and operational characteristics aimed at reducing crashes. Self-explaining roads are designed to make the function and role of a road immediately clear, recognizable, and self-enforcing. Design stimulates drivers to adapt and reduce speed. TSP involves explicitly, proactively, and comprehensively implementing measures known to reduce expected average crash frequency.

Table 17-1 summarizes the treatments related to network planning and design approaches and elements. There are currently no CMFs for these treatments. Appendix 17A presents general information and potential trends in crashes and user behavior for these treatments.

Table 17-1. Treatments Related to Network Planning and Design Approaches/Elements

HSM Section	Treatment	Urban	Suburban	Rural
Appendix 17A.2.2.1	Apply elements of self-explaining roadway design	T	T	T
Appendix 17A.2.2.2	Apply elements of TSP in transportation network design	T	T	T

NOTE: T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 17A.

17.4. CRASH EFFECTS OF NETWORK TRAFFIC CONTROL AND OPERATIONAL ELEMENTS

17.4.1. Background and Availability of CMFs

The material presented in this section focuses on treatments related to traffic control and operational elements that are applied across a network or sub-area. Network traffic control and operational elements include treatments such as implementing area-wide traffic calming, creating a network of one-way couplets, or modifying the specific level of access management across a set of facility types within a network.

Table 17-2 summarizes treatments related to network traffic control and operational elements and the corresponding CMFs available.

Table 17-2. Treatments Related to Network Traffic Control and Operational Elements

HSM Section	Treatment	Urban	Suburban	Rural
17.4.2.1	Implement area-wide traffic calming	✓	—	—
Appendix 17A.3.1.1	Convert two-way streets to one-way streets	T	T	T
Appendix 17A.3.1.2	Convert one-way streets to two-lane, two-way streets	T	T	T
Appendix 17A.3.1.3	Modify the level of access control on transportation network	T	—	—

NOTE: ✓ = Indicates that a CMF is available for the treatment.
T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 17A.
— = Indicates that a CMF is not available and a trend is not known.

17.4.2. Network Traffic Control and Operations Treatments with CMFs

17.4.2.1. Implement Area-Wide Traffic Calming

The main purpose of traffic calming is to reduce traffic volumes and operating speeds on residential local roads. The traditional approach to traffic calming is known as Level I Traffic Calming (11). In Level I Traffic Calming, various site-specific calming techniques are applied to a local street network, usually a residential area.

Numerous traffic calming measures can be used to reduce traffic volume and driving speed on an area-wide basis. Most measures focus on managing vehicles through physical or operational devices such as: vehicle restrictions, lane narrowing, traffic circles, speed humps, raised crosswalks, chicanes, rumble strips, pavement treatments, etc. Traffic calming is one application of the "self-explaining road" approach. The measures that are implemented are designed to lead drivers to reduce speed and to adapt their driving appropriately. Before implementing traffic calming, the effects on pedestrians (including those with disabilities who may rely on paratransit), bicyclists, emergency services vehicles, and transit may be considered.

The potential crash effects of applying area-wide or corridor-specific traffic calming measures to urban local roads while adjacent collector roads remain untreated are shown in Table 17-3 (2,4,6). These CMFs are not applicable to fatal crashes. The potential crash effects to non-injury crash frequency are also shown in Table 17-3. The base condition of the CMFs (i.e., the condition in which the CMF = 1.00) is the absence of area-wide traffic calming.

The potential crash effects of specific traffic calming measures are provided in Chapters 13 and 14.

Table 17-3. Potential Crash Effects of Applying Area-Wide or Corridor-Specific Traffic Calming to Urban Local Roads while Adjacent Collector Roads Remain Untreated (2,4,6) (injury excludes fatal crashes in this table)

Treatment	Setting (Road Type)	Traffic Volume AADT (veh/day)	Crash Type (Severity)	CMF	Std. Error
Area-wide or corridor-specific traffic calming	Urban (All area-wide roads)	< 2,000 to 30,000	All types (Injury)	**0.89**	**0.1**
			All types (Non-injury)	*0.95**	*0.2*
	Urban (Two-lane local roads)	< 2,000	All types (Injury)	**0.82**	**0.1**
			All types (Non-injury)	**0.94***	**0.1**
	Urban (Two-lane or multilane collector roads)	5,000 to 30,000	All types (Injury)	**0.94***	**0.1**
			All types (Non-injury)	*0.97**	*0.2*
Base Condition: Absence of area-wide traffic calming.					

NOTE: Injury excludes fatal crashes in this table.
Bold text is used for the most statistically reliable CMFs. These CMFs have a standard error of 0.1 or less.
Italic text is used for less statistically reliable CMFs. These CMFs have standard errors between 0.2 and 0.3.
* Observed variability suggests that this treatment could result in an increase, decrease, or no change in expected average crash frequency. See Part D—Introduction and Applications Guidance.

17.5. CRASH EFFECTS OF ELEMENTS OF ROAD-USE CULTURE NETWORK CONSIDERATIONS

17.5.1. Background and Availability of CMFs

National policy leads transportation authorities to improve safety by going beyond engineering-based strategies. Transportation authorities, in partnership with related organizations, seek ways to incorporate education, enforcement, and emergency services strategies into their goal for a safer transportation network. These strategies can potentially influence road-use culture and may be designed to create a safer road-use culture. Engineering and planning decisions create and shape the transportation network and clearly affect the safety of the transportation network. The road-use culture of the people using the network also affects the safety of the transportation network.

This HSM section discusses road-use culture and how expected average crash frequency may be reduced by understanding how road-use culture responds to engineering, enforcement, and education.

Road-use culture involves each individual road user's choices and the attitudes of society as a whole towards transportation safety. The choices made by each individual road user flow from the beliefs, values, and ideas that each road user brings to the road. The attitudes of society as a whole towards transportation safety flow from the social norms regarding acceptable behaviors on the road and from society's decisions regarding acceptable regulation, legislation, and enforcement levels. Road-use culture evolves as individuals influence society and as society influences individuals. Additional information regarding road-use culture can be found in Appendix 17A.

Table 17-4 summarizes treatments related to road-use culture and the corresponding CMFs available. The treatments summarized below encompass engineering, enforcement, and education.

Table 17-4. Road-Use Culture Network Considerations and Treatments

HSM Section	Treatment	Urban	Suburban	Rural
17.5.2.1	Install automated speed enforcement	✓	—	✓
17.5.2.2	Install changeable speed warning signs	✓	✓	✓
Appendix 17A.4.1.1	Deploy mobile patrol vehicles	T	T	T
Appendix 17A.4.1.2	Deploy stationary patrol vehicles	T	T	T
Appendix 17A.4.1.3	Deploy aerial enforcement	T	T	T
Appendix 17A.4.1.4	Deploy radar and laser speed monitoring equipment	T	T	T
Appendix 17A.4.1.5	Install drone radar	T	T	T
Appendix 17A.4.1.6	Modify posted speed limit	T	T	T
Appendix 17A.4.1.7	Conduct enforcement to reduce red-light running	T	T	T
Appendix 17A.4.1.8	Conduct enforcement to reduce impaired driving	T	T	T
Appendix 17A.4.1.9	Conduct enforcement to increase seat belt and helmet use	T	T	T
Appendix 17A.4.1.10	Implement network-wide engineering consistency	T	T	T
Appendix 17A.4.1.11	Conduct public education campaigns	T	T	T
Appendix 17A.4.1.12	Implement young drivers and graduated driver licensing programs	T	T	T

NOTE: ✓ = Indicates that a CMF is available for the treatment.
T = Indicates that a CMF is not available but a trend regarding the potential change in crashes or user behavior is known and presented in Appendix 17A.
— = Indicates that a CMF is not available and a trend is not known.

17.5.2. Road Use Culture Network Consideration Treatments with CMFs

17.5.2.1. Install Automated Speed Enforcement

Automated enforcement systems use video or photographic identification in conjunction with radar or lasers to detect speeding drivers. The systems automatically record vehicle registrations without needing police officers at the scene.

The crash effects of installing automated speed enforcement in urban or rural areas on all road types are shown in Table 17-5 (1,3,5,7,9,12). The base condition for this CMF (i.e., the condition in which the CMF = 1.00) is the absence of automated speed enforcement.

Table 17-5. Potential Crash Effects of Automated Speed Enforcement (1,3,5,7,9,12)

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Install automated speed enforcement	All settings (All types)	Unspecified	All types (Injury)	**0.83**[+]	**0.01**
Base Condition: No automated speed enforcement.					

NOTE: **Bold** text is used for the most statistically reliable CMFs. These CMFs have a standard error of 0.1 or less.
+ Combined CMF, see Part D—Introduction and Applications Guidance.

Multiyear programs indicate operating speeds dropped substantially at sites with fixed cameras compared with sites with mobile cameras (8). However, the magnitude of the crash effect of mobile- versus fixed-camera sites is not certain at this time.

Some speed enforcement approaches are known to have spillover effects across the network. For example, speed cameras may affect behavior at locations not equipped with the cameras. The publicity and public interest accompanying installation of the cameras may lead to a generalized change in driver behavior at locations with and without cameras (10). Some enforcement approaches may also have "time halo" effects. For example, the effect of operating speeds being enforced for a specific period may remain after the enforcement is withdrawn.

The box illustrates how to apply the information in Table 17-5 to calculate the crash effects of installing automated speed enforcement.

Effectiveness of Installing Automated Speed Enforcement

Question:
As part of an overall change to speed enforcement policy and an evolving safety culture, a local jurisdiction is proposing automated speed enforcement on an urban arterial. What will be the likely reduction in the expected average crash frequency?

Given Information:

- Existing roadway = urban arterial
- Expected average crash frequency without treatment (assumed value) = 10 crashes/year

Find:

- Expected average crash frequency after installing automated speed enforcement
- Change in expected average crash frequency

Answer:
1) Identify the applicable CMF

CMF = 0.83 (Table 17-5)

2) Calculate the 95th percentile confidence interval estimation of crashes with the treatment

= (0.83 ± 2 x 0.01) x (10 crashes/year) = 8.1 or 8.5 crashes/year

The multiplication of the standard error by 2 yields a 95 percent probability that the true value is between 8.1 and 8.5 crashes/year. See Section 3.5.3 in Chapter 3—Fundamentals for a detailed explanation.

3) Calculate the difference between the expected number of crashes without the treatment and the expected number of crashes with the treatment.

Change in Expected Average Crash Frequency:

Low Estimate = 10 – 8.5 = 1.5 crashes/year reduction

High Estimate = 10 – 8.1 = 1.9 crashes/year reduction

4) Discussion: Automated speed enforcement may potentially cause a reduction of 1.5 to 1.9 crashes/year.

17.5.2.2. Install Changeable Speed Warning Signs

Individual changeable speed warning signs give individual drivers real-time feedback regarding their speed (7). The potential crash effects of installing these warning signs are shown in Table 17-6. The base condition for this CMF (i.e., the condition in which the CMF = 1.00) is the absence of changeable speed warning signs.

Table 17-6. Potential Crash Effects of Installing Changeable Speed Warning Signs for Individual Drivers (7)

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Install changeable speed warning signs for individual drivers	Unspecified (Unspecified)	Unspecified	All types (All severities)	*0.54*	*0.2*
Base Condition: Absence of changeable speed warning signs.					

NOTE: Based on international study: Van Houten and Nau 1981.
Italic text is used for less statistically reliable CMFs. These CMFs have standard errors between 0.2 to 0.3.
Collective changeable speed warning signs give information such as the percentage of road users exceeding the speed limit.

17.6. CONCLUSION

The material in this chapter focuses on the potential crash effects of treatments that are applicable on a network-wide basis. The information presented is the CMFs known to a degree of statistical stability and reliability for inclusion in this edition of the HSM. Additional qualitative information regarding potential network-wide treatments is contained in Appendix 17A.

Other chapters in Part D present treatments related to specific site types, such as roadway segments and intersections. The material in this chapter can be used in conjunction with activities in Chapter 6—Select Countermeasures and Chapter 7—Economic Appraisal. Some Part D CMFs are included in Part C for use in the predictive method. Other Part D CMFs are not presented in Part C but can be used in the methods to estimate change in crash frequency described in Section C.7.

17.7. REFERENCES

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APPENDIX 17A

17A.1. INTRODUCTION

This appendix presents general information, trends in crashes and/or user behavior as a result of the treatments, and a list of related treatments for which information is not currently available. Where CMFs are available, a more detailed discussion can be found within the chapter body. The absence of a CMF indicates that at the time this edition of the HSM was developed, completed research had not developed statistically reliable and/or stable CMFs that passed the screening test for inclusion in the HSM. Trends in crashes and user behavior that are either known or appear to be present are summarized in this appendix.

This appendix is organized into the following sections:

- Network Planning and Design Approaches/Elements (Section 17A.2);
- Network Traffic Control and Operational Elements (Section 17A.3);

- Road-Use Culture Network Considerations and Treatments (Section 17A.4); and
- Catalogue of Treatments with Unknown Crash Effects (Section 17A.5).

17A.2. NETWORK PLANNING AND DESIGN APPROACHES/ELEMENTS

17A.2.1. General Information

Practitioners have opportunities to consider safety at every stage and level of transportation planning and the corresponding early stages of design. By striving to construct roadways that are as safe as possible, and by explicitly incorporating safety considerations into the planning and design stages, practitioners can minimize the need for crash mitigation after construction.

17A.2.2. Trends in Crashes or User Behavior for Treatments with No CMFs

17A.2.2.1. Apply Elements of Self-Explaining Roadway Design

Self-explaining roads convey a clear, simple, and consistent message about the road's function and role. The message is embedded in the design and appearance of the road, using a limited number of design options and traffic control devices based on the road class. Self-explaining roads are designed to reduce driver errors and crashes. The first self-explaining roads were introduced in Holland in the 1990s (21).

Drivers respond to the roadway design by adapting their driving and adjusting their speed. The cues may be physical and/or perceptual. For example, residential streets that are short and narrow create a sense of spatial enclosure that encourages drivers to slow down. Road surfaces that are color coded (e.g., to show bicycle lanes) convey information about how road users should use the space within the roadway. On self-explaining roads, drivers, pedestrians, and bicyclists readily recognize and understand the relationship between the road, the adjacent land use, and environment, and the appropriate road-user response.

Classification of self-explaining roads

Different road functionality requires different self-explaining design techniques. Self-explaining roads are most relevant to local planning. Three levels of functionality classification are suggested for self-explaining roads (25):

1. Roads with a through function;

2. Roads with a distributor function; and

3. Roads with an access function (residential streets).

Each road category is designed to match the road's function and desired operating speed. For example, access to homes, schools, and offices is provided from residential and distributor roads. The self-explaining approach is intended to prevent through motorists from encroaching on residential streets. This approach appears to reduce traffic volumes and crash rates on residential streets (3).

Self-explaining roads in residential areas

The design of self-explaining roads in residential areas stimulates drivers to be aware that they have left the network of arterials and collectors and must reduce their speed. The design also leads drivers to expect to encounter children, pedestrians, and bicyclists. The low speeds of self-explaining roads are particularly important for pedestrian and child safety. Children are highly vulnerable to speeding traffic because they are often impulsive and lack the experience and judgment necessary to assess traffic conditions.

Lower driving speeds and increased driver expectation potentially mitigate some of the factors that are known to contribute to pedestrian crashes. These factors include (9,15):

- Improper crossing of the roadway or intersection;

- Walking or playing in the roadway;
- Restricted sight lines;
- Limited time for drivers to respond to unanticipated pedestrian movements;
- Inadequate searching and checking by pedestrians and drivers, especially when the vehicle is turning;
- Speeding; and
- Pedestrians assuming that they are more visible than they actually are.

Self-explaining roads are generally designed to reduce operating speeds to about 18 mph in the zones where the roads are introduced. The roads are also designed to minimize the speed differential among different road users.

A study of the crash effects of self-explaining roads in Holland found that (25):

- The number of fatalities declined; and
- The vast majority of local residents were satisfied with the creation of an 18-mph zone.

Figure 17A-1 shows how the relationship between crash speed and the probability of a pedestrian fatality rises rapidly when the crash speed exceeds about 18 mph (17).

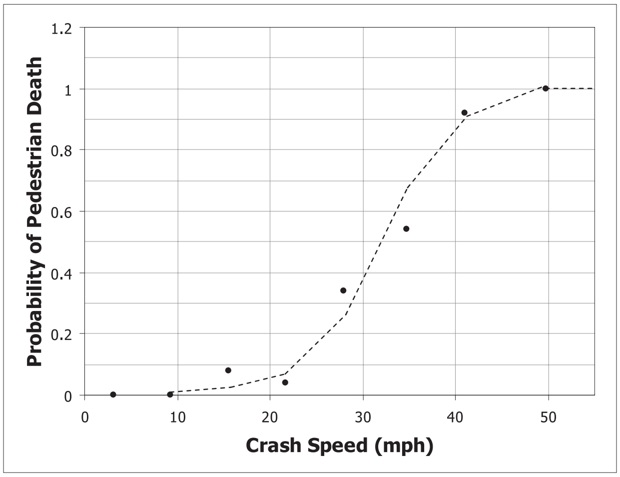

Figure 17A-1. Relationship between Crash Speed and the Probability of a Pedestrian Fatality (17)

Self-explaining roads appear to reduce crashes when applied in planning and design. However, the magnitude of the crash effect is not certain at this time. More specifically, it appears that crashes are reduced in residential areas planned with self-explaining roads principles compared with other residential areas planned with more traditional principles (11). Streets with no exit, such as cul-du-sacs, appear to be substantially safer for pedestrians, especially children, when compared with other street layouts (11). However, the magnitude of the crash effect is not certain at this time.

17A.2.2.2. Apply Elements of TSP in Transportation Network Design

TSP is a comprehensive, system-wide, proactive process that integrates safety into transportation decision making.[1] TSP applies to all transportation modes and all network levels (i.e., local, regional, and state). TSP aims to create safety planning procedures that are explicit and measurable. TSP also aims to reduce crashes by establishing inherently safe transportation networks. On an inherently safe transportation network, a driver is less likely to be involved in a crash (26).

1. The following websites provide information on the latest TSP strategies and tools: http://www.fhwa.dot.gov/planning/SCP and http://tsp.trb.org.

TSP elements appear to improve safety when applied in planning and design. However, the magnitude of the crash effect is not certain at this time. More specifically, it appears that crashes are reduced in residential areas planned with TSP principles compared with other residential areas planned with more traditional principles (11). Streets with no exit, such as cul-de-sacs, appear to be substantially safer for pedestrians, especially children, when compared with other street layouts (11). However, the magnitude of the crash effect is not certain at this time.

17A.3. NETWORK TRAFFIC CONTROL AND OPERATIONAL ELEMENTS

17A.3.1. Trends in Crashes or User Behavior for Treatments with No CMFs

17A.3.1.1. Convert Two-Way Streets to One-Way Streets

One-way operations may apply to a whole area or to only a few streets, and may be found in both downtown and residential areas. One-way streets, usually implemented to increase traffic capacity, appear to reduce crashes under certain conditions (11).

Implementing or removing one-way systems require careful thought and attention in their planning, design, and implementation. Detailed design considerations include the geometrics in the transition to and from one-way and two-way segments, appropriate regulatory signs, pavement markings, and suitable accommodation for turning movements at the beginning and end of one-way segments (11). A consideration is the effect the one-way operations may have on the surrounding road network with the intent of avoiding the transfer of crashes to a neighboring area.

One-way systems have potential operational benefits that appear to reduce crashes. These potential benefits include:

- Elimination of two-way traffic conflicts;
- Reduction in the large number of potential conflicts at intersections in a two-way system, including the elimination of left turns by opposing traffic;
- Possible reduction in waiting times for pedestrians at signals;
- Simplification of intersection traffic control; and
- Improved traffic signal synchronization. Platoons of traffic moving at the appropriate speed may travel the length of the street with few or no stops.

Converting two-way streets to one-way streets appears to reduce head-on and left-turn crashes (11,19). However, the magnitude of the crash effect is not certain at this time.

Potential operational and safety concerns with one-way systems include increased vehicle speed and longer trips for drivers who travel one or more blocks out of their way to reach their destinations. Constraints to emergency vehicle operations are an additional consideration for one-way street systems.

17A.3.1.2. Convert One-Way Streets to Two-Lane, Two-Way Streets

One-way operations may apply to a whole area or to only a few streets, and may be found in both downtown and residential areas. One-way streets, usually implemented to increase traffic capacity, appear to reduce crashes under certain conditions (11).

In a study focusing on a pair of one-way streets that passed through a business district and a residential area, the design for converting the one-way streets to two-lane, two-way streets included bicycle lanes, all-day parallel parking, wider sidewalks, and new trees and benches in the business district. "Zebra" crosswalk markings with pedestrian warning signs were added to the two intersections closest to a school (2). The study results showed that average speeds changed from 35 mph to about 25 mph. Travel times for car commuters increased slightly, and the number of bicyclists and pedestrians increased. Some vehicular traffic diverted to alternative routes (2).

17A.3.1.3. Modify the Level of Access Control on Transportation Network

The safety of an access point is influenced by broad characteristics, such as road class and environment, the average density of access points, and median presence on the roadway. The safety of an access point is also influenced by specific characteristics related to detailed design and traffic control devices. These characteristics include alignment with opposite driveways, proximity to intersections, permitted entry/exit movements, storage, sight triangles, etc. Changing an access and incorporating that decision into a broader access management plan or policy means the change in one access is considered in an area-wide context. The purpose of this network perspective is to minimize the likelihood that a safety concern is transferred from one location to another (12).

The following levels of access may be used on urban roadways (5):

- Minimal access control: high density of intersecting streets, driveways, and median openings;
- Moderate level of access control: frontage roads running parallel with the main roadway segment and fewer cross streets; and
- High level of access control: few driveways, cross streets, or median openings.

The high level of access control has the fewest access points. On urban roadways, a high level of access control appears to reduce injury and non-injury crashes and may also reduce angle and sideswipe crashes at intersections and mid-block areas (5). However, the magnitude of the crash effect is not certain at this time.

17A.4. ELEMENTS OF ROAD-USE CULTURE NETWORK CONSIDERATIONS

General Information

Road-use culture affects every aspect of driving behavior. Examples include driving above the speed limit, responses to red-light cameras at intersections, behavior at all-way stops, and attitudes towards pedestrians and bicyclists. Pedestrians and bicyclists use the transportation network in accordance with their road-use culture and perception of how to respond to the network and to other road users.

While road users' choices may not be fully understood, it is likely that the general level of patience and politeness, or of impatience and aggression, may vary over time and from place to place. Road-use culture is also affected by familiarity with surroundings.

Factors such as enforcement level and the efficiency of the supporting judicial system play a role in defining road-use culture. If drivers know that speeding tickets are unlikely to be processed or that speed limits are rarely enforced, drivers will see little reason to reduce their speed.

Road-Use Culture Development

The way in which road-use culture develops is not well known. It appears that visible behaviors such as using seat belts, speeding, stopping at stop signs, etc., whether desirable or undesirable, spread more quickly than invisible behaviors, such as impaired driving (27).

It also appears that conspicuous behaviors associated with a negative driving culture spread very quickly. Examples of these behaviors include parking on the wrong side of the street, "cutting off" another driver, making threatening gestures, or not signaling (27).

Studies suggest that it is particularly difficult to change road-use culture regarding driving speed and observing speed limits. Progress has been made in changing road-use culture regarding driving under the influence (DUI) and using seat belts. Programs and procedures targeted at younger drivers, such as Graduated Driver's License (GDL), and at older drivers aim to reduce the crash rates of these two vulnerable groups. Studies show that enforcement can change driver behavior, if only in the short term. Automated enforcement for speeding, combined with appropriate enabling legislation, offers the potential to reduce crashes.

Road-Use Culture and Traffic Enforcement
Acceptable driving speed is one of the most important "norms" that helps to define a driving culture. For example, driving 5 to 10 mph greater than the posted speed limit may be culturally acceptable and considered the norm. Being aware of the norm, a driver who notices that a driver ahead is slowing down to the speed limit or to below the speed limit will likely respond in a similar fashion.

Drivers who do not conform to the norm for driving behavior, or who are driving in unfamiliar surroundings where the prevailing road-use culture differs from their own, may be more likely to have a crash than drivers who are familiar with the local road-use culture and conform to it. Drivers often choose to exceed the posted speed limit. This choice is an important safety issue because the risk may increase as operating speeds increase (20).

Most drivers underestimate their driving speed, especially when driving fast. After a high-speed period, drivers who slow down typically perceive their new speed as less than it actually is. In addition, perceptual limitations to geometric features such as curvature can lead to drivers failing to respond appropriately to curves (20).

As most enforcement interventions appear to have little effect on modifying road-use culture, it is generally accepted that speed limits need to be self-enforcing. If drivers believe that speed limits are unreasonable, inappropriate, or inconsistently applied to the network, it is very unlikely that temporary enforcement measures can reduce speeds permanently.

Summary
Design of treatments and interventions that change driver behavior and result in crash reductions can be more successful through a better understanding of driver culture. An improved understanding of driver culture will also help contribute to increasingly effective safety campaigns and enforcement procedures.

17A.4.1. Trends in Crashes or User Behavior for Treatments with No CMFs

17A.4.1.1. Deploy Mobile Patrol Vehicles
Mobile patrol vehicles act as a speeding deterrent, but compliance with speed limits has been shown to decline with increased distance from the patrol vehicles (20). The visibility of the patrol vehicle is important. It has been shown that when overhead lights were removed from patrol cars, mobile patrols ticketed 25 percent more motorists than when the patrol cars retained their overhead lights (20).

The time halo effect of mobile patrol vehicles has been found to last from one hour to eight weeks depending on the length and frequency of the deployments (20).

17A.4.1.2. Deploy Stationary Patrol Vehicles
Stationary patrol vehicles have been shown to lead to "a pronounced decrease in average traffic speed (20)."

17A.4.1.3. Deploy Aerial Enforcement
Aerial speed enforcement has reduced vehicle crashes in Australia (20). In New York, aerial enforcement successfully apprehended drivers who used radar detectors and CB radio to avoid being caught speeding (20).

17A.4.1.4. Deploy Radar and Laser Speed Monitoring Equipment
Laser speed monitoring equipment can detect speeding drivers whose cars have radar detectors. These drivers tend to travel at the most extreme speeds (20).

17A.4.1.5. Install Drone Radar
Drone radars, or unattended radar transmitters, have been shown to slightly reduce average vehicle speed, and to decrease by 30 to 50 percent the number of drivers who exceed the speed limit by more than 10 mph (20).

17A.4.1.6. Modify Posted Speed Limit

Drivers tend to drive at the speed that they find acceptable and safe, despite posted speed limits.

Little or no effect on operating speed has been found for low- and moderate-speed roads where posted speed limits were raised or lowered (20). On high-speed roads such as freeways, “studies in the USA and abroad generally show an increase in speeds when speed limits are raised (20).”

The net crash effect of speed limits and changes in speed limits across the transportation network is not fully known. More information is needed to understand how drivers respond to speed limits and how driver behavior can be modified. This information would help to improve how speed limits are set and would help to maximize the results of speed enforcement efforts.

17A.4.1.7. Conduct Enforcement to Reduce Red-Light Running

Automated enforcement for red-light running, combined with appropriate enabling legislation, potentially reduces crashes.

17A.4.1.8. Conduct Enforcement to Reduce Impaired Driving

Although alcohol and drugs have a major effect on driver error, and although driving under the influence (DUI) of alcohol or other drugs is widely regarded as a major problem, attitudes towards drinking and driving are not fully understood.

Behavioral controls appear to provide the best results for reducing drunk driving among people with multiple DUI offenses (8). Behavioral controls include internal behavior controls such as moral beliefs concerning alcohol-impaired driving, and external behavioral controls such as the offenders’ perceptions of crashes and criminal punishment. Social controls or peer group pressure appear to be less effective.

Many approaches have been tried to reduce DUI, including:

1. Instituting classes for juvenile DUI offenders;

2. Providing alcohol abuse treatment as an alternative to license suspensions;

3. Lowering the legal blood alcohol limit to 0.05;

4. Introducing random breath testing;

5. Training bar staff;

6. Setting up highly publicized sobriety checkpoints;

7. Implementing underage drinking controls;

8. Limiting alcohol availability;

9. Using media advocacy; and

10. Punishing offenders, including ignition interlock devices or impounding vehicles for repeat offenders.

The first five approaches do not result in a clear pattern of driver response. Some drivers are frequent violators and appear to need special attention and policies (16).

As an example of a more severe approach, DUI laws introduced in California in 1990 included a pre-conviction license suspension on arrested DUI offenders. The approach was “ . . . highly effective in reducing subsequent crashes and recidivism among DUI offenders (18).”

On the other hand, some evidence shows a multipronged approach may be a more effective choice. "Drinking and driving prevention seems to be most successful when it engages a broad variety of programs and interventions (23)." Such a program in Salinas, California ". . . succeeded not only in mobilizing the community, but also in reducing traffic injuries and impaired driving over a sustained period of time. Traffic crashes, injuries, and drinking and driving rates all decreased as a result of the project (23)." Programs that concentrated only on sobriety checkpoints appear to reduce crash frequency and increase DUI arrests over the short-term but are not successful over the long term (23).

These DUI approaches suggest that road-use culture can be modified but that change requires concentrated legislation and enforcement efforts, as well as appropriate community programs, to achieve long-term and sustainable results.

17A.4.1.9. Conduct Enforcement to Increase Seat Belt and Helmet Use

The effectiveness of enforcing seat belt and helmet use is directly related to whether or not the laws are primary or secondary laws. A primary seat belt law allows law enforcement officials to ticket anyone not wearing a seat belt. A secondary seat belt law means that a police officer can only write a ticket for a seat belt violation if the driver is also cited for some other violation. If a seat belt law is secondary, not wearing a seat belt is still against the law; however, enforcement of the law is not as effective.

Adopting primary laws is likely to increase seat belt and helmet use and to modify road-use culture. Primary enforcement may also lead to an increase in seat belt and helmet use.

A change from secondary to primary seat belt use laws has been shown to increase seat belt usage and to decrease driver fatalities (10). Most jurisdictions have supported a change in law with enforcement campaigns. It appears that people are more likely to wear seat belts after legislation (22). "States in which motorists can be stopped solely for belt nonuse had a combined use rate of 85 percent in 2006, compared to 74 percent in other States (7)."

Similarly, universal helmet requirements for motorcyclists increase helmet use. In June 2006, 68 percent of motorcyclists wore helmets that complied with federal safety regulations in states with universal helmet laws, compared with 37 percent in states without a universal helmet law (6).

17A.4.1.10. Implement Network-Wide Engineering Consistency

Network-wide engineering consistency refers to the degree to which a jurisdiction implements transportation engineering solutions using consistent principles and criteria to design transportation infrastructure and to control traffic. Consistently and uniformly applying regulatory, warning, and informational signs is one example. Another example is applying consistent and uniform pavement markings.

The consistency of engineering measures at individual locations and across a jurisdiction's transportation network is likely to affect the driving habits and road-use culture of local users. Road users come to expect certain procedures and to act accordingly. Examples include all-red phases at traffic signals, right-turn-on-red, the use of left-turn arrows or flashing lights at traffic signals, and policies regarding yielding to other vehicles and non-motorized travelers at intersections and roundabouts.

When procedures are not consistent across the jurisdiction, safety may deteriorate. This effect is shown when drivers traveling in a foreign country encounter different rules of the road.

17A.4.1.11. Conduct Public Education Campaigns

Public education campaigns inform road users of new traffic control devices, general rules of the road, and similar topics.

Enforcement efforts can include public information, warnings, or educational campaigns. Such campaigns " . . . contribute significantly to the effectiveness of the technology . . . " used in enforcement, " . . . result in safer driving habits . . . ", and can improve the image of police enforcement activities (20). Extensive pedestrian safety education programs directed at children in elementary schools and those ages 4 to 7 appear to reduce child pedestrian crashes (4).

It is also recognized that not all public information and education (PI&E) programs are effective. A review of some PI&E programs found that the only programs that resulted in a substantial reduction in speed, speeding, crashes, or crash severity were those that were integrated with a law enforcement program (20). "General assessment of public information programs has shown [PI&E programs] to have limited effect on actual behavior except when they are paired with enforcement (14)."

Program effectiveness generally depends on the use of multimedia, careful planning, and professional production. The impact, however, is difficult to measure and extremely difficult to separate from the effects of a campaign's enforcement component (14).

17A.4.1.12. Implement Young Driver and Graduated Driver Licensing Programs

Graduated driver licensing (GDL) programs developed for novice drivers have been implemented in many jurisdictions. GDL programs typically include restrictions such as zero blood alcohol, not driving on high-speed highways, not driving at night, and limitations on the number and age of passengers. The restrictions are designed to encourage new drivers to gain experience under conditions that minimize exposure to risk and to ensure drivers are exposed to more demanding driving situations only when they have enough experience (13). The concern is new drivers are at risk while getting the experience they need.

Novice drivers are three times more likely to be involved in a fatal traffic crash than other drivers (1,24). Evidence also indicates that the most dangerous times and situations for drivers aged 16 to 20 years are (1):

- At night
- On freeways
- Driving with passengers

The level of risk for young drivers suggests that novice drivers need a learning period when they are subject to measures that " . . . minimize their exposure, especially in known risky circumstances like nighttime and on freeways (1)."

Although GDL programs and their results vary, it appears that there is a decrease in crash frequency with a GDL program (13). There is also an indication that "increased driving experience is somewhat more important than increased age in reducing crashes among young novice" drivers (13).

17A.5. TREATMENTS WITH UNKNOWN CRASH EFFECTS

No information about the crash effects of the following treatments was available for this edition of the HSM.

17A.5.1. Network Traffic Control and Operational Elements

- Implement network-wide or area-wide turn restrictions

17A.5.2. Road-Use Culture Network Considerations

- Install enforcement notification signs
- Mitigate aggressive driving through engineering
- Implement older driver education and retesting programs

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